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Ambiguity in Japanese relative clause processing

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Abstract: In Japanese, relative clauses have initial clause-type ambiguity. Because there are no overt RC markers, the structure is realized at a locus of disambiguation, typically the head noun. While previous studies have attenuated this ambiguity, these studies have not effectively investigated the processing asymmetry between subject/object-relatives during reading. The current study investigated RC processing within different ambiguity contexts using eye-tracking on native Japanese speakers. For ambiguous RCs, ORC difficulties were primarily observed during late-processing measures after disambiguation at the head noun and RC verb. This was possibly due to the inherent difficulty of assigning thematic roles when the object appears outside the clause as the object-before-subject-bias predicts or due to factors such as expectation, structural-integration and similarity interference. Because all predict ORC difficulties in ambiguous RCs, the exact nature of the processing remains uncertain. For unambiguous RCs, ORC difficulties were instead observed during early-processing measures at the head noun. We attribute this to expectation-based processing because the clause no longer requires a structural reconfiguration. Specifically, with increased cues for the RC interpretation, expectation-based processing effects became more observable at the head. In conclusion, clause type ambiguity is an integral factor for Japanese relative clause processing.

Keywords: Japanese, relative clauses, ambiguity, expectation

1 Introduction

The current study aims to reveal the influence ambiguity has on Japanese relative clause (RC) processing by investigating the classical subject/object relative clause asymmetry. Specifically, for the majority of the world languages, object-extracted relative clauses (ORC) have been found to be more difficult to process and comprehend than their subject-extracted relative clause (SRC)

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counterparts. While previous studies have frequently shown that ORCs are more difficult to process in Japanese, there are many accounts that can satisfactorily explain this difficulty. The number of theories available might even become problematic when attempting to reach a specific or more narrowed conclusion on RC processing. Therefore, to determine which factors are truly bottlenecks of processing, more work is needed in Japanese to tease apart these processing accounts.

In the Japanese language, RCs are often ambiguous in terms of clause structure, which has been a contentious issue because the ambiguity allows for a garden path effect to occur up to the head noun. While recent studies have begun to investigate RCs in Japanese within unambiguous contexts, these studies either did not compare the asymmetry or revealed similar patterns to ambiguous RCs. Therefore, the current study aims to investigate RCs in Japanese within both ambiguous and unambiguous contexts to determine how ambiguity influences RC processing in Japanese. In line with previous studies arguing for hybrid models of sentence processing containing both expectation-based processing effects as well as effects of working memory, we argue that this is also the case for Japanese RC processing. Considering that previous studies in other languages have shown that with attenuated ambiguity, expectation-based processing becomes more salient during reading, we aim to demonstrate this in Japanese. We suspect that changes in processing behaviour will be limited to the locus of the sentence which acts as the cue for the RC interpretation as well as serving as the locus of integration/retrieval between the filler-gap dependencies, i.e. the head noun.

1.1 Relative clauses

A relative clause in Japanese is a noun-modifying expression in which the head noun is required to be a grammatical argument within the clause itself. According to Na and Huck (1993: 197) *argument condition*, “A RC must contain an element E that the clause predicates something of, where E is either (A) a gap co-indexed with the clause head or (B) a nominal whose denotation is thematically subordinate to that of the head noun”. Accordingly, RCs would differ from other similar structures in which the head does not satisfy one or more of the above conditions. For instance, while other embedded clauses (e.g. [-*koto*] ‘thing/about that’ and [-*zizitu*] ‘fact that’) and gapless-RCs bear a similarity to RCs, their heads have no co-reference to any grammatical position within the clause. Thus, they should not be considered to fall under the specific category of RC.

While there are many types of relative clauses, this study will focus on only two types, that is, subject-extracted relative clauses and object-extracted relative clauses. When discussing RC processing, the term filler-gap parsing is often used. The *filler* is the co-indexed element that fills the *gap* created at the trace of a *wh*-movement. In the glossed English examples below, it can be seen that the head noun is co-indexed with the relative pronoun which originated from a deeper syntactic position within the RC where grammatical assignment and case is received. Afterwards, the relative pronoun undergoes *wh*-movement to the left edge of the clause where it can assign *wh*-features to the clause. Because there are no overt RC markers in Japanese, this interpretation of RCs might be problematic. Admittedly, the underlying structure for RCs in Japanese is debated. Some researchers (Bugaeva and Whitman 2016; Kaplan and Whitman 1995) consider there to be a gap within the RC which might involve covert movement of a *wh*-operator, similar to reduced-RCs in English (Browning 1987). In contrast, others (e.g. Comrie 2008; Davis 2006; Matsumoto 1997) disagree and instead argue that there is a null/empty pronominal element which is co-indexed with the head. While Watanabe (2003) claimed that covert operator movement exists for head-internal RC arguments, he was hesitant making the claim for typical head-external RCs due to the opposition against movement. However, because Bugaeva and Whitman (2016) demonstrate that RCs are distinct from other noun-modifying expressions due to island violations, we henceforth assume a gapped interpretation. See examples below.

(1)[1] a. Subject-extracted relative clause (SRC)
市長を非難したレポーターは医師を面接した。
[GAP$_i$ *Sityô-o hinansita*] *repôtâ$_i$-wa ishi-o mensetusita*.
[GAP$_i$ mayor-ACC criticized] reporter$_i$-TOP doctor-ACC interviewed
'The reporter$_i$ [who$_i$ GAP$_i$ criticized the mayor] interviewed the doctor.'

[2]b. Object-extracted relative clause (ORC)
市長が非難したレポーターは医師を面接した。
[*Sityô-ga* GAP$_i$ *hinansita*] *repôtâ$_i$-wa ishi-o mensetusita*.
[mayor-NOM GAP$_i$ criticized] reporter$_i$-TOP doctor-ACC interviewed
'The reporter$_i$ [who$_i$ the mayor criticized GAP$_i$] interviewed the doctor.'

1 Abbreviations used are as follows: ACC (Accusative), TOP (Topicalizer).

2 Abbreviations used are as follows: NOM (Nominative).

1.2 Ambiguity in Japanese relative clauses

Temporary ambiguity can lead the mental parser to a classic garden path effect, i.e. an initial misinterpretation of word meaning or sentence structure which requires a reanalysis at a point of disambiguation within the sentence. However, garden path effects can be attenuated using a variety of methods such as discourse priming, prosody, punctuation or syntactic cues. Similar to Mandarin Chinese and Korean, Japanese is an East Asian language which has prenominal RCs, i.e. head-final, and exhibit temporary clause-type ambiguity. In Japanese, RCs typically lack overt marking, and the language also permits pronominal dropping and syntactic scrambling. These features permit Japanese RCs to be ambiguous. Importantly, out-of-the-blue RC-initial expressions lack RC-specific discourse and syntactic markers. Thus, when encountered, the mental parser is likely to incorrectly assign a matrix-clause interpretation to the RC structure until a viable cue signals otherwise. This cue can be considered as the locus of disambiguation. In Japanese, this point is regularly the head noun of the RC. Yet, even if an initial cue is given to disregard a matrix clause interpretation, other embedded clause interpretations are available. For example, because-adjuncts, fact-expressions and gapless-RCs can look identical to an RC up to the embedded verb. Therefore, an RC interpretation is difficult to form until the head noun is parsed. As illustrated in the fragments (2a) and (2b) below, the initial word orders between these fragments are identical to (1a) and (1b) on the surface up to the head of the structure.

(2)[3] a. Subject-drop fact clause
市長を非難した事実
[pro *Sityô-o hinansita*] *zizitu*
[pro mayor-ACC criticized] fact
'The fact [(that) someone criticized the mayor]'

b. Object-drop fact clause
市長が非難した事実
[*Sityô-ga* pro *hinansita*] *zizitu*
[mayor-NOM pro criticized] fact
'The fact [(that) the mayor criticized someone]'

3 Abbreviations used are as follows: pro (Pronominal).

1.3 Attenuating ambiguity

Past Japanese studies have attenuated ambiguity using discourse-priming (Miyamoto 2016; Miyamoto and Tsujino 2016), punctuation (Niikuni and Muramoto 2014), prosodic effects (Hirose 2003), clause-type plausibility (Nakamura and Arai 2015), successive case marking (Miyamoto 2002), pre-RC cues (Kahraman et al. 2014) and post-RC cues (Arai and Kahraman 2016; Arai 2017). The bulk of these studies observed that the processing burden for RC processing at the head noun can be attenuated when the RC becomes unambiguous. For example, there is an increased probability of an embedded clause when the sentence contains successive case markings (Miyamoto 2002). Both the sentences (3a) and (4b) below are ambiguous. The verb 'interrogated' appears to be a matrix predicate until the head noun 'policeman' is encountered. On the other hand, because 'Tanaka' and 'reporter' in (3b) and (4a) have the same case marking, it becomes likely that the second noun is contained within an embedded clause. This creates a clause boundary between the two nouns (Miyamoto 2002; Yamashita 1995). Thus, the head noun is easier to parse because it lacks structural reanalysis and is anticipated. In contrast, (3a) and (4b) should have a garden path effect at the head causing a reading slowdown.

(3) a. in situ object-modified SRC
田中がレポーターを尋問したお巡りさんを見た。
Tanaka-ga [*repôtâ-o zinmonsita*] *omawarisan-o mita*.
Tanaka-NOM [reporter-ACC interrogate] policeman-ACC saw.
'Tanaka saw the policeman who interrogated the reporter.'
b. in situ object-modified ORC
田中がレポーターが尋問したお巡りさんを見た。
Tanaka-ga [*repôtâ-ga zinmonsita*] *omawarisan-o mita*.
Tanaka-NOM [reporter-NOM interrogate] policeman-ACC saw.
'Tanaka saw the policeman who the reporter interrogated.'

(4) a. scrambled subject-modified SRC
田中をレポーターを尋問したお巡りさんが見た。
Tanaka-o [*repôtâ-o zinmonsita*] *omawarisan-ga mita*.
Tanaka-ACC [reporter-ACC interrogate] policeman-NOM saw.
'The policeman who interrogated the reporter saw Tanaka.'
b. scrambled subject-modified ORC
田中をレポーターが尋問したお巡りさんが見た。
Tanaka-o [*repôtâ-ga zinmonsita*] *omawarisan-ga mita*.
Tanaka-ACC [reporter-NOM interrogate] policeman-NOM saw.
'The policeman who the reporter interrogated saw Tanaka.'

This design, however, might not be suitable to compare SRC and ORC processing because it does not allow for equal comparisons. To specify, in two conditions successive case creates a clause boundary while the other two retain a garden path effect. Furthermore, these garden paths are not equal as (3a) appears to be a canonical matrix clause while (4b) appears to be a matrix clause involving simple scrambling. Additionally, comparing (3b) and (4a) is problematic because the successive case in (4a) appears to violate the *double-o constraint* (Harada 1973), i.e. two accusative marked nouns cannot appear within the same verb phrase, and (4a) also involves scrambling. Therefore, we argue that other contexts are needed which lack these confounds.

Another method of attenuating ambiguity is using pre-RC cues to enhance the RC interpretation, implemented by Kahraman et al. (2014). In their study on Japanese processing, they inserted numerical classifiers in the pre-RC position which either matched or mismatched with the RC noun. See fragments of their examples below.

(5)[4] a. Match-SRC
一人の快活なおじさんを真似した黄色い鸚鵡
Hitori-no kaikatuna ozisan-o manesita kîroi ômu
1 person-GEN cheerful uncle-ACC imitated yellow parrot
'The yellow parrot that imitated one cheerful uncle'

b. Match-ORC
一人の快活なおじさんが真似した黄色い鸚鵡
Hitori-no kaikatuna ozisan-ga manesita kîroi ômu
1 person-GEN cheerful uncle-NOM imitated yellow parrot
'The yellow parrot that one cheerful uncle imitated'

c. Mismatch-SRC
一羽の快活なおじさんを真似した黄色い鸚鵡
Itiwa-no kaikatuna ozisan-o manesita kîroi ômu
1 bird-GEN cheerful uncle-ACC imitated yellow parrot
'One yellow parrot that imitated the cheerful uncle'

d. Mismatch-ORC
一羽の快活なおじさんが真似した黄色い鸚鵡
Itiwa-no kaikatuna ozisan-ga manesita kîroi ômu
1 bird-GEN cheerful uncle-NOM imitated yellow parrot
'One yellow parrot that the cheerful uncle imitated'

4 Abbreviations used are as follows: GEN (Genitive).

Their results revealed that when the classifier matched with the RC noun, ORC difficulty was observed at spillover regions to the head noun. In contrast, when the classifier mismatched, ORC difficulties were not observed. They thus concluded that with an increased expectation for an RC structure, processing difficulties can be attenuated, and that the numerical classifier mismatch cue is effective at eliminating ambiguity. However, there is one issue with this paradigm which might have allowed for ORCs to become just as easy/difficult to parse than SRCs. Specifically, the animacy values for the RC noun and head noun could be problematic for their account. It is well known that animacy contrast is a major factor for RC processing. For example, it is often found that SRCs are preferred to have an animate head and inanimate RC noun with ORCs being the opposite (e.g. Mak et al. 2002; Traxler et al. 2005; Wu et al. 2011). Considering this, Japanese is likely to be similar. Accordingly, in the sense that many classifiers are for inanimate objects or for animals which are lower on the animacy hierarchy scale than humans (c.f., Aissen 1999; Ransom 1977) there should be higher expectations for ORCs when said classifiers are provided, thus attenuating some difficulty. This by no means diminishes the value of the findings by Kahraman et al. (2014) but instead implies that their findings might relate more to the particular expectations attributed to the distributions of animacy contrast rather than the frequencies of RCs as a whole. Bearing in mind that the distributions of RCs are more equal when both nouns are animate, it might be better to test RCs in this more neutral environment. Thus, pre-RC numerical classifiers might not be the best method in this case.

While post-RC cues, occurring after the RC and before the head, can also attenuate ambiguity, clause-type ambiguity is not attenuated until after processing the RC structure. Instead of the head noun being the locus of disambiguation, the garden path effect would only occur up to the cue. See examples (6a-c) below from Arai and Kahraman (2016) and Arai (2017).

(6) a. SRC + Adjective
大学院生を非難した意地悪な研究者
Daigakuinse-o hinansita iziwaruna kenkyusya
graduate.student-ACC criticized mean researcher
'The mean researcher who the graduate student criticized'

b. SRC + Genitive
大学院生を非難した風力発電の研究者
Daigakuinse-o hinansita hûryokuhatsuden-no kenkyusya
graduate.student-ACC criticized wind.energy-GEN researcher
'The wind-energy researcher who the graduate student criticized'

c. SRC + Demonstrative
大学院生を非難したその研究者
Daigakuinse-o hinansita sono kenkyusya
graduate.student-ACC criticized that researcher
'That researcher who the graduate student criticized'

Such cues can be demonstratives, adjectives, or genitive phrases. Recently, Arai (2017) investigated Japanese RC processing using these cues and found that asymmetry between RCs can be explained by the structural frequencies of the language (i.e. expectation-based processing). Yet, this design also permits a garden path effect during the initial parsing of the RC. Therefore, to view the processing of RCs without a garden path effect, pre-RC cues are more appropriate in this regard. Consequently, for the current study, we decided to use pre-RC demonstrative cues, discussed in Section 2.3.6.

1.4 Processing theories

In the following subsections, several processing theories are described and their relation to Japanese RC processing is spelled out. The following processing accounts are by no means an exhaustive list for RC processing. We have limited the discussion to memory-mechanisms and expectation-based processing because they are prominent accounts of RC processing. The *object-before-subject-bias* theory is also included as a recent counter-hypothesis to both expectation and memory.

1.4.1 Integration-based resources

For filler-gap dependencies (Clifton and Frazier 1989; Fodor 1989), the head noun is required to be integrated with the gap to assume its grammatical role within the RC. Otherwise, the RC would not be properly understood. For integration processes (Gibson 2000; Lewis and Vasishth 2005; O'Grady 1997), the process is generally understood as a function of working memory and that the activation level of a referent in working memory decays. Thus, the processing burden associated with integration is contingent on the level of decay, which, however, is measured differently between theories.

According to Gibson's (2000) *dependency locality theory* (DLT), the metric of integration is often described as the *linear* metric because the processing work during integration increases as the number of intervening referents between the filler and gap increase on the surface structure, not the syntactic. In Japanese, the distance between the head noun and gap is greater for SRCs in comparison to ORCs, indicating that the integration process should be more demanding in SRCs. In contrast, the predictions made in English call for greater ORC difficulty because the gap is more distant in the object position. The differences with English are not limited to Japanese as other prenominal languages such as Korean and Mandarin display this pattern as well.

In a similar vein to the DLT, Lewis and Vasishth's (2005) *activation-based model*, based within the scope of the *adaptive control of thought–rational* (ACT-R) model (Anderson 1996), proposes that the decay of the initial activation increases as a function of time, i.e. the *temporal* metric. This metric of integration also predicts greater SRC difficulty in Japanese which again contrasts with English. Because this metric makes the same prediction as DLT (i.e. greater SRC difficulty in Japanese), these two accounts will henceforth be collapsed into a single account for the purpose of this study.

Lastly, the *structural-phrase hierarchy* model (O'Grady 1997) instead proposes that the decay in memory is attributed to the number of intervening phrases in syntactic hierarchy, i.e. the *structural* metric. This model directly contrasts with the above because intervening material on the surface, which does not intervene between two co-indexed dependencies in structure, does not impact the level of decay. In Japanese, because there are more intervening syntactic phrases in hierarchy between the filler and gap for ORCs, there is greater difficulty for ORC processing than SRC processing. This is also true in English and is a near language universal. Refer to Figure 1 below for an illustration of each metric in English and Japanese.

As mentioned, the syntactic structure for Japanese RCs is debated. Importantly, the above predictions for the linear/temporal metrics are contingent upon the syntax. To clarify, for syntactic interpretations involving covert *wh*-movement, there is an additional issue as to where the operator moves. If it moves to the left [Spec, CP], i.e. the left of the clause, ORCs would be predicted to be more difficult because the distance between the gap and operator would be more local for SRCs. In contrast, if it moves to the right of the clause, i.e. between the RC and the head, then the above predictions would not change. This issue was also addressed by Ueno and Garnsey (2008) who ultimately measured the direct distance between the filler and gap. While we claim that RCs are a result of movement in Japanese, we also do not take a hard stance on the exact nature of this movement and thus will retain the above predictions. In Figure 1 below, we include operators at left [Spec, CP] of the Japanese RCs for reference.

In summary, for Japanese there are contrastive predictions based upon the metric used to define the distance between the filler and gap. It is currently

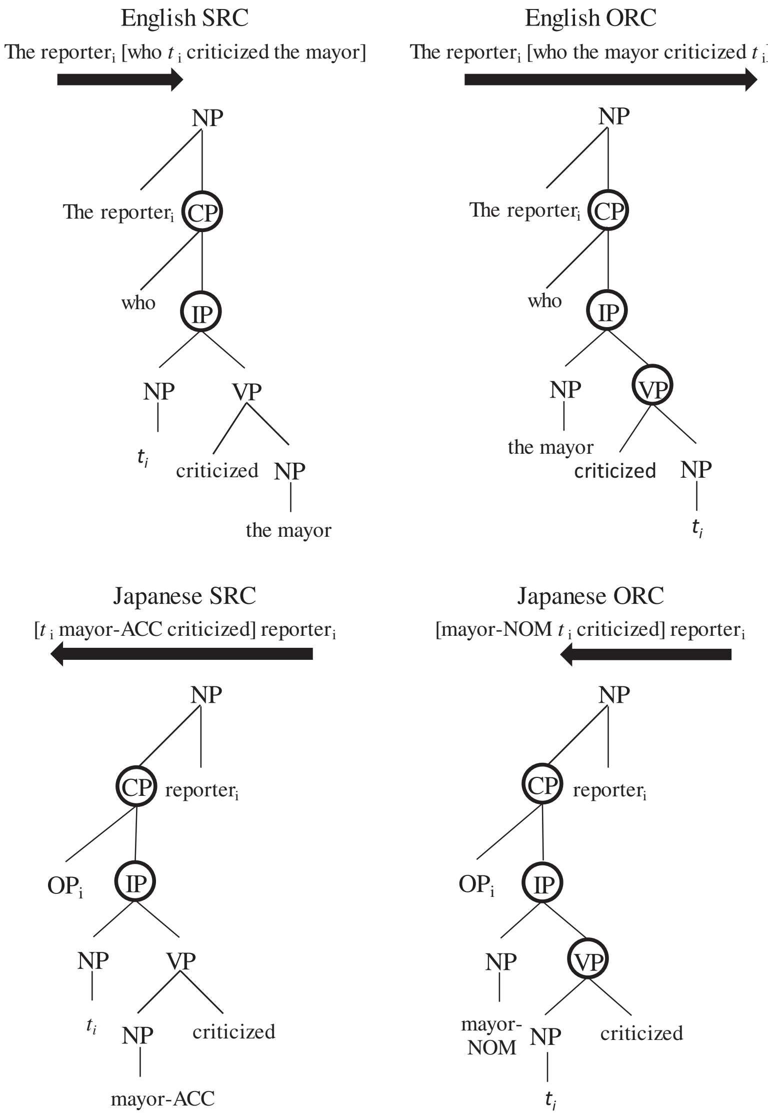

Figure 1: Integration metric predictions for English and Japanese RCs.

believed that when defining distance by either the linear or temporal metric SRCs should engender difficulty, while ORCs would induce difficulty if integration is defined by structural distance.

The linear/temporal metric distance is indicated by the horizontal arrow, and the longer the arrow, the greater the decay in memory. The structural-phrase metric distance is indicated by the circles around the phrases, and the more phrases circled intervening between the filler and the gap, the greater the decay.

1.4.2 Expectation-based processing

Expectation-based Processing (Hale 2001; Levy 2008) models are probabilistic models of processing which assume processing is incremental (e.g. Gerry TM and Kamide 1999) and is constantly drawing from prior language exposure to make predictions for the upcoming structure. As described by Levy's (2008) *surprisal theory*, at each individual word, ranked-parallel expectations are being formed and revised based upon the structural frequencies of the possible structures which can match with the ongoing input. Processing work described here generally reflects the difficulty in revising the ongoing expectation when an unexpected or less frequent structure is encountered. This can be understood as a less frequent structure being more difficult to process than a more frequent structure at a point where two structures diverge.

For languages such as English (Staub 2010), Russian (Price and Witzel 2017), Korean (Kwon et al. 2010; Mansbridge et al. 2017a) and Mandarin (Jäger et al. 2015; Mansbridge et al. 2017b), expectation-based processing has been well supported in terms of RC frequencies. For the structural frequencies of Japanese RCs, it has been shown that ORCs occur less often in corpora than their SRC counterparts. Both Collier-Sanuki (1993) and Yun et al. (2015) found that SRCs occur more frequently than ORCs. While Collier-Sanuki (1993) used translated novel corpora to reveal RC frequencies, Yun et al. (2015) used the Kyoto Corpus 4.0 (Kurohashi and Nagao 2003). From their investigation it was revealed that SRCs (537 token counts) are overwhelmingly more frequent than their ORC counterparts (116 token counts) in Japanese, which is significant by a chi-square goodness of fit test, χ^2 (1, N = 653) = 271.43, $p < 0.001$. Thus, despite arguments that ORCs occur just as often than SRCs as revealed by child acquisition studies (Ozeki and Shirai 2007) and sentence completion tasks producing varied results (c.f., Kahraman et al. 2014; Miyamoto and Tsujino 2016; Nakamura and Miyamoto 2012; Ueno and Garnsey 2008), corpora evidence shows that SRCs occur statistically more frequent than ORCs; thus, ORCs should be more difficult to process.

There is a simple explanation as to why sentence completion tasks revealed mixed findings. Simply, the ORC fragments are more constrained to RC interpretations due to the rarity of object pro-drop while SRC fragments allow for greater variation. This reasoning, however, does not necessarily imply that ORCs invoke a higher expectation during reading than SRCs because attestation accounts for both SRCs and complement clauses with a pro-drop subject are higher than ORCs (Yun et al. 2015). Accordingly, it is possible that despite the initial expectation made upon an SRC fragment, the amount of work required to revise the expectation during reading should be less than an ORC fragment due to the bias for a subject gap or pro within a ranked-parallel parser. In other words, despite the structural probabilities of an ORC fragment favouring an RC structure for offline production purposes, the processing work required to reach said structure during reading is greater. Considering the initial-clause type ambiguity, however, these effects should not be observed until the correct RC interpretation is realized at the head noun. This implies that a garden path effect exists up to this locus of disambiguation.

For unambiguous RCs, on the other hand, the first cue in the sentence that could potentially indicate the RC type (e.g. ORC or SRC) would be the case marking on the RC noun. If only an accusative noun is given, then the structure should be interpreted as being an SRC. In contrast, if a noun marked with nominative case is provided, then an ORC should be understood. Thus, ORC difficulty should be observed prior to the head noun if the RC structure is understood properly.

Another frequency-based account is the *entropy reduction hypothesis* (Hale 2006; Yun et al. 2015). While Hale claims that the underlying calculations of frequency are similar to that of surprisal (Levy 2008), Hale interprets processing difficulty to be the result of reductions in the structural entropy between words. According to Hale, there is a degree of uncertainty left in the structure at each word, and when this level of uncertainty is lowered at the subsequent word, processing work has occurred. In Yun et al. (2015), the entropy levels for the structure were calculated at each word of the RC, and according to their findings, an ORC should be more difficult to process because its structure has greater drops in entropy compared to an SRC structure.

Starting with the RC noun without morphology, both structures are reported by Yun et al. (2015) to have the same level of entropy. The structural probabilities at this point in the sentence overwhelmingly favour a matrix clause interpretation. This mono-clausal structure is likely to be an intransitive clause, transitive clause with subject pro drop and a transitive clause with two overt arguments respectively. Unsurprisingly, given just a noun, no processing differences are predicted between RC conditions.

According to Yun et al. (2015), differences between conditions begin at the morpheme affixed to the RC nouns. The differences in case morphology between ORCs (i.e. nominative case) and SRCs (i.e. accusative case) should reveal a greater reduction in entropy for ORCs because the nominative case would likely constrain the noun's interpretation as being a subject in a matrix clause with either an intransitive or transitive predicate respectively. In contrast, the SRC at this point is highly likely to be a matrix clause with a subject pro-drop followed by an RC interpretation, thus having higher reported entropy. Consequently, as early as the reading of the case morpheme affixed to the RC noun, ORCs are predicted to engender processing difficulty.

Moving on to the verb, while the structural probabilities do not change for SRCs, ORCs probabilities are reported to change to a transitive matrix clause with a missing object and an RC respectively (Yun et al. 2015). In comparison to SRCs, Yun et al. (2015) report that the overall likelihood for pro in the SRC fragment is greater than the probability of pro in the ORC fragment. Accordingly, despite object pro being rare and SRCs being more frequent, there is greater certainty for pro in SRC fragments while ORC fragments are more uncertain between pro and gap. Because neither structure has a reduction in entropy, neither structure is predicted to be more difficult than the other.

At the head noun, Yun et al. (2015) predict that ORCs should engender processing difficulty due to another reduction in entropy while SRC entropy is reported to increase when eliminating the pro interpretations. It is important to specify that this model predicts ORC difficulty at the RC noun and head noun for ambiguous Japanese RCs. For unambiguous RCs, Yun et al. (2015) speculate that no difficulty would be invoked if the structure is understood. Relating back to the particular expectations invoked by the ongoing structure, we, however, argue that it is important to consider both the overall statistical distribution of structures in corpora and the structural probabilities for the ongoing structure of an ambiguous RC fragment.

1.4.3 Similarity-based interferences

Similarity-interference is another working memory account for processing difficulty. Generally speaking, when two referents are stored into working memory with similar features, there is greater difficulty in selecting a specific referent from memory due to the interference from the other. However, the details of similarity-interference are not agreed upon. While some see it as difficulty in storage, encoding, maintenance and retrieval (e.g. Gordon et al. 2001), others consider difficulty to occur primarily during retrieval (e.g. Lewis and Vasishth 2005). For an overview on these points, refer to Lewis et al. (2006). To put it succinctly, while reading sentences, the parser stores and maintains noun dependents with their assigned syntactic and semantic features in working memory for later reactivation and integration with their respective verbs or anaphora. Accordingly, if two or more similar nouns are stored in memory, they might interfere with each other during the retrieval of one of them. This would also be modulated by how similar these nouns are. As they become more similar in gender, number, noun type, semantic or grammatical role, the interference will also become greater.

For Japanese RCs, ORCs should incur a greater processing cost due to similarity-interference in comparison to SRCs because both the ORC noun and head noun share overlapping features in grammatical role (e.g. subject role). Specifically, the RC noun would proactively interfere with the head noun for ORCs during the retrieval of the matrix subject at the matrix verb. Also considering Gordon's account for similarity-interference, late-stage difficulty might also be observed at the head noun or even within the RC if the head noun retroactively interferes with the RC noun.

1.4.4 The object-before-subject-bias

Nakamura and Miyamoto (2013) claim that ORC difficulty can be better explained by other processing accounts rather than expectation and working memory. Within the framework of their object-before-subject-bias model, ORC difficulty in Japanese can be explained by difficulties in thematic assignment. Drawing upon the *verb-object bonding principle* for transitive arguments (Tomlin 1986), the claim that the thematic role of the direct object is assigned by the transitive verb and the subject's role by the direct object, Nakamura and Miyamoto (2013) argue that when each argument is stated (i.e. overt; see Nakamura and Miyamoto 2013 for understated, dropped arguments in Japanese) there is inherently greater difficulty for ORC constructions. See below for an example of how the object regulates the assignment of the theta role for the subject.

(7) English example
Prefix string: The man caught…
Theta Role Option 1: a ball ['the man' becomes <agent>]
Theta Role Option 2: a cold ['the man' becomes <experiencer>]

They claim that not only is there greater difficulty for ORCs because the object argument is juxtaposed outside the clause as a head in comparison to when it is within the clause, there is also greater difficulty with ORCs because of how thematic roles are first assigned for the object head and then back to the RC subject. In comparison with SRCs, the assignment of the subject head's theta role requires only one step at the head noun. This difficulty in assignment, they claim, would manifest itself at the head noun and the RC verb as well. See below for examples of the ordering of thematic roles.

(8) Ordering of thematic arguments: Japanese examples

SRC: 市長を非難したレポーター
Sityô-o hinansita repôtâ
mayor-ACC criticized reporter-NOM
[Theta role assignment: (1) the object 'mayor and then (2) the subject 'reporter'. In other words, the RC theta role for 'reporter' is immediately assigned.]

ORC: 市長が非難したレポーター
Sityô-ga hinansita repôtâ
mayor-NOM criticized reporter-NOM
[Theta role assignment: (1) the object 'reporter' and then (2) the subject 'mayor. The RC theta role for 'senator' is assigned after reading 'reporter'.]

However, as Nakamura and Miyamoto (2013: 324) note, the assignment of the thematic role for the subject can appear prior to the integration of an object due to anticipatory resources. This is a probable scenario for unambiguous Japanese clauses, which would allow the assignment of thematic roles to occur earlier out of greater anticipation for a head noun. As such, we believe that this would remove some processing difficulty related to thematic role assignment at the head noun and RC verb. However, if the subject/object asymmetry persists at the head, then other processing accounts might be indicative of the difference when the clause is unambiguous, especially because the clause would no longer require a major structural reanalysis. Considering evidence for expectation-based resources in other prenominal RC languages such Mandarin (Jäger et al. 2015) and Korean (Kwon et al. 2010) when the RC is unambiguous, we predict to find evidence of expectation-based resources in Japanese.

1.5 Current issues

Most of the current literature surrounding East Asian languages with prenominal RCs is now investigating the classical processing asymmetry between SRCs and ORCs using unambiguous RCs. This is because RC ambiguity is viewed as an undesired confound. However, many of the above Japanese studies, which used unambiguous RCs, either did not account for RC asymmetry or did not offer ideal circumstances for investigating the differences in processing. For past studies using ambiguous RCs in Japanese (Ishizuka 2005; Kahraman et al. 2011; Kahraman and Sakai 2015; Miyamoto and Nakamura 2003; Ueno and Garnsey 2008), it was clearly observed that ORCs, as in many other languages, were more difficult to process and comprehend compared to SRCs. Some of these studies explained ORC processing difficulty in Japanese from the perspectives of the *accessibility hierarchy* (Keenan and Comrie 1977), which posits that the subject position is in a more accessible position within the RC compared to the object position, and the syntactic-phrase hierarchy integration metric (O'Grady 1997). However, ambiguous RCs are not an ideal context to properly compare these conditions because both require structural reanalysis at the head noun.

One case study investigating the processing of ambiguous RCs in Japanese is Ueno and Garnsey (2008). In their study, they investigated processing using both self-paced reading and event related potentials (ERP) methods and found both behavioural and electrophysiological evidence for ORC difficulties at the head noun. Yet, mixed evidence for ORC difficulties were seen at the RC verb. Particularly, while ERPs revealed ORC difficulty, response times were seen to be longer for SRCs. The overall importance of this study was that the ERP results were found to be similar to that of studies detailing filler-gap dependencies in English. Specifically, the greater frontal-bilateral anterior negativity at the RC verb (at the 300 to 600 ms timecourse) and the greater centro-posterior positivity at the head noun (starting at the 500 ms timecourse) were similar to the lateral-anterior negativity (i.e. the LAN effect) and positivity around the 600 ms timecourse (i.e. the P600 effect) for ORCs in English (Kaan et al. 2000; Kluender and Kutas 1993). As such, Ueno and Garnsey (2008) concluded that the ORC difficulties found in their study reflected difficulties of integration. Importantly, they argued that these difficulties were manifested by a long-distance dependency being integrated with the head noun as defined by the structural-integration metric (O'Grady 1997).

They did, however, note two counter-explanations of their findings. First, the bilateral-anterior negativity for ORCs at the RC verb could instead reflect the parser's sensitivities to subject/object-pro drop (Kaan and Swaab 2003). Second, the P600 effect at the head can reflect either the process of syntactic reanalysis or the effects of syntactic expectation rather than integration (Osterhout and Holcomb 1992; Osterhout et al. 1994). While they ultimately dismissed these points, they are nevertheless important to keep in mind. This is because there are multiple processing factors that can collectively engender ORC difficulties within ambiguous Japanese RC and overburden the parser for both RC types. As such, it is imperative to manipulate sentential contexts to observe the subtle changes in processing behaviour. In other words, only investigating processing in ambiguous or unambiguous contexts is problematic.

Another issue relates to the nature of the Japanese RC structure and the principles of working memory during sentence processing. Nakamura and Miyamoto (2012) and Miyamoto (2016), drawing upon the aspect of *closure* (Frazier and Fodor 1978) and the fact that Japanese is head-final and an early closure language, argue that at the embedded RC verb, the clause would close, and the contents would be purged from working memory prior to integration of the head noun. Therefore, the processing of ambiguous RCs in Japanese is unlikely to use memory-based resources related to the integration/retrieval of filler-gap dependencies. Additionally, these studies also contend that expectation-based processing (Hale 2001; Levy 2008) might not be a principal factor for Japanese RC processing as well (see Kahraman et al. 2014; Nakamura and Miyamoto 2012; Miyamoto and Tsujino 2016; Ueno and Garnsey 2008 for conflicting evidence for expectations in Japanese). Yet, as Levy (2008: 1,116) puts it, observations of expectation are likely to be masked by other operations such as integration. In Japanese, structural reanalysis at the head might be preventing expectation effects from being seen clearly.

In summary, for RC processing in Japanese, it is well known that ORCs are more difficult; yet, there are many competing accounts which support the general finding that ORCs are more difficult to process than SRCs. What is more, these investigations, while addressing ambiguity as a potential factor, have not fully addressed ambiguity as a factor because comparisons were chiefly made within ambiguous or unambiguous RCs. These investigations were carried out without a proper comparison of effects between the two contexts which eliminated confounds such as the garden path effect. Consequently, an investigation is needed to compare the processing of both ambiguous and unambiguous RCs which are attenuated by a method which can be used equally for both RC types.

1.6 Current study

The current study investigates RC processing in Japanese via two eye-tracking experiments. Each experiment differs with respect to the level of the initial clause type ambiguity. The experiments demonstrate how processing patterns change under different ambiguity contexts at the head noun. Specifically, this study explores the detailed patterns of reading behaviour within a normal reading design by using eye-tracking. Experiment 1 compares the processing of strictly ambiguous RCs in Japanese, while Experiment 2 compares both ambiguous and unambiguous RCs by inserting a potential syntactic cue to help attenuate clause-type ambiguity. We predict that ambiguous and unambiguous contexts each have distinct patterns of processing. Particularly, we predict that the object-before-subject-bias will account for the processing asymmetry when the clause is ambiguous, and once the clause-type ambiguity has been attended to, expectation-based resources will explain the processing difference.

2 Experiment 1

The main purpose of Experiment 1 was to replicate the results from previous studies which used ambiguous RCs in Japanese. Specifically, we wished to replicate the results of Ueno and Garnsey (2008) using eye-tracking and investigate which accounts would explain RC difficulties. As previously mentioned, their results revealed that within ambiguous RCs in Japanese, ORCs were found to be more difficult to process at the head noun. Accordingly, when using eye-tracking we predicted that ambiguous Japanese ORCs would be more difficult to process at the head noun compared to SRCs.

2.1 Methods

2.1.1 Participants

Thirty-three (Female = 16) native Japanese speakers were recruited from a University in Japan. These participants were undergraduate, graduate or research students at the time of the study. The mean age of the participants was 22 years and 3 months; ranging from 18 years and 8 months to 46 years and 2 months.

2.1.2 Materials

All 40 relative clause (SRC vs. ORC) experimental items were taken from Ueno and Garnsey (2008). These items were put into counterbalanced lists to ensure that participants would only see one RC variant for each item. An additional ten practice and 50 distractor items were included in each list. SRC and ORC conditions only varied by the case marking attached to the RC noun (i.e. accusative or nominative case). The head noun was an oblique adjunct marked with a dative and topic marker to reduce the chance of *perspective shift* effects (MacWhinney 1977, 1982), i.e. the difficulty of maintaining and shifting perspectives within a sentence, and similarity-based interference effects.

(9)[5] a. Subject-extracted relative clause (SRC)
せこい議員を非難した記者には長年の相棒がいた 。
[GAP$_i$ *Sekoi giin-o hinansita*] *kisya$_i$-ni-wa naganenno aibô-ga ita*.
[GAP$_i$ stingy senator-ACC criticized] reporter$_i$-DAT-TOP long.term colleague-NOM existed
'The reporter who criticized the stingy senator had a long-term colleague.'

b. Object-extracted relative clause (ORC)
せこい議員が非難した記者には長年の相棒がいた 。
[*Sekoi giin-ga* GAP$_i$ *hinansita*] *kisya$_i$-ni-wa naganenno aibô-ga ita*.
[stingy senator-NOM GAP$_i$ criticized] reporter$_i$-DAT-TOP long.term colleague-NOM existed
'The reporter who the stingy senator criticized had a long-term colleague.'

2.1.3 Apparatus and procedure

Stimulus sentences were displayed horizontally on the centre left of a computer monitor at a distance of 70 cm from the head and chin rest mount. All characters were displayed in Japanese MS P Gothic 22pt. Eye-movements were recorded using an EyeLink 1000 Core System (SR Research Ltd., Ontario, Canada). The sampling rate was 1000 Hz An attached gamepad was used for button-responses.

Participants were instructed in Japanese that they would be reading Japanese sentences one at a time on the computer monitor. Prior to each stimulus, a drift-checking mask was presented at the centre left of the screen, the point at which the sentence would begin. Once the participant accurately fixated on the mask, the proctor would remove the mask and display the sentence. Participants were given a maximum time of 12 seconds to read the sentence and were instructed to press a button on an interfaced gamepad when they had finished reading and comprehending the sentence. When the participants pressed the button, the sentence was replaced with a comprehension probe (e.g. *Did the reporter hit the senator?*). Participants were given a maximum of eight seconds to answer the question using "TRUE" or "FALSE" marked buttons on the gamepad. Reading times were collected from the onset of a stimulus item to the button response. Prior to each session and periodically

5 Abbreviations used are as follows: DAT (Dative).

throughout the session, participants' eyes were calibrated using a 9-point calibration and validation technique.

2.1.4 Eye-tracking measures

Reading time measures were collected for each word of the sentence. The earliest processing measure reported here is *first-fixation duration* which refers to only the first fixation made in an interest region. Next is *first-pass* time which is composed of all fixations made within an interest region from when it is first entered until it is exited in either direction. This measure can be a collection of one or more fixation points; thus, it is equal to or greater than first-fixation duration. Next is *go-past* time which is the total reading of an interest region before it is exited to the right for the first time. Go-past time also includes any regressive readings out of the region to the left before going right. Therefore, go-past time is greater than or equal to first-pass time. For eye-tracking studies, go-past has been observed to be an indication of early or late stages of processing, depending on the context in which it is found. For RC processing in particular, the phenomenon of integration is often observed during go-past time at the given locus for both post-nominal and prenominal RC languages.

The late reading time measures reported in this study are *re-reading* time which is the sum of all fixations after first-pass RT for an interest region (dwell time in the region minus first-pass RT) and *dwell time* which is the sum of all fixations in an interest region. Dwell time, however, is also representative of early effects. Additionally, *regression-out* (i.e. first-pass regression-out) and *regression-in* proportion measures are reported. In this study, we report on the sentence as a whole and all regions except the initial adjective: RC noun, RC verb, head noun, adjective, matrix object and matrix verb. For more on eye-tracking measures, see Clifton et al. (2007).

2.1.5 Predictions

Here, we briefly discuss key processing predictions for ambiguous RCs as described by the above theories in terms of eye-tracking measures.

For integration-based processing effects, the process of integrating the filler with its gap is predicted to occur at the head noun. For filler-gap parsing within RCs, while this process can be observed as early as first-pass reading time, we believe that regressive measures such as go-past time would better reflect the integration process. This is because within studies detailing the processing of both post-nominal (Gordon et al. 2006; Staub 2010; Staub et al. 2017) and pre-nominal languages (Kwon et al. 2010; Mansbridge et al. 2017a, 2017b), this measure has frequently been observed to occur at loci of integration. If this measure is greater for ORCs, this would indicate that the distance between the filler-gap dependencies is greater than SRCs which would support the structural-metric of integration (O'Grady 1997). If the reverse is found, it would support the linear/temporal metrics (Gibson 2000; Lewis and Vasishth 2005).

Expectation-based processing accounts predict early difficulties within the RC for the ORC condition prior to the reading of the head noun. Importantly, these difficulties would occur prior to the clause-type disambiguation. Surprisal theory (Levy 2008) would predict early-stage difficulty at the RC verb. At the reading of the RC verb, the contents of the RC would be interpreted as either a matrix clause with a subject pro-drop for SRCs or a matrix clause with an object pro-drop for ORCs. Considering that the statistical probability for encountering an object pro-drop is vastly lower than subject pro-drop, the ORC condition would engender greater processing demands for the infrequent structure. The same effect would also occur at the head noun when disambiguation of clause type occurs but in terms of RC probabilities. Here, the SRC structure would have higher expectation than the ORC structure. Following previous research investigating surprisal effects in RC processing, we predict that these difficulties would be observed during the earliest stages of processing such as first-fixation duration and first-pass time. In a similar vein, the entropy-reduction hypothesis (Hale 2006) also predicts difficulties for the ORC condition prior to the reading of the head. As described above, this difficulty would occur upon the reading of the case morpheme at the RC noun for ORCs. Considering that the difficulty occurs at the morpheme, we believe that indications of this effect would be revealed during first-pass time. Akin to surprisal, early difficulty at the head noun is predicted for ORCs.

For similarity-based interference, predictions made by Gordon et al.'s (2001) account is more variable than Lewis and Vasishth (2005). The former would predict either early-stage or late-stage difficulty at loci where multiple similar dependencies are stored (e.g. the head noun and RC noun) or loci where a retrieval for either of these dependencies would occur (e.g. the RC verb and matrix verb). Difficulties could also manifest more generally within the sentence due to the comprehension difficulties of maintaining two similar nouns. The latter account, however, would only predict local difficulty at the matrix verb. Because the effects are limited to the verb itself, first-fixation or first-pass reading would best reflect the difficulty.

Lastly, for the object-before-subject-bias (Nakamura and Miyamoto 2013), difficulties would manifest at the head noun, RC verb and possibly the RC noun.

The difficulties within the RC itself would be encountered during later-stages of processing as reflected by re-reading times and regression-in proportions. At the head noun, however, it is not exactly clear at what time-frame difficulty would occur. Considering that OBSB is described more of a repair process in the understanding of thematic roles, difficulty would likely be found during later-stages of processing such as re-reading, dwell time, go-past time and regression-out proportion.

2.2 Results

A series of linear mixed effect (LME) model analyses (Baayen et al. 2008) were conducted on the collected reading times and binomial data (i.e. regression-in and regression-out proportion) using the lme4 package (Bates et al. 2014) within R (R Core Team 2015); the RC condition (ORC = –0.5 and SRC = 0.5) comprised the fixed effects, and random effects were the subjects and items. Analyses of RTs and regression data only included items with correct responses. RT measures with zero RT or regions which were skipped were treated as missing values and were not included in the RT analyses. The lmerTest package (Kuznetsova and Brockhoff 2014) was used to provide RT models with *p*-values using Satterthwaite's approximation for the degrees of freedom. For accuracy and regression proportions, glmer (binomial) within lme4 was used to calculate the *z* distribution using Laplace approximations. Data outliers (RTs only) were trimmed upon ± 2.5 standard deviations of each model (1.62 %) for better normality of residuals. Refer to Tables 1–2 for means and LMEs. Refer to Figure 2 for plots of reading times.

2.2.1 Sentence

At the sentence level, there was a significant difference between RC conditions for accuracy ($p < 0.001$) and the total reading time of the sentence ($p < 0.05$). It was revealed that the questions for SRCs were answered more accurately, and the sentences overall were read more quickly for SRCs compared to their ORC counterparts.

2.2.2 RC noun

No eye-tracking index revealed a significant difference between RC conditions at the RC noun. Accordingly, RCs did not differ substantially at this locus within the RC.

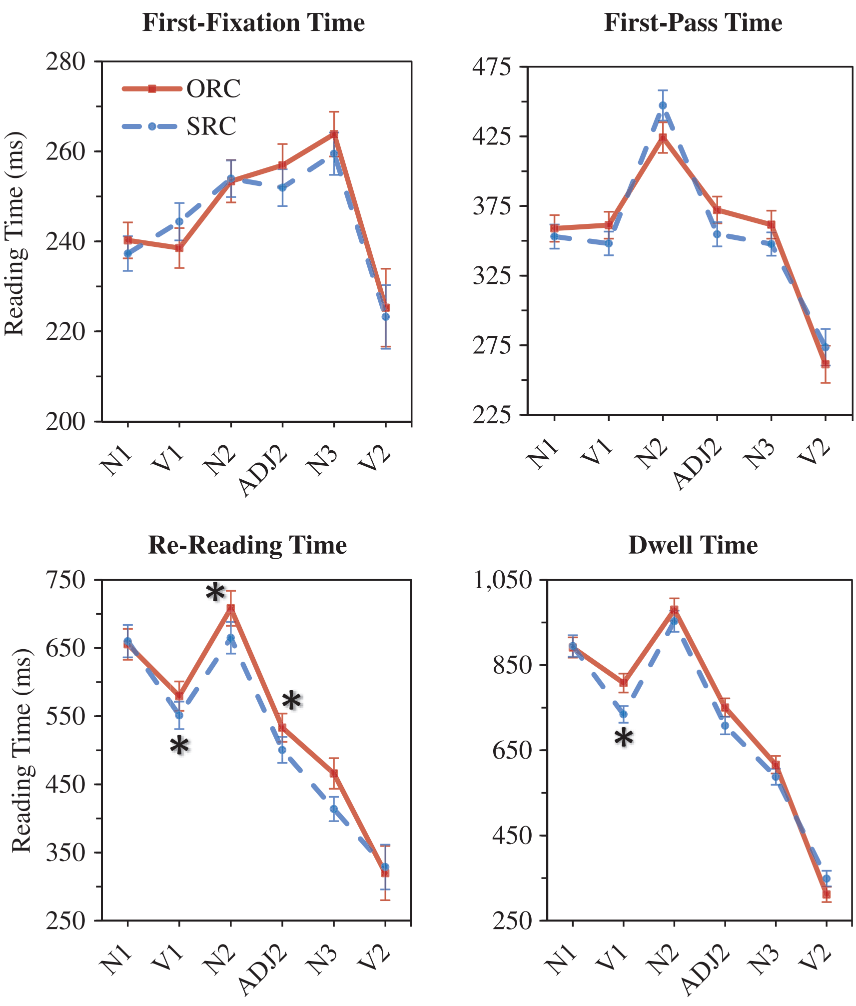

Figure 2: Experiment 1 reading time plots.

2.2.3 RC verb

Only re-reading time ($p < 0.05$) and dwell time ($p < 0.01$) revealed that ORCs had significantly longer reading times than SRCs. Because early measures did not reveal significant differences between conditions, these ORC difficulties reflect late-stage difficulty at the RC verb and likely began after the clause was disambiguated.

Table 1: RC condition means of Experiment 1.

	ORC		SRC			ORC		SRC		
	Mean	**SE**	**Mean**	**SE**		**Mean**	**SE**	**Mean**	**SE**	
	Sentence									
TT	4,956	93	4,807	90	*					
ACC	65.20%	1.90%	79.50%	1.60%	***					
	N1 (RC Noun)					V1 (RC Verb)				
FF	240	4	237	4		239	4	244	4	
FP	359	10	353	9		361	10	348	9	
RR	655	23	660	24		579	22	551	20	*
DT	891	24	895	25	†	808	22	734	20	**
GP	479	15	479	16		449	16	424	12	
RO	19.20%	1.90%	16.10%	1.60%		11.40%	1.50%	12.00%	1.40%	
RI	61.50%	2.40%	64.20%	2.10%		47.00%	2.40%	44.60%	2.20%	
	N2 (Head Noun)					ADJ (Adjective)				
FF	253	5	254	4		257	5	252	4	
FP	424	11	447	11	†	372	10	355	9	
RR	708	26	665	23	*	533	21	500	19	*
DT	980	26	953	25	†	750	21	708	20	†
GP	554	19	547	18		498	22	441	17	
RO	16.80%	1.80%	13.30%	1.50%	†	14.60%	1.70%	13.60%	1.50%	
RI	46.20%	2.40%	44.40%	2.20%		40.80%	2.40%	40.50%	2.20%	
	N3 (Matrix Object)					V2 (Matrix Verb)				
FF	264	5	260	5		225	9	223	7	
FP	362	10	348	8		261	13	274	13	
RR	466	22	414	18	†	320	40	329	33	
DT	616	21	588	19		312	18	349	18	
GP	1,687	77	1,640	66		2,111	119	2,298	131	
RO	65.70%	2.30%	71.80%	2.00%	*	96.30%	1.40%	90.50%	2.10%	*
RI	6.60%	1.20%	5.50%	1.00%						

Note: $p < 0.1$†, $p < 0.05$*, $p < 0.01$**, $p < 0.001$***. Means and errors of reading times are displayed in milliseconds. TT stands for Total Reading Time of the Sentence, FF stands for First-Fixation Duration, FP stands for First-Pass Time, RR stands for Re-Reading Time, DT stands for Dwell Time, GP stands for Go-Past Time, RO stands for Regression-Out Proportion, and RI stands for Regression-In Proportion.

2.2.4 Head noun

Only re-reading time ($p < 0.05$) revealed a significant difference between conditions: ORCs had longer re-reading times at the head noun. While all other measures were

Table 2: LME estimates and t/z values of Experiment 1.

	coef.	SE	*t/z* value		coef.	SE	*t/z* value	
	Sentence							
TT	−0.04	0.02	−2.53	*				
ACC	1.03	0.15	6.86	***				
	N1 (RC Noun)				V1 (RC Verb)			
FF	−0.02	0.02	−0.76		0.03	0.02	1.61	
FP	−0.02	0.03	−0.63		< 0.00	0.03	−0.07	
RR	−0.06	0.04	−1.48		−0.1	0.05	−2.11	*
DT	−0.05	0.03	−1.65	†	−0.1	0.03	−3.23	**
GP	−0.04	0.03	−1.21		< 0.00	0.03	−0.04	
RO	−0.21	0.18	−1.16		0.03	0.2	0.15	
RI	0.08	0.15	0.56		−0.13	0.14	−0.95	
	N2 (Head Noun)				ADJ (Adjective)			
FF	0.01	0.02	0.71		< 0.00	0.02	−0.23	
FP	0.05	0.03	1.82	†	−0.02	0.03	−0.7	
RR	−0.11	0.05	−2.34	*	−0.1	0.05	−2.11	*
DT	−0.05	0.03	−1.75	†	−0.05	0.03	−1.67	†
GP	−0.02	0.03	−0.47		−0.05	0.04	−1.37	
RO	−0.34	0.19	−1.78	†	−0.06	0.2	−0.33	
RI	−0.09	0.14	−0.66		−0.05	0.15	−0.33	
	N3 (Matrix Object)				V2 (Matrix Verb)			
FF	−0.02	0.02	−1.08		0.01	0.04	0.2	
FP	−0.02	0.03	−0.6		0.04	0.05	0.82	
RR	−0.1	0.06	−1.73	†	0.03	0.13	0.25	
DT	−0.04	0.03	−1.09		0.08	0.06	1.52	
GP	0.04	0.05	0.65		0.04	0.06	0.69	
RO	0.42	0.17	2.44	*	−1.09	0.5	−2.18	*
RI	−0.19	0.29	−0.66					

Note: A positive estimate indicates an increase in reading time for SRCs. $p < 0.1$ †, $p < 0.05$*, $p < 0.01$**, $p < 0.001$***. TT stands for Total Reading Time of the Sentence, FF stands for First-Fixation Duration, FP stands for First-Pass Time, RR stands for Re-Reading Time, DT stands for Dwell Time, GP stands for Go-Past Time, RO stands for Regression-Out Proportion, and RI stands for Regression-In Proportion.

not shown to have significant differences between conditions, dwell time ($p = 0.080$) and regression-out ($p = 0.075$) had marginal tendencies for longer reading times and regressions made from the head noun for ORCs. In contrast, first-pass time ($p = 0.069$) showed a marginal trend for longer reading times within SRCs.

2.2.5 Adjective

At the second adjective which exists at the Head + 1 region (i.e. a spillover region), the only significant difference between RC conditions was observed during re-reading time ($p < 0.05$) with ORCs necessitating longer re-reading times than SRCs. No other measure had significant differences between conditions. Dwell time ($p = 0.095$), though, revealed a marginal difference between RCs, again showing longer reading times for ORCs.

2.2.6 Matrix NP-NOM object

Interestingly, regression-out proportion ($p < 0.05$) revealed that there was a higher probability for sentences containing SRCs to have a regression out of the matrix object than sentences with ORCs. No other significant differences were seen.

2.2.7 Matrix verb

Regression-out proportion ($p < 0.05$) was the only measure revealing a significant difference between conditions. Here, ORCs had a higher probability of regressing out to other regions of the sentence.

2.3 Discussion

These results demonstrated greater ORC difficulties for ambiguous RCs, replicating the general findings from previous studies such as Ueno and Garnsey (2008). However, this difficulty was only shown during later stages of processing (i.e. re-reading time and dwell time) at the RC verb, head noun and the overall sentence. In the following sub-sections, ORC difficulty will be explained in terms of each processing account.

2.3.1 Similarity-based interference

Ueno and Garnsey (2008) claimed that by using dative-topic case marking for the head noun, the effects of similarity-based interference should be controlled. As such, they argued that these effects are unlikely to contribute to the overall difficulties with RC processing. However, that might not have been the case. Despite the case markings being different between the RC noun and head noun, the head noun can still be understood as the sentential subject with the other matrix NP marked with nominative case understood as the object. In other words, the head noun might be a dative-subject while the other NP could be a nominative-object. Thus, grammatical roles rather than case morphology might have a more important role in causing similarity-interference. This explanation would serve to explain why re-reading times and dwell times in particular were longer for ORC conditions. Also, the increased regression-out ratio of the matrix verb for ORCs fits into this interpretation. Accordingly, similarity-interference should not be completely ruled out as a potential factor for ORC difficulty, especially because it is compatible within the framework of Gordon's similarity-interference account (Gordon et al. 2001).

2.3.2 Integration-based resources

The linear (Gibson 2000) and temporal distance (Lewis and Vasishth 2005) metrics both predict SRC difficulty in Japanese, assuming the head noun integrates directly with the gap. The structural-phrase hierarchy metric, on the other hand, predicts ORC difficulty. Because significant ORC difficulty was found at the head noun, as in the previous studies, the only conclusion which could be made is that decay increases as a function of structural-distance. Thus, the distance between the head noun and gap is more local in terms of structural-distance for SRCs. However, late measure effects such as re-reading are most likely not indications of an integration/retrieval process. Typically, difficulties with these processes are demonstrated by early-measures and regressive measures, yet none revealed any difference between RC conditions. Accordingly, evidence for integration is only tacit as indicated by these results.

2.3.3 Expectation-based processing

Expectation-based processing (Hale 2001; Levy 2008) predicts ORC difficulty at the head noun. Considering that these clauses were ambiguous up to the point of the head noun, difficulty should not be observed until this locus. However, there was no immediate difficulty for ORCs at the head noun, and only late ORC difficulty was observed at both the head noun and RC verb. Thus, even though expectation-based processing predicts ORC difficulty, it does not seem to be the case that the ORC difficulty here is a clear indication of expectation.

For the entropy reduction hypothesis (Hale 2006; Yun et al. 2015), though ORC difficulty is predicted at the head noun as well, ORC difficulty should first be observed at the case morphology on the RC noun. However, ORC difficulty was not observed at this region. Thus, entropy-based reduction is unlikely to account for the ORC difficulty here. Yet, it could be the case that because only case morphology acts as the cue to lower the entropy, the indices of processing here were too coarse to reveal any difference.

2.3.4 The object-before-subject-bias

Considering that the head noun and RC verb both became more difficult for ORCs during later measures of processing, this might reflect the greater difficulty in thematic assignment for ORCs in comparison to SRCs as Nakamura and Miyamoto (2013) claim. In other words, after restructuring the clause at the head noun, there is difficulty to assign the thematic role of the object head and then the role for the RC subject thus increasing re-reading at the head noun and RC verb for ORCs. But then again, it is still possible that working memory, expectation and OBSB all contributed to the ORC difficulties in some fashion. Because only late-stage overall difficulties were found, it is hard to attribute the difficulties to any single processing account or determine their interrelations.

2.3.5 Processing summary

Overall, it appears that participants were parsing the sentence without trouble up to the head noun. Looking at the first-pass times in Figure 2, it can be seen that there was a spike in first-pass time at the head noun for both RC types. It is our interpretation that they experienced a garden path effect and had to reanalyse the clause from a matrix-clause to an RC which was taxing to their parsers. As Nakamura and Miyamoto (2013) suggest, because of this misparse, the contents of the RC might have been purged from working memory after the reading of the embedded verb. Accordingly, much effort was needed to restructure or reinterpret the clause. Despite this, it appears that participants were likely to continue reading through the sentence as indicated by the low regression-out proportions at the head noun. Note that this measure represents regressions made out during the initial first-pass. Rather than immediately reading back, participants seemed to finish reading the sentence and then looked back at previous regions. Within these regressive readings, ORC difficulties were centred on the RC verb and head noun. Because participants were required to answer a post-sentence comprehension probe after reading the sentence, these difficulties probably represent issues in comprehension, particularly, the role of the head noun in relation to the RC argument. This can be attributed to similarity-interference or issues of thematics for the RC argument. The former explanation is less credible as the head noun was an adjunct-oblique rather than a clear subject; yet, in some cases the head might nevertheless have been understood as a subject thus causing some interference. The latter possibility appears to serve as a more suitable explanation. Because participants were going back and trying to remember the sentence, they had to re-construct the RC argument. This effectively makes the parser subject to OBSB again during the re-reading of the sentence.

2.3.6 Ambiguity

Altogether, ambiguous RCs might not be the most suitable context to investigate expectation- or memory-based processing models in Japanese. This is because each RC condition involves a reanalysis of clause type. This can explain why ORCs only became more difficult during later measures. In Experiment 2, we aim to demonstrate that the disambiguation of clause type is a source of processing difficulty at the head.

Considering that discourse-priming, successive case, clause-type plausibility, and numerical classifiers can all be slightly problematic methods to disambiguate the RC from a matrix clause interpretation initially, another method of disambiguation should be used. In Japanese, there is one pre-RC cue which has yet to be explored. That is pre-RC demonstratives. In Japanese, the demonstrative can either follow or precede the RC while still grammatically modifying the same head noun (e.g. Ishizuka 2008). Following Kamio (1977; as reported by Ishizuka 2008), if the demonstrative follows the RC, then the RC can have both a restrictive or non-restrictive RC interpretation while for pre-RC demonstratives only a restrictive RC interpretation is possible. See below for examples from Kamio (1977: 153–154; as reported by Ishizuka 2008).

(10) a. Pre-RC demonstrative
その兄貴が買って来たりんご
Sono [*aniki-ga katte-kita*] *ringo*
that brother-NOM buy-came apple
'that apple that brother bought'

b. Post-RC demonstrative
皆が探しているその論文
[*Minna-ga sagasiteiru*] *sono ronbun*
everyone-NOM look.for that paper
'that paper, which everyone is looking for'

By using this pre-RC cue, similar to that of Kahraman et al. (2014), the clause-type ambiguity can become disambiguated and a clause boundary might be formed. There is one issue with this design however. Because the demonstrative can also modify the RC noun, there is a chance that this condition would still be ambiguous. Therefore, a word which cannot be modified by the demonstrative must intervene between the two. Jäger et al. (2015) used a similar task design with determiner and classifiers in Mandarin Chinese. To prevent the determiner and classifier from modifying the RC noun, they inserted a temporal adverb at the start of the RC which would intervene between the two thus preventing modification. Their findings revealed that this method was quite effective at creating a clause boundary and effective at having the determiner and classifier modify the head of the RC. Thus, by using pre-RC demonstratives and Jäger et al.'s (2015) design, RCs in Japanese should have attenuated ambiguity at the start of the RC. This will be explored in Experiment 2.

3 Experiment 2

The aim of the Experiment 2 was to compare RC processing under both ambiguous and unambiguous contexts using the combined designs of Kahraman et al. (2014) and Jäger et al. (2015): A pre-RC demonstrative article modifying the head noun prior to the RC was inserted with a temporal adverb inserted at the start of the RC.

3.1 Methods

3.1.1 Participants

Forty (Female = 6) native Japanese speakers were recruited from a University in Japan. These participants were either undergraduate or graduate students at the time of the study. The mean age was 19 years and 4 months; ranging from 18 years and 2 months to 22 years and 11 months. None of the participants took part in Experiment 1.

3.1.2 Materials

Thirty-two experimental items were created in a 2 (condition: SRC vs. ORC) by 2 (type: ambiguous vs. unambiguous) design. The items were put into counterbalanced lists such that only eight items of each were shown per participant. For the unambiguous types, a demonstrative modifying the head noun appeared at the sentence initial position. To ensure that the demonstrative could not modify the noun in the RC, the demonstrative was followed by a temporal adverb which blocked other interpretations. Additionally, an adverb also now intervened between the RC noun and RC verb, and the matrix clause was expanded so that the first matrix predicate could include regressive measures. For the ambiguous condition, the pre-RC demonstrative was simply not included. See below for RC examples. Eight practice and 72 distractor items were also included.

(11) a. Subject-extracted relative clause (SRC)
その昨夜給仕さんを激しく襲った顧客は上司から聞いて、事件を伝えた。
Sono sakuya kyûzi-san-o hagesiku osotta kokyaku-wa zôshi-kara kiite, ziken-o tutaeta.
(that)[last.night customer-ACC fiercely hit]waiter-TOP boss-DAT heard incident-ACC reported
'That waiter who fiercely hit the customer last night heard the boss and reported the incident.'

b. Object-extracted relative clause (ORC)
その昨夜給仕さんが激しく襲った顧客は上司から聞いて、事件を伝えた。
Sono sakuya kyûzi-san-ga hagesiku osotta kokyaku-wa zôshi-kara kiite, ziken-o tutaeta.
(that)[last.night customer-NOM fiercely hit]waiter-TOP boss-DAT heard incident-ACC reported
'That waiter who the customer fiercely hit last night heard the boss and reported the incident.'

3.1.3 Apparatus and procedure

The same apparatus of Experiment 1 was used in Experiment 2. The overall procedure remained the same; however, feedback was provided after each question as an attempt to improve accuracy scores. After a participant responded to the verification question, feedback was automatically displayed in the middle of the display which replaced the question with the feedback message. The feedback displayed respective correct and incorrect messages in Japanese. By giving the participants feedback, we had hoped that participants would become more involved in the task.

3.1.4 Predictions

Predictions for the processing of unambiguous RCs are given below.

The predictions for integration remained unchanged. We expected to find indications of integration during go-past times at the head noun.

The predictions made by expectation-based processing differ slightly for unambiguous RCs. While pre-head difficulty is still predicted within surprisal theory, the difficulty would reflect the greater surprisal for encountering the ORC structure at the RC noun in comparison to the SRC condition. This is because the case morpheme at the RC noun should act as a cue for the RC type. This difficulty might also be seen at the RC verb where it is confirmed that no other RC argument exists. These difficulties should be observed during early-stage measures such as first-pass reading time.

The predictions for similarity-interference would remain unchanged from the predictions for ambiguous RCs as multiple dependencies with overlapping features still must be stored, maintained and retrieved throughout the reading of the sentence. Again, this might occur during both early and late measures of processing.

According to early accounts of OBSB, difficulties for the ORC condition are not expected to occur because upon reading an unambiguous clause, there would be greater anticipation of the object's role, thus attenuating difficulty. Consequently, we do not expect to find evidence of this as indicated by our earlier predictions.

3.2 Results

The same LME procedures were repeated for Experiment 1. For the eye-tracking data cleaning treatment, 8.44 % of eye-tracking fixations were trimmed during the cleaning procedure. Ambiguous and unambiguous RC types were analysed separately. RC condition composed the fixed effect and subject and items were treated as random effects. RTs were log transformed and 1.51 % of the data was trimmed. The following regions were analysed: the sentence as a whole, RC noun, RC adverb, RC verb, head noun, matrix object, and matrix verb. Refer to Tables 3–4 for means and standard errors and Table 5–6 for LMEs. See Figures 3–4 for plots of reading times (excluding go-past).

Table 3: Ambiguous RC condition means of Experiment 2.

	ORC		SRC			ORC		SRC		
	Mean	**SE**	**Mean**	**SE**		**Mean**	**SE**	**Mean**	**SE**	
	Sentence									
TT	4,623	99	4,459	93	*					
ACC	73.40%	2.50%	76.80%	2.40%						
	N1 (RC Noun)					ADV2				
FF	253	7	231	6	**	219	5	210	4	
FP	401	15	347	13	**	233	6	234	7	
RR	613	29	509	23	**	458	25	356	20	***
DT	877	30	754	25	***	504	23	430	18	**
GP	551	21	519	20		307	13	311	13	
RO	22.00%	2.70%	29.90%	2.90%	*	14.40%	2.50%	14.10%	2.40%	
RI	70.30%	3.00%	70.50%	2.90%		56.20%	3.50%	48.60%	3.40%	†
	V1 (RC Verb)					N2 (Head Noun)				
FF	231	6	230	5		251	6	255	7	
FP	303	11	289	9		325	11	324	11	
RR	460	26	384	19	*	532	31	503	26	
DT	644	29	555	23	*	733	30	665	25	*
GP	395	20	359	15		498	28	461	22	
RO	11.90%	2.20%	16.10%	2.40%		18.90%	2.60%	18.80%	2.50%	
RI	46.30%	3.30%	41.50%	3.20%		53.70%	3.30%	47.30%	3.20%	
	N3 (Matrix Object)					V2 (Matrix Verb)				
FF	229	5	239	6		241	6	235	5	
FP	286	10	285	9		312	11	289	9	
RR	493	26	440	22	†	418	25	421	23	
DT	643	26	620	24		541	22	554	23	
GP	477	28	407	22	†	557	33	486	29	†
RO	26.10%	2.90%	18.90%	2.50%	*	32.40%	3.10%	28.70%	2.90%	
RI	54.40%	3.30%	54.60%	3.20%		24.00%	2.90%	27.00%	2.90%	

Note: $p < 0.1$†, $p < 0.05$*, $p < 0.01$**, $p < 0.001$***. Means and errors of reading times are displayed in milliseconds. TT stands for Total Reading Time of the Sentence, FF stands for First-Fixation Duration, FP stands for First-Pass Time, RR stands for Re-Reading Time, DT stands for Dwell Time, GP stands for Go-Past Time, RO stands for Regression-Out Proportion, and RI stands for Regression-In Proportion.

3.2.1 Sentence

Ambiguous: There were no significant differences between RC conditions for question accuracy, ($p = 0.275$). However, the total reading time of the sentence

Table 4: Unambiguous RC condition means of Experiment 2.

	ORC		SRC			ORC		SRC		
	Mean	**SE**	**Mean**	**SE**		**Mean**	**SE**	**Mean**	**SE**	
	Sentence									
TT	4,930	102	4,814	93						
ACC	76.70%	2.40%	74.90%	2.40%						
	N1 (RC Noun)					ADV2				
FF	231	6	228	5		215	5	225	5	†
FP	346	13	330	13		228	6	243	6	*
RR	650	30	664	29		408	26	321	17	*
DT	924	31	847	28	*	453	20	400	15	†
GP	636	28	687	33		365	21	352	17	
RO	38.40%	3.10%	41.90%	3.20%		21.00%	2.80%	16.20%	2.50%	
RI	64.90%	3.10%	60.20%	3.20%		44.30%	3.40%	41.40%	3.30%	
	V1 (RC Verb)					N2 (Head Noun)				
FF	228	5	235	5		265	6	239	5	**
FP	303	11	293	10		343	10	313	9	*
RR	448	22	435	22		489	26	458	24	
DT	627	23	569	23		704	26	623	24	*
GP	409	20	378	18		523	29	511	30	
RO	16.40%	2.40%	14.20%	2.30%		22.30%	2.70%	22.10%	2.70%	
RI	45.00%	3.20%	45.90%	3.30%		51.70%	3.20%	47.60%	3.30%	
	N3 (Matrix Object)					V2 (Matrix Verb)				
FF	242	5	230	5		230	5	245	5	*
FP	292	9	274	8		295	10	309	10	
RR	511	30	447	25		365	22	392	23	
DT	642	28	598	24		510	21	550	22	
GP	427	23	424	23		429	22	434	21	
RO	20.80%	2.60%	18.00%	2.50%		24.90%	2.80%	23.50%	2.80%	
RI	50.00%	3.30%	45.90%	3.30%		28.70%	2.90%	28.70%	3.00%	

Note: $p < 0.1$†, $p < 0.05$*, $p < 0.01$**, $p < 0.001$***. Means and errors of reading times are displayed in milliseconds. TT stands for Total Reading Time of the Sentence, FF stands for First-Fixation Duration, FP stands for First-Pass Time, RR stands for Re-Reading Time, DT stands for Dwell Time, GP stands for Go-Past Time, RO stands for Regression-Out Proportion, and RI stands for Regression-In Proportion.

revealed significant differences between RC conditions ($p < 0.05$). It was observed that ORCs had significantly longer RTs than SRCs.

Unambiguous: Again, differences in question accuracy were not significant between conditions, ($p = 0.513$). Additionally, the total reading time did not have significant differences between conditions as well ($p = 0.780$).

Table 5: Ambiguous LME estimates and t/z values of Experiment 2.

	coef.	SE	*t/z* value		coef.	SE	*t/z* value	
	Sentence							
TT	−0.02	0.01	−2.08	*				
ACC	0.1	0.1	1.09					
	N1 (RC Noun)				ADV2			
FF	−0.04	0.02	−2.61	**	−0.02	0.01	−1.31	
FP	−0.07	0.02	−3.12	**	< 0.00	0.02	−0.16	
RR	−0.09	0.03	−3.2	**	−0.13	0.03	−3.87	***
DT	−0.07	0.02	−3.36	***	−0.07	0.03	−2.66	**
GP	−0.03	0.02	−1.25		< 0.00	0.02	−0.22	
RO	0.27	0.12	2.34	*	−0.03	0.15	−0.22	
RI	−0.01	0.11	−0.09		−0.17	0.1	−1.7	†
	V1 (RC Verb)				N2 (Head noun)			
FF	< 0.00	0.01	0.26		< 0.00	0.02	0.26	
FP	−0.01	0.02	−0.68		−0.01	0.02	−0.37	
RR	−0.07	0.03	−1.98	*	−0.02	0.03	−0.68	
DT	−0.06	0.02	−2.44	*	−0.05	0.02	−2.15	*
GP	−0.02	0.03	−0.74		−0.02	0.03	−0.76	
RO	0.2	0.14	1.41		< 0.00	0.12	−0.03	
RI	−0.11	0.1	−1.06		−0.15	0.1	−1.53	
	N3 (Matrix Object)				V2 (Matrix Verb)			
FF	0.02	0.01	1.2		−0.01	0.01	−0.42	
FP	< 0.00	0.02	0.1		−0.03	0.02	−1.37	
RR	−0.06	0.03	−1.81	†	0.02	0.04	0.44	
DT	−0.03	0.02	−1.27		0.01	0.02	0.34	
GP	−0.05	0.03	−1.89	†	−0.06	0.03	−1.91	†
RO	−0.28	0.13	−2.16	*	−0.1	0.1	−0.93	
RI	−0.02	0.1	−0.19		0.09	0.11	0.78	

Note: A positive estimate indicates an increase in reading time for SRCs. $p < 0.1$ †, $p < 0.05$ *, $p < 0.01$ **, $p < 0.001$ ***. TT stands for Total Reading Time of the Sentence, FF stands for First-Fixation Duration, FP stands for First-Pass Time, RR stands for Re-Reading Time, DT stands for Dwell Time, GP stands for Go-Past Time, RO stands for Regression-Out Proportion, and RI stands for Regression-In Proportion.

3.2.2 RC noun

Ambiguous: During first-fixation ($p < 0.01$), first-pass ($p < 0.01$), re-reading ($p < 0.01$) and dwell time ($p < 0.001$) measures, it was revealed that ORCs required significantly longer RTs compared to SRCs. Regression-out ($p < 0.05$) on the other hand, revealed that SRCs were significantly more likely to regress out.

Table 6: Unambiguous LME estimates and t/z values of Experiment 2.

	coef.	SE	*t/z* value		coef.	SE	*t/z* value	
		Sentence						
TT	< 0.00	0.01	−0.28					
ACC	−0.06	0.1	−0.65					
		N1 (RC Noun)				ADV2		
FF	< 0.00	0.02	−0.3		0.03	0.01	1.84	†
FP	−0.03	0.02	−1.11		0.03	0.02	2.05	*
RR	0.02	0.03	0.82		−0.09	0.04	−2.26	*
DT	−0.05	0.02	−1.97	*	−0.05	0.03	−1.88	†
GP	0.03	0.03	0.89		< 0.00	0.03	0.11	
RO	0.09	0.1	0.89		−0.18	0.13	−1.37	
RI	−0.08	0.1	−0.83		−0.03	0.11	−0.28	
		V1 (RC Verb)				N2 (Head noun)		
FF	0.01	0.01	0.92		−0.04	0.01	−3.252	**
FP	< 0.00	0.02	−0.05		−0.04	0.02	−2.059	*
RR	−0.01	0.04	−0.29		−0.03	0.03	−0.865	
DT	−0.04	0.03	−1.58		−0.05	0.02	−2.309	*
GP	−0.03	0.03	−1.02		−0.02	0.03	−0.803	
RO	−0.09	0.13	−0.71		−0.01	0.12	−0.05	
RI	0.02	0.1	0.21		−0.07	0.1	−0.756	
		N3 (Matrix Object)				V2 (Matrix Verb)		
FF	−0.02	0.01	−1.34		0.03	0.01	2.12	*
FP	−0.03	0.02	−1.54		0.02	0.02	1.15	
RR	−0.06	0.04	−1.61		0.04	0.04	1.05	
DT	−0.02	0.03	−0.94		0.04	0.03	1.37	
GP	−0.01	0.03	−0.47		< 0.00	0.03	0.16	
RO	−0.1	0.13	−0.82		−0.06	0.12	−0.49	
RI	−0.1	0.1	−0.96		0.02	0.11	0.17	

Note: A positive estimate indicates an increase in reading time for SRCs. $p < 0.1$†, $p < 0.05$ *, $p < 0.01$ **, $p < 0.001$ ***. TT stands for Total Reading Time of the Sentence, FF stands for First-Fixation Duration, FP stands for First-Pass Time, RR stands for Re-Reading Time, DT stands for Dwell Time, GP stands for Go-Past Time, RO stands for Regression-Out Proportion, and RI stands for Regression-In Proportion.

Unambiguous: Only dwell time ($p < 0.05$) was observed to have a significant difference between RCs revealing that ORCs required overall longer RTs. The remaining indices did not contain significant differences between SRCs and ORCs.

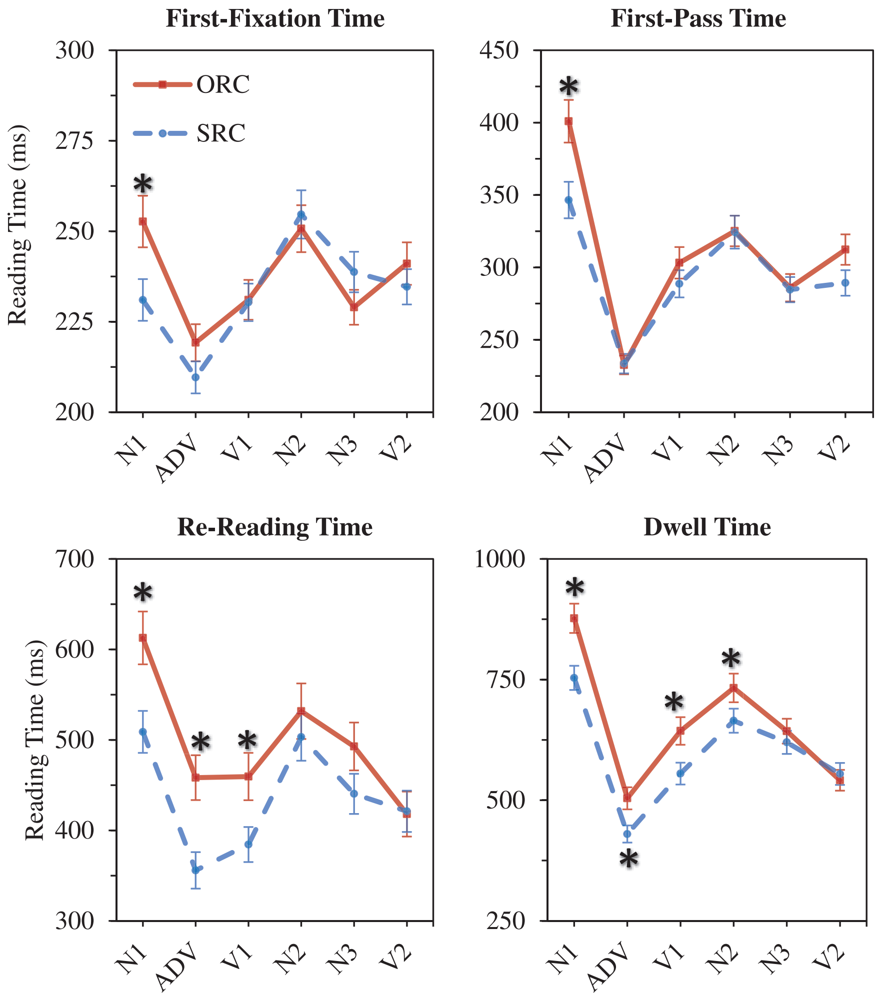

Figure 3: Experiment 2 ambiguous RC reading time plots.

3.2.3 RC adverb

Ambiguous: Both re-reading time ($p < 0.001$) and dwell time ($p < 0.01$) revealed that ORCs required significantly longer reading times during later measures of processing. However, dwell time here should only be considered to reflect the difference in re-reading because early measures revealed no significant differences.

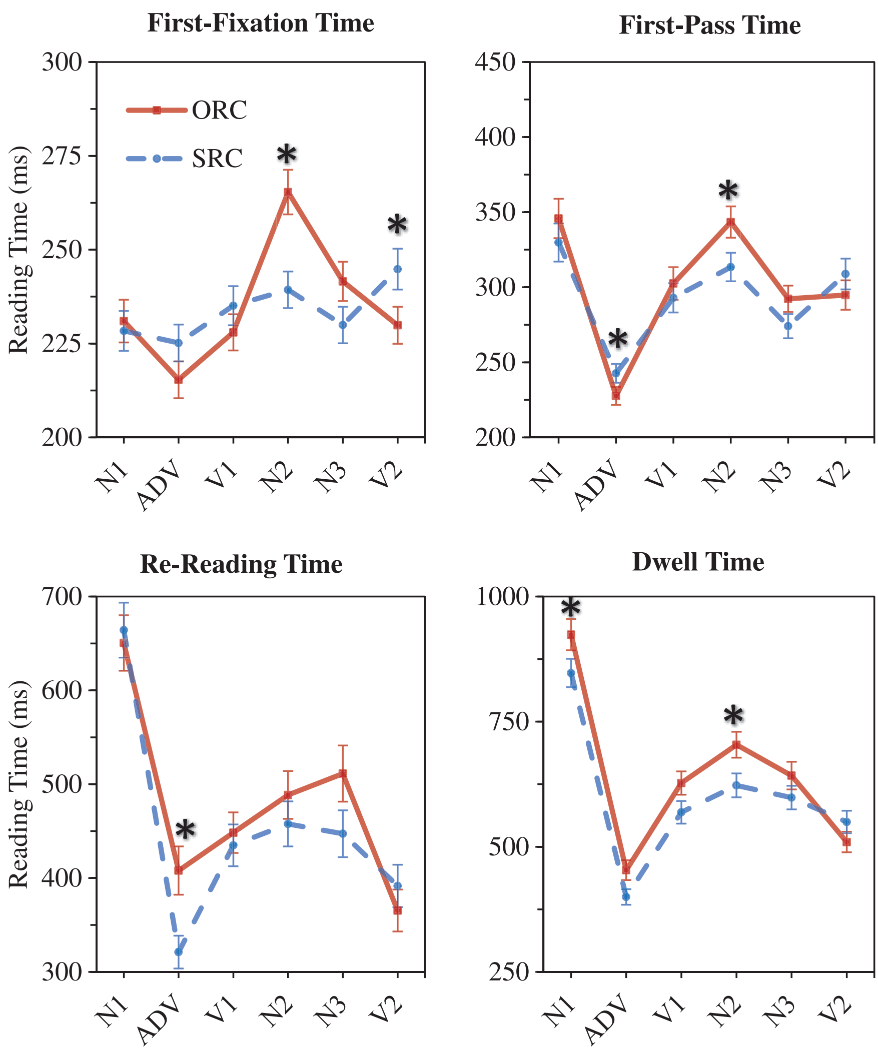

Figure 4: Experiment 2 unambiguous RC reading time plots.

Unambiguous: Both first-pass reading time ($p < 0.05$) and re-reading time ($p < 0.05$) were shown to reveal significant differences in reading times between RC conditions. However, while first-pass demonstrated longer reading times for SRCs, this was reversed for re-reading time. Also, during dwell time ($p = 0.061$), ORCs were found to require marginally longer overall reading times compared to SRCs.

3.2.4 RC verb

Ambiguous: It was revealed that during re-reading ($p < 0.05$) and dwell time ($p < 0.05$) the ORC condition had significantly longer RTs. Other measures were not observed to have significant differences between RCs.

Unambiguous: No index revealed a significant difference between RC conditions at the RC verb for unambiguous RC types.

3.2.5 Head noun

Ambiguous: Only dwell time ($p < 0.05$) showed a significant difference between RCs revealing that ORCs required longer overall RTs. Other measures were not observed to have significant differences between RCs.

Unambiguous: First-fixation ($p < 0.01$), first-pass ($p < 0.05$) and dwell time ($p < 0.05$) measures demonstrated that ORCs were read more slowly than SRCs at the head. The remaining measures did not differ significantly between RCs.

3.2.6 Matrix object

Ambiguous: Only regression-out proportion ($p < 0.05$) revealed a significant difference between RC conditions; ORCs had a higher likelihood to regress out of the matrix object. While all other measures did not have significant RC differences, go-past time ($p = 0.059$) had a marginal trend showing that ORCs had longer regressive reading times before moving on to the matrix verb.

Unambiguous: No measure displayed significance between RC conditions.

3.2.7 Matrix verb

Ambiguous: No measure displayed a significant difference between RC conditions.

Unambiguous: Surprisingly, first-fixation duration ($p < 0.05$) revealed that SRCs required significantly longer reading times than ORCs during the earliest measure of processing at the matrix verb. However, this effect quickly diminished because no other measure of processing was significantly different between RC conditions.

3.2.8 Post-hoc sentence completion task

We conducted a sentence completion task after the completion of the eye-tracking study in Experiment 2. The sentence completion task is thought of as a technique to tap into production preferences of native speakers. Previous studies concerning Japanese relative clause processing have conducted sentence completion tasks on their items to determine if an item set would elicit a particular RC interpretation at a greater frequency than its counterpart. As mentioned above, these investigations have often yielded conflicting results in Japanese. This is, however, not surprising when considering the statistical properties of various syntactic structures for Japanese. Specifically, while SRCs are more frequent than ORCs, subject pro-drop is overwhelmingly more frequent than object pro-drop (see Yun et al. 2015: 141). Thus, this creates a conflict in predictions when a provided NP contains accusative case because both an RC interpretation and a pro-drop interpretation have high preference biases. As such, the reading up to the first verb is less constrained for the SRC condition allowing for greater structural variance. In contrast, because object pro-drop is infrequent in comparison to ORCs, it should be easier for participants to consider the clause as an RC.

While the level of entropy or uncertainty in the fragment is higher for ORCs at the embedded RC verb compared to SRCs (Yun et al. 2015: 136), the hierarchy for the probabilities of the remaining structures would favour ORC interpretations. For each RC condition, although the structures with the highest probabilities are a matrix clause and an RC respectively, after these, structural probabilities begin to diverge. Importantly, for ORC fragments, the following two structures are ORCs with varying syntax while for SRC fragments, the structures are a complement clause and another SRC respectively. Thus, while SRCs are more frequent than ORCs, the data collected from this task is unlikely to reflect the overall distribution of RCs. Instead, the data will most likely reflect the varying structural probabilities that are permissible in the ongoing structure.

In summary, if predictions for RC completions were to be based upon the overall distribution of RCs or the ORC difficulties observed at the head noun from the current and previous studies, then SRCs should be formed at a greater percentage than ORCs. On the other hand, ORCs would be expected to occur more frequently when considering the syntactic probabilities of the ongoing structure.

Considering the issues discussed above, we primarily concerned ourselves with whether the formation of an RC interpretation exceeded chance level. This was to determine whether there were issues in item design that prohibited an RC interpretation. The distribution of RC types was a secondary inquiry. Forty-four native Japanese speakers, undergraduates at a Japanese University, were recruited to participate in this task (N = 44, Female = 20). No subject participated in either eye-tracking experiment. For the task, the items for Experiment 2 were made into fragments such that the string ended at the RC verb. In order to not prime participants for an RC interpretation, the pre-RC demonstrative cue was not included. Two counterbalanced lists were created, each containing 32 fragments. Half contained an accusative marked NP and the other half contained a nominative marked NP. The ordering of fragments was also controlled so that items of the same NP case marking would not repeat more than twice.

(12) a. Subject-extracted relative clause fragment
昨夜給仕さんを激しく襲った
Sakuya kyûzi-san-o hagesiku osotta
[last.night waiter-ACC fiercely hit]
'(gap/pro) fiercely hit the waiter last night'
b. Object-extracted relative clause fragment
昨夜給仕さんが激しく襲った
Sakuya kyûzi-san-ga hagesiku osotta
[last.night waiter-NOM fiercely hit]
'the waiter fiercely hit (gap/pro) last night'

For this task, participants were instructed that they must complete the fragment provided to make it into a grammatical sentence. They were also instructed that they must provide at least one additional word and not end the sentence with a noun. For data collection purposes, we recorded whether participants created an externally headed RC out of the fragment upon completing the sentence. See below for examples.

(13) a. Relative Clause – 1 (an RC)
昨夜給仕さんを激しく襲った顧客は逮捕された。
Sakuya kyûzi-san-o hagesiku osotta kokyaku-wa taihosareta
[last.night waiter-ACC twice hit] customer-TOP was.arrested
'The customer who fiercely hit the waiter last night was arrested.'
b. Relative Clause – 0 (not an RC)
昨夜給仕さんを激しく襲ったと聞いた。
Sakuya kyûzi-san-o hagesiku osotta to kiita
[last.night customer-ACC twice hit] COMP heard
'(I) heard that (pro) fiercely hit the customer last night.'

The results of the sentence completion task were analysed using both chi-square goodness of fit tests and LME methods. For this data set, if it was determined that the participant made the fragment into an RC upon finishing the sentence, the item was given a value of 1, and if another structure was created, the item was given a 0 value (i.e. binomial data). For the analyses to determine whether RCs formations exceeded random chance, chi-square goodness of fit tests were used. For the analysis comparing RC conditions, the glmer function within lme4 was used in R. The RC conditions comprised the fixed effect, and both subject and items were treated as random effects with both random intercepts and random slopes.

The overall likelihood for participants to turn the fragments into RCs was significantly greater than chance [X^2 (1, $N = 1408$) = 192.05, $p < 0.001$] with RCs obtaining 964 tokens. This was also true when analysing within both the ORC [X^2 (1, $N = 704$) = 198.69, $p < 0.001$] and SRC [X^2 (1, $N = 704$) = 30.28, $p < 0.001$] conditions. ORCs received 539 RC tokens while SRCs obtained 425. Accordingly, when prompted to finish a fragment with either a missing subject or object, participants created RC structures at a rate exceeding random chance. The rate of non-RC constructions among all completions slightly differed from Ueno and Garnsey (2008): mono-clausal sentences (ORC: 1.3 % and SRC: 1.0 %), adjunct clauses (ORC: 6.0 % and SRC: 12.5 %), fact-clauses (ORC: 3.8 % and SRC: 5.7 %), and other clauses (ORC: 0.4 % and SRC: 0.4 %). Specifically, while adjunct and fact-clauses were shown to have more instances in the SRC fragment category, the difference between conditions for mono-clausal sentences diminished. Another notable difference was the uptake in adjunct clauses in the current study. Given the fragments, when not forming RC structures, participants preferred to form adjunct clauses and fact-clauses with pro-drop interpretations for both conditions.

Moving on to the glmer analysis, the results revealed that when participants completed the fragments, the likelihood of the fragment being made into an ORC (Mean = 0.766, SE = 0.016) was much more probable than the fragment becoming an SRC (Mean = 0.604, SE = 0.018); coefficient = −1.42, SE = 0.33, $z = -4.31$, $p < 0.001$). To properly complete the task, participants did not have to commit to an RC interpretation as there were a wide range of permissible structures, for instance, complement and adjunct clauses. Accordingly, this result is consistent with the above prediction that the ORC prefix string is more constrained to an RC interpretation than its SRC counterpart, a point addressed by Yun et al. (2015) and Ueno and Garnsey (2008). Briefly put, other syntactic options are more permissible for the SRC condition. This finding, on the other hand, contradicts with the overall distribution of RCs in the language (i.e. SRCs are more frequent than ORCs) and the difficulties observed for ORCs at the head noun in the current study and previous studies.

Overall, the sentence completion task data does not appear to relate to the difficulties observed during sentence processing. Instead, the task seems well suited at exploring the level of certainty in the ongoing formation of the structure. Importantly, the degree of certainty might only engender difficulty during on-line processing when entropy is reduced between words, Hale's (2006) entropy-reduction hypothesis, or during the ongoing process of revising structural expectations, Levy's (2008) surprisal theory. However, we believe that the task has less conflict with the entropy-reduction hypothesis than surprisal theory because, despite ORCs being more constrained, the overall reduction in entropy would nevertheless be greater between the RC verb and head noun. In contrast, if the data collected here and by other researchers were to be applied to expectations during reading, it would suggest that there would be a lesser need to revise the structural expectations for ORCs compared to SRCs. Yet, the above eye-tracking results directly contradict this. Thus, completions elicited by participants appear not to directly relate to the expectations native speakers generate incrementally during the reading of the structure but instead might relate more to the certainty of the structure.

In conclusion, we advise caution using the sentence completion task to predict Japanese native speakers' expectations during reading. It nevertheless remains unclear which of the two expectation accounts applies to the participants' on-line processing or if working memory is more heavily involved in sentence processing than expectations. Another possibility is that there is a general conflict between offline production and on-line reading data. Specifically, the nature of the task might elicit participants to form other permissible structures to avoid repetition. What is apparent is that the items used in Experiment 2 had a high likelihood of activating an RC structure.

3.2.9 Post-hoc naturalness decision task

To determine whether a particular condition was more natural than the other, a post-hoc naturalness decision task was also conducted on the above stimuli.

Twenty (N = 20, Female = 12) native Japanese speakers were recruited from a Japanese University. All participants were undergraduate students, and none took part in the above eye-tracking experiments or sentence completion task. The experimental stimuli were separated into four counterbalanced lists with each containing eight items for each RC and ambiguity condition. A seven-point Likert scale was used for this task with −3 being rated as most unnatural and +3 being rated as most natural. Participants were instructed to rate the items on the naturalness of each sentence, not grammaticality or plausibility. Each response was recorded as −3 to +3 respectively. LME models were used to analyse the data. RC condition and ambiguity type composed the fixed effects with subject and items as random factors. The results revealed that there was a significant difference between RC condition (coefficient = 0.341, SE = 0.110, $t = 3.09$, $p < 0.01$) which demonstrated that SRCs (Mean = 0.27, SE = 0.10) were rated more natural than ORCs (Mean = −0.72, SE = 0.10). Similarly, there was a difference between ambiguity contexts (coefficient = 1.295, SE = 0.111, $t = 11.67$, $p < 0.001$) revealing that the ambiguous context (Mean = 0.74, SE = 0.10) was more natural than the unambiguous context (Mean = −0.54, SE = 0.09). There was no effect of interaction.

As mentioned, using pre-RC demonstratives should be quite unnatural. However, it was the point of the design to use a context which would enhance the RC interpretation. Because there was no interaction effect, we do not consider the use of the pre-RC demonstrative to be problematic.

In terms of relating the data found here with the above sentence processing results, it might be the case that the naturalness of the sentences favoured the SRC conditions during reading. Yet, the extent of this might not have far reaching consequences as processing differences were apparent between ambiguity conditions during reading. Importantly, while unambiguous ORC sentences as a whole were not as difficult to process as unambiguous SRCs, it was the case that ambiguous ORCs had a higher overall processing cost than ambiguous SRCs. Furthermore, for the ambiguous RC conditions, ORC difficulties were more widespread than the unambiguous condition. If the item naturalness greatly impacted on-line processing, then its effect on processing would have likely been more similar between ambiguity conditions. However, it is difficult to attribute item naturalness as the leading cause of ORC difficulty in both cases because observations of ORC difficulty differed. Nonetheless, while we admit that item naturalness might be a limitation of Experiment 2, the influence of naturalness during on-line processing was likely minimal.

3.3 Discussion

Overall, Experiment 2 revealed greater ORC difficulties in the processing of RCs by native Japanese speakers. Similar to the case in Experiment 1, ambiguous RCs revealed ORC difficulties at the RC verb and head noun with additional difficulties observed at the RC noun. For unambiguous RCs, on the other hand, ORC difficulty was chiefly limited to the head. In the following sections, each processing account will be addressed in relation to the data. Moreover, the influence of ambiguity will also be explored.

3.3.1 Similarity-based interference

For ambiguous RCs, similarity-based interference models (Gordon et al. 2001) were supported at the RC noun, RC verb and head noun, i.e. the RC argument. Because ORC heads and RC nouns had matching features, the ORC head could retroactively interfere with the RC noun. Drawing on aspects of the object-before-subject-bias (OBSB) account (Nakamura and Miyamoto 2013), the pre-nominal RC structure requires the head of the ORC be integrated into the structure before the assignment of theta to the subject. As such, similarity-interference occurring after the first reading of the RC agrees with OBSB. Moreover, because a garden path effect exists up to the head noun, the entire structure would need to be reanalysed, and this might induce comprehension difficulties for the RC argument due to the interference between nouns.

For unambiguous RCs, on the other hand, there were less indications of similarity-based interference because difficulties were no longer shown at the RC verb. However, it would be hasty to rule out interference effects altogether. Essentially, having a head noun modified by a demonstrative might make the head more distinct in working memory. If this reasoning is accurate, there should be less proactive and retroactive interference between the NPs which should attenuate the interference effect.

3.3.2 Integration-based resources

According to linear/temporal distance metrics (Gibson 2000; Lewis and Vasishth 2005), SRCs should be more difficult because the distance between the filler and gap is more local for ORCs. In contrast, the structural distance metric predicts the opposite. Because both ambiguous and unambiguous RCs produced ORC difficulty at the head noun, the structural metric (O'Grady 1997) is better supported. Yet, we claim that neither case provided the crucial evidence for integration processes using eye-tracking. In the ambiguous context, ORCs were more difficult during late measures while for unambiguous RCs this difficulty was seen during early measures of processing. Even though some might suggest that both support a structural distance metric of integration, we claim that regressive eye-tracking measures of processing, such as go-past time and regression-out proportion, would better represent integration effects. Consequently, despite that the structural metric being supported here, we do not believe that it is the best account for the ORC difficulties at the head noun.

3.3.3 Expectation-based processing

For ambiguous RCs, the first indication of greater ORC difficulty was found at the RC noun as early as first-fixation duration. Considering that these clauses were ambiguous and thus should be initially parsed as a simple matrix clause sentence, this finding goes against surprisal theory (Levy 2008) which would not necessarily predict processing biases at this locus. This is because attestation accounts for combined transitive and intransitive clauses are approximately equal (see Yun et al. 2015). Yun et al. (2015), however, argued that difficulties at the RC noun during early measures of processing are predicted by the entropy-based reduction hypothesis (Hale 2006). That is, there is greater reduction in entropy at the processing of a nominative case marker than an accusative one. Notably, this finding conflicts with that of Experiment 1 which did not reveal any significant differences at the RC noun, let alone early measurements of ORC difficulty. We address these differences in Section 4.1.1 below. Nevertheless, similar to Experiment 1, ORC difficulty was observed at the RC verb and head noun during late-stage measures of processing. While expectation-based models (e.g. surprisal and entropy-reduction) predict ORC difficulty at the head noun, these models would be better supported if ORC significant difficulties occurred during early-stage processing.

For unambiguous RCs, the first indication of early ORC difficulty was observed at the head noun which is a drastic shift in processing compared to the ambiguous items of Experiment 1 and 2. We believe this change in processing to reflect the higher activation level of the SRC structure. This was due to the additional cues to disambiguate the clause-type ambiguity. However, these cues did not allow the parser to utilize RC frequencies immediately for expectation purposes. Within unambiguous RCs, there were no differences between RC conditions at the RC noun which would serve as a potential cue for RC type due to case morphology. Instead, ORC difficulty likely first occurred at the head noun (i.e. the locus of disambiguation) which suggests that the parser must have waited for a viable cue to assign RC features to the clause, and only after this, differences between RC conditions in terms of frequencies and expectation were observed.

Nonetheless, the additional cues were able to enhance the expectation of the RC structure and likely increased the activation level for each structure. But because SRCs are more frequent in Japanese, these cues had a greater benefit for SRCs than ORCs.

Moving on to the entropy-reduction model (Hale 2006), Yun et al. (2015) claim the changes in entropy might be minimal for an unambiguous RC if the structure is certain. This might explain why no difficulty was observed early at the RC noun. However, following their rational, it is suspicious that there was still lingering difficulty at the head noun. It could be that while the cues attenuated the ambiguity, there was still lingering uncertainty left in the structure which was subject to difficulties in entropy reduction between the embedded RC verb and head noun.

For the sentence completion task, ORC fragments were shown to have a higher probability of having an RC structure formed than SRC fragments. As argued above, this result is expected because ORCs fragments are more constrained to RC interpretations than SRC fragments, which explains why SRCs were formed less often. Also, the findings of the sentence completion task do not translate well to on-line reading behaviour because ORC difficulty was primarily observed. Thus, data collected from sentence completion tasks might not relate to structural expectations during reading but instead reflect the degree of certainty for the structures which can complete the fragment. To clarify, the results of the sentence completion task and the eye-tracking results might support the entropy-reduction hypothesis more so than surprisal theory.

In general, expectation-based processing in languages like Japanese might be as simple as a general advantage for transitive clauses which lack a subject in comparison to clauses lacking an object. Accordingly, regardless of the initial interpretation made on an embedded clause, clauses lacking an object will likely be observed to be more difficult to parse at the head due to revised expectations (Levy 2008) or the reduction of entropy (Hale 2006) when using eye-tracking methods.

In summary, expectation-based processing models were shown to be satisfactory predictors of ORC processing for unambiguous RCs. When the RC structure became less ambiguous, expectation-based processing observations became clearer and more robust.

3.3.4 The object-before-subject-bias

The results of Experiment 2 revealed that the general pattern for ambiguous items was replicated when the items were strictly ambiguous. In other words, the late processing difficulty was still observed for ORCs. This result provides support for the object-before-subject-bias. Specifically, for ORCs after reading the head noun, there were inherent difficulties involved in thematic assignment for RC arguments. This resulted in increased reading times during late-stage measures at the RC noun, RC verb and head noun.

For unambiguous RCs, however, ORC difficulty was no longer observed at the RC verb and the late difficulty for ORCs at the head noun was shifted to earlier measures of processing. Nakamura and Miyamoto (2013) suggested that OBSB might not induce ORC processing difficulty for unambiguous RCs because the head noun would be more anticipated. Miyamoto (2016), on the other hand, argued counter to this point and claimed that there would still be issues in thematic assignment. We argue along the lines of the earlier claim that OBSB should not reflect the ORC difficulties of unambiguous RCs. If the RC structure is understood, then the thematic class of head noun should be able to be predicted at the verb due to the collocations between the predicate and its direct object. What is more, the attenuated ORC difficulty at the RC verb gives the impression that after reading the head noun there was less of a need to interface back with the predicate to assign the theta role of the subject. In summary, we claim that OBSB is a better predictor for ORC difficulty when the clause is ambiguous.

3.3.5 Processing summary

Our interpretation of participants processing for ambiguous RCs remained relatively unchanged. Only minor differences between experiments were present. Most notably, early ORC difficulty was observed at the RC noun. This finding, however, is explained by the entropy-reduction hypothesis. As such, the difficulty found here most likely represents the processing work of eliminating uncertainty in the structure. After this point, we do not consider the differences between experiments to drastically change the overall processing behaviour besides the increased re-reading at the RC noun for ORCs. As such, refer back to Section 2.3.5 for the processing pattern for ambiguous RCs.

For the processing of unambiguous RCs (i.e. attenuated ambiguity), the pattern of processing was quite distinct from ambiguous RCs. During the reading of the RC, it appears participants did not experience considerable difficulties. Unlike the ambiguous RCs, we argue that here participants must have been aware that they were reading within an embedded clause if not specifically an RC. Unlike ambiguous RCs, the head noun did not induce RTs drastically for both conditions in respect to the other regions. Instead, only ORC difficulty was observed at the head. However, this goes against our initial predictions that ORC difficulty should be seen early at the RC noun or the RC verb. In fact, this should have been the case regardless if a complement clause or an RC interpretation was made. Consequently, the clause itself might lack its respective features until the head, or participants adopted a wait-and-see approach to the understanding of the clause. While we argue that it is the former, the latter cannot be completely ruled out. Regardless, once participants started reading the head noun, they began to experience difficulties with ORCs. This is most likely associated with issues in encountering an infrequent structure in respect to a more frequent one. After reading the sentence, we suspect that participants again re-read the sentence to answer the following question. However, unlike the ambiguous RCs, participants did not find one sentence type to be any more difficult than the other. We attributed this to the attenuated similarity-interference effects as well as OBSB no longer being key processing factors.

3.3.6 Ambiguity

Comparing the effects of ambiguous and unambiguous RCs, there was a clear change in processing behaviour. Importantly, processing changed at the head noun. For the ambiguous RCs, the key results of Experiment 1 were replicated (i.e. general late ORC difficulties); however, for unambiguous RCs, ORC difficulty was observed much earlier. As mentioned above, we consider this change between conditions as an indication of expectation-based processing becoming more prominent. In all, the expectation-based processing account provides the most suitable explanation for the results found in Experiment 2. Because cues were introduced to eliminate the matrix clause interpretation and likely generated an RC interpretation, upon reaching the locus of disambiguation, the activation level for SRCs would have been much higher than ORCs due to their higher frequency in corpora. Also, the parser would be less bottlenecked by other processing factors such as OBSB and similarity-interference.

4 General discussion

The purpose of this study was to investigate how relative clause processing in Japanese unfolds as a factor of ambiguity. Particularly, we wished to investigate the validity of the object-before-subject-bias, memory-effects (i.e. integration and similarity-interference) and expectation-based processing within different contexts of ambiguity. Overall, the results revealed that different patterns of processing were associated with the different levels of ambiguity found in each context: (1) ambiguous items had general ORC difficulty during later reading times and (2), when the head noun was modified by a demonstrative article preceding the RC, ORCs had longer reading times during early-stages at the head noun. In general, processing was altered when there was greater anticipation for a head noun. In other words, when RCs were ambiguous, the object-before-subject-bias provided the best account for the ORC difficulty, and when they were unambiguous, expectation-based processing was better at predicting ORC difficulty. Below, we provide a summary for each RC context.

4.1 Ambiguous relative clause processing

Within the processing of ambiguous RCs in Japanese, it appears the effects of expectation-based processing and integration were masked or diminished. Even though both accounts predict ORC difficulty at the head noun, the observations found do not best reflect either account. While the surprisal model (Levy 2008) predicts ORC difficulty at the head noun during disambiguation of clause type, this processing account would be better supported if early-stage difficulty was also observed. For integration effects, we contend that concrete evidence would be reflected by go-past times. Rather, only late-stage difficulty was observed at the head noun. This can be attributed to multiple processing demands occurring at the head, for example, a heavy syntactic reanalysis and filler-gap parsing. These effects in tandem (and possibly others) would overload the processing bottleneck and diminish processing observations at this locus during early measurements of processing. As noted earlier, when methods to attenuate the ambiguity are introduced, the processing burden at the head noun is attenuated as well. Consequently, SRCs and ORCs might only have subtle differences in observations of processing when a heavy syntactic reanalysis is required.

While we contend that integration-effects were not conclusively supported by our results, Ueno and Garnsey (2008) provided convincing evidence that filler-gap parsing is involved at the head noun. Although, as mentioned earlier, their results are also subject to interpretation. Assuming their results are indeed reflective of the integration process, the differences between studies might reflect the different degrees of sensitivity each method brings or other task related influences. Importantly, ERP methods typically only allow for a serial reading of the sentence, i.e. word-by-word at a fixed interval with no re-reading or preview while eye-tracking presents the sentence all at once and allows re-reading, preview and skipping. Rather than saying that the studies disagree with one another, it might be more appropriate to claim that each study introduces different insights into the processing of RCs in Japanese. Consequently, we maintain that part of the processing difficulty for ORCs at the head is elicited by a long-distance gap dependency as revealed by Ueno and Garnsey (2008). However, this was not clearly observed in the current study.

The object-before-subject-bias (Nakamura and Miyamoto 2013), on the other hand, appears well suited to explain the ORC difficulty for ambiguous RCs in Japanese. Within ambiguous RCs, processing difficulty was chiefly observed at the head noun and RC verb during later stages of processing which is consistent with the predictions made by OBSB. As such, the ordering of theta roles for the RC argument allows SRCs to be easier to process because the object is integrated first with the RC verb prior to the head noun. Conversely, ORCs are more difficult because the parser is required to wait until the head noun to go back and assign the theta role to the RC subject.

Along with OBSB, similarity-based interference (Gordon et al. 2001; Lewis and Vasishth 2005) can also explain the extra processing demands for ORCs in both experiments. This is particularly interesting because Ueno and Garnsey (2008) had attempted to control for the effect in their items by making the head noun an oblique-adjunct with dative-topic case. Despite this, the head noun might still have been interpreted as subject-like in some cases thus allowing for some overlapping features between nouns. In Experiment 2, however, it should have been much clearer that the head noun was the subject of the matrix clause. In all, when multiple subject arguments were stored, there was greater difficulty in maintaining these arguments as well as retrieving a specific one from memory which agrees more to Gordon et al.'s (2001) account of similarity-interference. Overall, similarity-based interference should be considered as an interactive factor in Japanese RC processing. To better control the influences of similarity-based interference in future studies investigating ambiguous RCs, we suggest that researchers should use RCs modifying an indirect object as it might better attenuate this effect. For instance, 'The mailman delivered the letter to the reporter who criticized the mayor.'

In summary, the current study provides tacit support for expectation-based processing and a structural integration (O'Grady 1997) and clearer support for the object-before-subject-bias (Nakamura and Miyamoto 2013) and similarity-interference (Gordon et al. 2001; Lewis and Vasishth 2005) for the processing of ambiguous RCs in Japanese. Importantly, the felicitous argument here would be that these effects are collectively influencing the processing of Japanese RCs.

4.1.1 Differences between experiments

While we argue that the overall interpretation for the results do not differ between the ambiguous RC items of Experiments 1 and 2 (i.e. late-stage ORC difficulty supports the object-before-subject-bias), the eye-tracking results slightly differed between them.

Notably, early-stage difficulty for ORCs was observed at the RC noun (N1) in Experiment 2, and differences between RC conditions were more pronounced during re-reading times in Experiment 2. We highlight possible explanations as to why the two experiments differed below.

One explanation that might help reconcile the early-stage differences is the slight differences between stimuli. While both experiments used ambiguous RC items, the contents of the items differed between experiments. Particularly, in Experiment 1, the RC contents were composed of an adjective, a noun and a verb, while in Experiment 2 they were composed of a temporal adverb, a noun, another adverb and a verb. As such, one possibility is that moving from a temporal adverb to a noun involves a different process than from an adjective. Thus, it might be that participants in Experiment 2 preferred a subject-pro instead of an overt subject whereas no such preference was held by the participants in Experiment 1.

While the difficulty of nouns marked with nominative case is often considered a typical observation in Japanese sentence processing, the entropy-reduction hypothesis considers the difficulty to reflect the greater reduction of entropy between a noun and its nominative case marking compared to a noun and its accusative marking. Thus, the early ORC difficulty at the RC noun in Experiment 2 might reflect this process. As to the reason why no difference was observed in Experiment 1, the possibilities could also reflect the above differences in items which allowed the effect to be more pronounced in Experiment 2.

Also, the differences in the items' naturalness might have allowed for differences in reading behaviour between the two experiments to appear; yet, this is not the best explanation. As discussed above, if item naturalness was the major cause of the discrepancies, then unambiguous items of Experiment 2 should have been more similar to the ambiguous items in terms of ORC difficulties.

Concerning the difference during re-reading, another possibility is the minor difference in experimental methodology. While the procedures were nearly identical, there were two aspects that differed. First, more time was allotted for reading the sentence due to the increase in item length for Experiment 2. However, by comparing the overall total reading times of the sentences for each ambiguous RC condition, the reading times for Experiment 1 were numerically longer than Experiment 2. As such, giving more time to the participants did not likely alter their reading behaviour. However, it is important to note that the lengths of the ambiguous items in Experiment 2 were longer than the item lengths of Experiment 1. This oddity might be explained by the second difference in methodology, which is feedback. Specifically, in Experiment 1 feedback was not given after the participant responded to the comprehension probe, whereas in Experiment 2, it was. Again, by comparing the re-reading times of the RC between experiments, Experiment 1's re-reading times were also longer than Experiment 2's re-reading times for the regions within the RC. As such, one could infer or speculate that without feedback, participants spent more time re-reading the sentence prior to moving on to the question. In other words, this could be construed as extra cognitive effort being given to prepare for the post-sentence comprehension question during the reading of the stimulus. At the very least, participants might have oriented their reading differently based on the presence of feedback.

For both the early-stage and late-stage differences, another possibility is that there is random variability among native speakers of Japanese. While the participants of both groups were primarily composed of undergraduate students, their majors differed. Specifically, the ratio between agricultural, economics and engineering students differed between experiments as well as the distribution of male and female participants. Accordingly, there is some possibility that the differences among these small subsets of native Japanese speakers might represent the differences between the Experiments.

In summary, while the differences between the two experiments are noteworthy, we do not consider them to warrant major concern for the overall interpretation of late-stage difficulty for ambiguous ORCs.

4.2 Unambiguous relative clause processing

In Experiment 2, we introduced an unambiguous RC context. Admittedly, the terminology 'attenuated ambiguity' would more appropriately describe the context. Because we believed that the parser is bottlenecked at the head noun for ambiguous RCs, we inserted pre-RC demonstratives to eliminate a matrix clause interpretation and increase an RC one. Surprisingly, ORC difficulty was still localized at the head noun rather than the RC NP which contained case morphology cues. However, a clear change of processing was nonetheless apparent as difficulties were shifted from late-stage measurements to early-stage ones.

One argument could be made that the clauses were still ambiguous thus making disambiguation obligatory at the head noun. However, we do not believe this to be the case. First, the results of our sentence completion task as well as tasks in other studies reveal that RC structures are formed more often than non-RC structures. Second, even if a non-RC interpretation was made, the ORC condition should nevertheless be found to be more difficult, owing to the fact that object-drop is far less frequent than subject-drop. Similarly, the attestation counts provided by Yun et al. (2015) would suggest that RCs would have a higher rank in a probabilistic parallel parser in comparison to a complement clause upon reading the transitive embedded verb. Third, considering that the current study and previous studies (e.g. Miyamoto and Tsujino 2016) did not find ORC difficulty prior to the reading of the head noun within unambiguous contexts, our results are not dissimilar. In addition, studies for other prenominal RC languages (e.g. Kwon et al. 2010; Mansbridge et al. 2017b) also found no indications of immediate effects of expectation. Thus, even between languages, similar patterns are found. Rather than being a locus of disambiguation, we contend that the head noun here acts as a cue to assign the RC value to the clause and after this point the parser is susceptible to the influences of RC probabilities.

Our rationale for this argument comes from recent findings in English by Staub et al. (2018). In their study, they compared the processing of RCs against complement clauses. Importantly, the key aspect of their study was that there was ambiguity in one RC condition which would provide an incorrect complement clause interpretation for the RC (e.g. 'The report that the senator prepared' vs. 'The report that the senator was sick'). Using eye-tracking, they found that despite the higher probability of forming an RC, RC conditions were instead favoured to have a complement clause interpretation. Drawing on aspects of the *minimal chain principle* (De Vincenzi 1991) such that the parser will not create a filler-gap dependency unless it is forced, they concluded that in contexts of ambiguity, a serial-based parser will take a non-RC interpretation until it is proven incorrect. This could of course be influenced by cues within the sentence to force the RC interpretation earlier. Their argument, however, challenges the ranked-parallel parser premise of surprisal (Levy 2008) and has severe implications for prenominal-RC languages. Specifically, unless strong cues are inserted, disambiguation is likely to occur within both ambiguous and unambiguous RCs at the same locus. This would help explain recent findings by Mansbridge et al. (2017b) and Kwon et al. (2010). Importantly, both studies revealed expectation-based effects for unambiguous clauses at the predicted locus of disambiguation for ambiguous RCs.

Unlike Staub et al. (2018), however, we do not believe that only a single interpretation is permissible by the parser at a time. Instead we contend that while interpretations are ranked, structural probabilities are also modulated by other processing principles, in this case the minimal chain principle. Within our argument, we contend that the while structure is activated in the parser, the difficulties in terms of expectation are not observed until a cue can assign specific clause features to the structure. Importantly, this is because a processing bias should have been observed prior to the locus of disambiguation regardless if the parser interpreted the clause as an RC or a complement clause, not only for Japanese but Korean and Mandarin as well.

One difference between these prenominal languages is that the ORCs difficulties in Korean (Kwon et al. 2010) and Mandarin (Mansbridge et al. 2017b) were first observed prior to the head noun. The importance of this is that the entire structure was not required to be parsed out for ORC difficulties to occur. We thus can conclude that these effects are neither immediate nor terminal in regard to loci of ambiguity. It was instead the specifics of the Japanese language that caused this. Specifically, typical Japanese RCs have no markers while both Mandarin Chinese and Korean have relativizers and adnominal markers prior to the head.

Together, these prenominal languages differ with key post-nominal languages such as English and Russian such that relativizers in these post-nominal languages are typically encountered upon entering the clause. This is important because RC or other clause-type features can be assigned to the clause initially. This explains why processing asymmetries can be observed at the first available loci in these languages whereas it comes later for prenominal languages. As such, it is our argument that for the parser to be sensitive to structural probabilities, a key element or cue is first required to be integrated into the structure. This in turn would help the parser from forming committed expectations of a structure with filler-gap dependencies when other possibilities exist, importantly, even if RCs are more frequent in corpora.

As mentioned, however, we disagree with Staub et al. (2018) claim for a serial-based parser. If that were the case, then the object/subject asymmetry in the current study should not have altered substantially. Rather, it is our interpretation that structural probabilities were being activated prior to the head noun for the unambiguous RC conditions. Because the matrix clause interpretation was eliminated, other embedded clause structures were being activated thus increasing the activation level for RCs, regardless if complement clauses were ranked higher or not. When the RC feature was assigned at the head noun, there were greater gains in activation for the SRC structure owing to its higher frequency. This in turn facilitated the early readings at the head for SRCs and induced reading times for ORCs which have a structural dispreference. It is our opinion that this interpretation is well suited at explaining the ORC difficulties for unambiguous Korean and Mandarin RCs as well.

In all, for expectation-based processing, we believe that more investigations are needed. One issue that requires further clarification is to determine if parsing is serial or parallel. This would be particularly important to determine if a complement clause interpretation or an RC one is taken despite RCs being the more frequent structure. Another important issue is to determine if all possible structures are available immediately in the probabilistic parser, if certain structural probabilities are only introduced after additional elements are integrated into the string or if some other intricate process is involved. In other words, it is important to determine the timing and manner for weighting structural probabilities in the parser. As we see it, the results of the current study, results of other prenominal languages and even results of post-nominal languages have confused these matters. Our interpretation is that while multiple probabilities are weighted against one another during the parsing of a string, our sensitivities to these expectations are only realized when there is a link to our past experience. For this to occur, certain features of a structure must first be parsed (i.e. bottom-up processing) in order to determine if the current string agrees with the expectations drawn from past exposure (i.e. top-down processing).

Moving on to effects of integration, while it is likely that such effects occurred during the processing of these sentences, conclusive evidence was lacking. While the early reading times at the head noun can also represent the process of integration, it is hard to make a definite claim without differences within regressive eye-tracking measures. As mentioned, the structure of Japanese RCs is debated, and the possibility remains that Japanese RCs might lack gaps. However, considering ERP evidence and evidence found in similar languages such as Korean, we do not believe this to be the case. In order to resolve this issue, more studies are needed that focus solely on the integration process in Japanese.

Another memory-based component of processing not observed during the reading of these unambiguous RCs was similarity-interference. Despite the head and the RC noun having clearer overlapping features than in Experiment 1, no late ORC difficulties were observed, and ORC difficulties were lacking at the matrix verb. However, this finding is not surprising because these heads were additionally modified by the demonstratives which could have caused the parser to be less susceptible to interference effects. Similarly, Staub et al. (2017) also reported reversals in ORC difficulties when ORC included an extra prepositional phrase intervening between the RC verb and matrix verb. To explain this, they argued along the framework of cue-based retrieval (Lewis and Vasishth 2005) such that repeated activations on an item increase the activation level thus making it more distinct in memory. For their study, the extra activations occurred during the reading of the prepositional phrase, while it occurred during the reading of the demonstrative in ours. Additionally, this could help explain the lack of clear observance of integration-based effects here. Specifically, the added modification could have caused an antilocality effect during the later-stages of processing. Overall, we find the diminished effects of interference to be similar between languages.

Lastly, we will discuss whether the object-before-subject-bias is relevant for the processing of unambiguous RCs. Interpreting OBSB for unambiguous RCs is problematic because Nakamura and Miyamoto (2013) first claimed that OBSB might not account for ORC difficulty if the clause is unambiguous while Miyamoto (2016) claimed that the model still applies for unambiguous clauses. Thus, there seems to be disagreement. Yet, considering that the unambiguous RCs in Experiment 2 did not reveal ORC difficulty at the RC verb, it appears that OBSB was no longer a factor. If it was, the parser would revisit and interface with the RC predicate to assign the theta role, but no evidence for this was shown. Instead, the results suggest that upon the initial reading of the sentence, there was no longer any difficulty in terms of assigning the theta roles to the RC arguments. We contend that this arises from greater anticipation of the subject's role in the ORC condition when a clause boundary is formed prior to the first reading.

In summary, the findings for unambiguous RC processing in Japanese support expectation-based processing and again provides tacit support for integration. However, both similarity-interference and OBSB were less supported for unambiguous RCs.

5 Conclusion

We conclude that clause type ambiguity is an integral factor in Japanese relative clause processing. Furthermore, eliminating this ambiguity had great impact on the processing of the sentence, particularly at the head noun as predicted. When the RC was ambiguous, ORCs were more difficult to process after disambiguation, possibly due to the inherent difficulty of assigning thematic roles when the object appears outside the clause as object-before-subject-bias predicts. Yet, at the same time, other processing factors such as expectation, structural-integration and similarity interference were also supported because all predict ORC difficulty. Thus, for ambiguous RCs it is challenging to attribute ORC difficulties to any individual account listed above. In contrast, when the RC was unambiguous, ORCs experienced early difficulty at the head noun. We attribute this as a factor of expectation-based processing. Specifically, with attenuated difficulty and increased cues for the RC interpretation, expectation-based processing effects became more observable. In conclusion, this study adds to the growing body of literature showing that expectation-based processing is a key factor for unambiguous RCs.

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Compliance with ethical standards

No authors had a conflict of interest. All personal information collected from participants was stored in a secured location, and participants were given numerical pseudonyms for data analysis purposes to ensure privacy. Participants were not subject to harm and could have only experienced mild discomfort from prolonged seating or reading. Participants were allowed to take short breaks to prevent discomfort. In the current study, all participants first gave informed consent prior to the experimental sessions. After the completion of the eye-tracking sessions and the sentence completion task, all participants received monetary compensation. For the naturalness decision task, participants partook in the survey on a voluntary basis, thus they did not receive monetary compensation.

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