Japanese EFL Learners' Sentence Processing of Conceptual Plurality: An Analysis

Focusing on Reciprocal Verbs

Names and affiliations of the authors
Yu TAMURA (Kansai University)
Junya FUKUTA (Shizuoka University)
Yoshito NISHIMURA (Graduate School of International Development, Nagoya University)
Yui HARADA (Meijo University Senior High School)
Kazuhisa HARA (Okazaki Women's Junior College)
Daiki KATO (Tokoname Senior High School)

Address for Correspondence

Name: Yu TAMURA
Mailing address: Faculty of Foreign Language Studies, Kansai University, 3-3-35 Yamate-cho, Suita-shi, Osaka, 564-8680, Japan
Telephone number: +81-6-6368-0034 (Ext. 3958)
Email address: yutamura@kansai-u.ac.jp

Abstract

This study aimed to investigate how Japanese EFL learners, whose first language does not have obligatory morphological number marking, process conceptual plurality. The targeted structure was reciprocal verbs, which require conceptual plurality to interpret their meanings correctly. The results of a sentence completion task (SCT) confirmed that participants could use reciprocal verbs reciprocally in English. In a self-paced reading experiment, participants read sentences with reciprocal verbs and those with optionally transitive verbs (e.g., *while the king and the queen kissed/left the baby read the book in the bed*). There was no reading time delay for reciprocal verbs but a delay for optionally transitive verbs. Therefore, the participants succeeded in processing L2 conceptual plurality in the online sentence comprehension task.

Keywords: conceptual plurality, reciprocal verbs, English, garden-path effect, Japanese EFL learners

1. Introduction

In psycholinguistic research, there has been considerable debate over how number information is represented in cognitive processing of both one's first language (e.g., Patson, George, & Warren, 2014) and one's second language (e.g., Foote, 2010; Hoshino, Dussias, & Kroll, 2010; Wei, Chen, Liang, & Dunlap, 2015). One way of investigating the interface between morphosyntactic processing and semantic or conceptual processing is to examine how comprehenders process number agreement in various constructions (e.g., Bock & Miller, 1991; Eberhard, 1999; Humphreys & Bock, 2005). One reason for investigating the number agreement process is that although number agreement has been considered almost solely in terms of grammatical processing, researchers have found that in some cases conceptual information invades grammatical processing, as we will review later in this paper (e.g., Humphreys & Bock, 2005).

Even L1 English speakers are likely to make agreement errors when the number of a local NP mistakenly agrees with the verb, such as in *the gang on the motorcycles were*.... (Humphreys & Bock, 2005). In addition to the conceptual plurality present in collective nouns, comprehenders also use conceptual number/plural information denoted by means such as an NP consisting of singular head NP and plural local NP: *the label on the bottles was/were*… (e.g., Eberhard, 1999). In this case, comprehenders conceptually represent multiple bottles with the same label (that is, identical labels) attached to them, and thereby the number of *label* becomes conceptually plural. The evidence of the use of conceptual number information during language processing has been found both in production (e.g., Bock, Eberhard, Cutting, Meyer, & Schriefers, 2001; Bock et al., 1999, Eberhard, 1999) and comprehension (e.g., Kreiner, Garrod, &

Sturt, 2013; Nicol, Forster, & Veres, 1997; Pearlmutter, Garnsey, & Bock, 1999). Though most of the studies mentioned above focused on L1 sentence processing, other research has investigated whether or not L2 speakers can show a processing tendency similar to that L1 speakers are known to use (Foote, 2010; Hoshino et al., 2010; Nicol & Greth, 2003; Nicol, Teller, & Greth, 2001; Wei et al., 2015). Possible cognitive overload in online tasks partially due to low language proficiency (Foote, 2010, Hoshino et al., 2010; Jackson, Mormer, & Brehm, 2018) and the characteristics of the learners' first language (Jackson et al., 2018; Wei et al., 2015) are considered to be factors that hinder the use of conceptual number information in number agreement.

Despite our awareness of these factors, however, L2 studies investigating the availability of conceptual information in online sentence processing have mostly been based on eliciting number agreement errors. Just as L1 studies have reinforced the results obtained through the agreement attraction effect with those from tasks that investigated various types of conceptual plurality (e.g., Patson et al., 2014), L2 studies also have to move beyond the number agreement phenomenon, as there are other situations where conceptual plurality is critical in language processing; for example, the processing of reciprocal verbs (e.g., Patson & Ferreira, 2009).

To investigate the role of conceptual plurality in the processing of reciprocal verbs, the present study developed a sentence comprehension task making use of the traditional psycholinguistic technique of self-paced reading. The logic behind this approach is demonstrated by an interesting property of reciprocal verbs, as shown in (1).

(1a) Ken met Natsuko yesterday. (transitive reading)

(1b) Ken and Natsuko met yesterday. (reciprocal reading)

(1c) They met yesterday. (reciprocal reading)

(1d) *Ken met yesterday. (intransitive reading is not available)

As this example shows, reciprocal verbs can be used both transitively (1a) and reciprocally (1bc). If the reciprocal verbs are used reciprocally, they require two or more people to be involved in the event, as both agent and patient; therefore, if the subject of the sentence carries conceptual plurality, reciprocal verbs are used under the same restrictions as transitive verbs (1bc). In contrast, if the subject of the sentence is singular, the reciprocal verb must have an object or the sentence becomes ungrammatical (1d). As discussed in section 2.3, Gleitman et al. (1996) insist that (1d) "is not ungrammatical; rather, it is semantically ill formed" (p. 354). In addition, if the subject NP is singular, the verb can no longer function as a reciprocal verb because no reciprocal reading is available in that case (see section 2.3 for further discussion). Thus, whether reciprocal verbs are being used grammatically or not must involve judgment of the number information of the sentential subject. However, to our knowledge, little L2 psycholinguistic research has investigated whether L2 English speakers understand the characteristics of reciprocal verbs. Therefore, in addition to the online self-paced reading task, we investigated L2 speakers' knowledge of English reciprocal verbs using an offline sentence completion task in which participants were asked to complete sentences following a sentence fragment (e.g., *while the man and the woman dated....*/ *while the couples dated....*).

In the following background sections, we will review in detail how conceptual plurality has been operationalized and investigated in L1 and L2 research.

2. Background

2.1 Conceptual Plurality in L1 Research

How languages express number information varies. In the case of most English nouns, plurality is marked by the bound morpheme -*s*. Exceptions are irregular nouns (e.g., *child-children*, *cactus-cacti*) and nouns that have "zero plurals" (e.g., *deer-deer*, *sheep-sheep*). This plural -*s* represents what is often called *morphological* or *grammatical number*. In contrast, there is another type of number information present in the noun phrase, called *notional* or *conceptual number*. Conceptual number usually corresponds to grammatical number, but not always. For instance, please see (2a), an author-generated example, below. Looking at (2a), the word *scissors* is morphologically/grammatically plural in that it has a morphological marker that makes plural agreement with the plural copula *are*. However, in speakers' minds, *scissors* denotes only one entity, meaning it is conceptually singular.

(2a) The blue scissors are mine.

(2b) The government is going to put their new policy into action.

Similarly, *government* in (2b) is grammatically singular because it lacks a plural marker and makes singular agreement with the copula. Nevertheless, the possessive determiner *their* in the antecedent-anaphora in (2b) shows that the government is treated as plural. In pronoun agreement, unlike subject–verb agreement, singular forms of collective nouns (e.g., *government*, *committee*) tend to agree with plural pronouns rather than singular pronouns (e.g., Nicol, Teller, & Greth, 2001). Note, however, that in specifier–head agreement, singular collective nouns cannot make plural agreement (e.g., *these *family/families*). This asymmetry demonstrates that both grammatical plurality and conceptual plurality exist and that they have to be considered separately.

Another type of conceptual plural affecting language processing comes from so-

called *distributive effects* (e.g., Eberhard, 1999; Humphreys & Bock, 2005), in which the meaning of the noun phrase can be interpreted as indicating multiple instances of the singular head noun, required by the multiple objects represented by the local plural noun (e.g., *the label on the <u>bottles</u>...*). In the distributive-effects sentences, we mentally represent the same *label* attached to multiple *bottles*.

The research mentioned above argued that the number of the local NP impacts subject–verb agreement, based on the results of oral sentence completion tasks, where the participants were provided a subject NP (*the label on the bottle/bottles*) and asked to complete the sentence. If the participants mistakenly produced plural verbs even with a singular head NP, it was concluded that they were distracted by conceptual number (e.g., Bock & Miller, 1991; Eberhard, 1999).

Other research has investigated the representation of plural nouns' constituents. Kaup, Kelter, and Habel (2002) investigated whether native English speakers differentiated plural sets from their own members, presenting sentences like *John and Mary went shopping* with two alternative accompanying sentences, (a) *Both bought a gift*, and (b) *They bought a gift*. Participants were asked to answer the question, *How many gifts did John and Mary buy?* The results showed that when the subject was *both* (a), participants tended to answer that two gifts were bought, indicating that *John* and *Mary* were represented as constituents of a plural set—a so-called *complex reference object*. In contrast, for (b), participants more often answered that only one gift was bought, suggesting that *John* and *Mary* were represented as a group. Thus, the human language processor is sensitive to whether individuals in the plural sets are mentioned explicitly or vaguely. This prediction has also been supported by other L1 psycholinguistic research (e.g., Patson & Ferreira, 2009; Patson & Warren, 2011;

8

Patson et al., 2014). In eye-tracking experiments, Patson and Ferreira (2009) found that only coordinated NPs (e.g., *the man and the woman*) can block garden-path effects (3a–c); neither plural definite descriptions (PDDs; e.g., *the lovers*) nor numerically quantified plurals (e.g., *the two cats*) were represented as complex reference objects, but coordinated NPs were. Since, in coordinated NPs, the constituents of plural nouns are easily accessible, the parsing system easily construes the reciprocity and avoids assigning an object role to the NP following the reciprocal verb.

(3a) Soon after the singer and the model met the director cast them in his movie.

(3b) Soon after the models met the director cast them in his movie.

(3c) Soon after the two models met the director cast them in his movie.

Patson and Ferreira (2009) also found that no blocking effect is observed when the first verb of the sentences is optionally transitive, even if the subject of the optionally transitive verb is coordinated. Patson and Ferreira revealed further that clearly differentiating the characteristics of the individuals in plural sets is critical to conceptually representing those complex reference objects.

The studies reviewed above give evidence that not only linguistic but also conceptual information derived from linguistic representations impacts L1 sentence processing. More recently, L2 researchers have also started to investigate whether L2 speakers process conceptual number information in terms of distributive effects, as we will review in the next section.

2.2 Conceptual Plurality in L2 Research

Though few L2 studies have investigated conceptual number information in

9

sentence processing, some research has looked at whether distributive effects are observed by L2 speakers (e.g., Foote, 2010; Hoshino et al., 2010; Nicol & Greth, 2003; Nicol et al., 2001; Wei et al., 2015). These studies have considered three main questions: whether distributive effects are found in sentence production by L2 speakers and if so how they resemble/differ from those in L1 (Foote, 2010; Hoshino et al., 2010; Nicol & Greth, 2003; Nicol et al., 2001); whether age of acquisition or proficiency level influence the magnitude of distributive effects (Foote, 2010; Hoshino et al., 2010; Jackson et al., 2018); and whether L1 background plays a role in distributive effects in L2 (Jackson et al., 2018; Wei et al., 2015).

Regarding the first question, Nicol et al. (2001) found distributive effects in both Spanish–English and English–Spanish bilinguals, to a similar extent as in Spanish and English native speakers. Moreover, Nicol and Greth (2003) investigated distributive effects in English–Spanish bilinguals and found distributive effects similar in magnitude across L1 and L2.

Foote (2010) also investigated distributive effects in Spanish–English and English–Spanish bilinguals of intermediate and advanced levels, taking into account the second issue, age of acquisition and proficiency. Foote (2010) found that, overall, all the groups demonstrated notional number attraction effects, which, however, differed in magnitude across the groups: they were larger in early bilinguals than late bilinguals, larger in intermediate than advanced group, and larger in English than Spanish. The overall tendency was consistent across English–Spanish and Spanish–English bilinguals. One exception was that the intermediate group who started learning the second language late demonstrated larger distributive effects in Spanish than in English. Foote tentatively concluded that this "less attraction effect" for late-intermediate group

10

implied that English–Spanish bilinguals were not able to make use of Spanish number morphology to overwrite the mismatching notional number in the demanding online task. As a result, the rate of erroneous agreement in Spanish was a little higher than in English for only the late-intermediate group, contrasting the overall tendency.

Similar to Foote (2010), Hoshino et al. (2010) also investigated how proficiency influences sensitivity to conceptual and grammatical number agreement, adapting the L1 model of Hartsuiker and Barkhuysen (2006) to an L2 context. In an L1 context, Hartsuiker and Barkhuysen had investigated the basic effect of cognitive demand on this sensitivity to distributive effects, finding that although number mapping from conceptual to functional representation in the first stage of agreement (the "marking process" per Eberhard et al. (2005)) is less affected by cognitive resource limitations, the second stage of agreement, where the language processor resolves number feature conflict between the head NP and local NP (the "morphing process" in Eberhard et al.'s (2005) term), is more affected by cognitive resource limitations.. Hoshino et al. (2010) then operationalized cognitive demand in terms of language proficiency (high or low), and found that highly proficient Spanish–English bilinguals were sensitive to both grammatical and conceptual number agreement in both L1 and L2, whereas the low proficiency group were sensitive to only grammatical number agreement in L2 (but to both types in L1). On this basis, Hoshino et al. (2010) argued that sufficient cognitive resources to maintain conceptual number information were required to check number agreement in the second stage. Similarly, Hoshino, Kroll, and Dussias (2012) did not find distributive effects in Japanese EFL learners, who were less proficient than the Spanish–English bilinguals in Hoshino et al. (2010) but who might have shown sensitivity to conceptual information if they were as proficient as that group. The results

of Hoshino et al. (2010, 2012) conflict with those of Foote (2010), because Foote found a small but significant distributive effect even for less proficient bilinguals. Wei et al. (2015) explained that these contradictory results may be related to the presence of pictures during the task (as in Foote (2010)) versus their absence (as in Hoshino et al. (2010)). Wei et al. (2015) also confirmed that distributive effects in production were rare if learners' L1 did not have a subject–verb agreement system, as in the case of Chinese–English bilinguals; however, showing pictures eased the Chinese–English bilinguals of this cognitive load in L2 production, leading to distributive effects.

All the research on conceptual number representation in L2 speakers reviewed above applied distributive effects, in which sentence fragments (e.g., *the label on the bottles*) were presented and participants were asked to complete the sentence. As recent L1 research (e.g., Patson & Ferreira, 2009; Patson et al., 2014; Patson & Warren, 2010) has developed a variety of methodologies to examine the conceptual representation of number apart from number agreement, L2 studies should also focus not only upon distributive effects but also upon other linguistic features; among these, we focused on reciprocal verbs.

As mentioned in the introduction, reciprocal verbs have an interesting characteristic: Their interpretation is influenced by the number of people involved in the action. In the following section, we will review the characteristics of reciprocal verbs in detail to help us consider the conceptual representation of plurality.

2.3 Reciprocal Verbs and Plurality

As noted above, a reciprocal verb means the denoted event is pluralized. Like many other languages, Japanese, the first language of the present study's participants, features reciprocals. The most relevant one to the discussion of the present study is

Japanese suffix *-aw*. Once *-aw* attaches to a verb, it introduces a reciprocal reading, as shown in (4).

(4a) kodomo-tachi-ga rouka-de hanashi-teiru

(The) child-tachi[pl]-ga[NOM] the hallway-de[LOC] talk-teiru[PROG]

'(The) children are talking in the hallway.'

(4b) kodomo-tachi-ga rouka-de hanashi-at-teiru[PROG]

(The) child-tachi[pl]-ga[NOM] the hallway-de[LOC] talk-*aw*-teiru[PROG]

'(The) children are talking *to each other* in the hallway.'

Though (4a) might imply a reciprocal reading, (4b) clearly conveys that the children are talking 'to each other'. Conversely, (4a) could be interpreted that more than one child is talking to somebody, possibly on the phone, whereas (4b) does not allow this interpretation.

Reciprocal reading requires two or more people to be involved in the action denoted by the main verb. Because Japanese does not have an obligatory plural suffix as English does, the sentences in (4ab) can be rendered without the Japanese plural marker *-tachi* (5ab).

(5a) kodomo-ga rouka-de hanashi-teiru

(The) child/children-ga[NOM] the hallway-de[LOC] talk-teiru[PROG]

'(The) child/children is/are talking in the hallway.'

(5b) kodomo-ga rouka-de hanashi-at-teiru[PROG]

(The) *child/children-ga[NOM] the hallway-de[LOC] talk-*aw*-teiru[PROG]

'(The) *child/children is/are talking *to each other* in the hallway.'

13

Without *-tachi*, the discrepancy between (5a) and (5b) becomes clearer. In (5a), it is unclear whether one child is talking to somebody who does not appear in the sentence, or more than one child is talking to somebody independently, or more than one child is talking to other children in the same group (the reciprocal interpretation). In contrast, with the suffix *-aw* attached to *hanasu* 'talk' in (5b), only the reciprocal interpretation is allowed, entailing that *kodomo* carries plurality despite the lack of plural marker *-tachi*—that is, *kodomo* is grammatically singular but conceptually plural (see Nakanishi & Tomioka (2004) on the use of *-tachi* with proper nouns). Thus, *-aw* requires the subject to be plural, but this plurality does not have to be marked grammatically.

As these examples demonstrate, *-aw* introduces a reciprocal reading and, more importantly, enables an unmarked singular NP to be conceptually plural. When we consider the characteristics of reciprocal verbs and reciprocal sentences in English, it emerges that the prerequisite of an NP's being the subject of a reciprocal sentence is conceptual, but not necessarily grammatical, plurality.

Fiengo and Lasnik (1973) argued that not grammatical plurality, but semantic, or in our terms conceptual, plurality is what makes sentences reciprocal. As we discussed in section 2.1, conceptual and grammatical number are sometimes in conflict in English, for instance in so-called pluralia tantum (e.g., *scissors*, *pants*, *binoculars*), as in (6).

(6a) The binoculars are on the table.

(6b) *The binoculars are focused differently from each other (one pair).

(Fiengo & Lasnik, 1973, p. 452)

The reason (6b) is ungrammatical is that *each other* cannot be in anaphoric relationship with a conceptually singular NP. A similar claim was made by Gleitman, Gleitman, Miller, and Ostrin (1996), who argued that a lexical-semantic property of reciprocal verbs, rather than syntactic verb subcategorization information, requires conceptual plurality of subject NPs. (Verb subcategorization information is information about the argument structures a verb can take. For example, the English verb *talk* cannot take a person as a direct object (e.g., **he talked you last night*), but *ask* can (e.g., *he asked you last night*).) According to Gleitman et al. (1996), this is why reciprocal verbs can be used with grammatically singular but conceptually plural collective nouns (e.g., *the group meets*).[1] Gleitman et al. conclude that oddity in singular NP–reciprocal verb combinations is not a matter of grammar but of the semantic properties of the sentence.

In summary, reciprocal verbs require plurality from subject NPs. If the subject NP is singular, the object NP(s) must necessarily follow the verb to make the sentence grammatical (e.g., **Bob met* vs *Bob met Mary*), and the verb is no longer called reciprocal because there is no reciprocal reading available. Plurality here is not a grammatical property but a conceptual one; thus, how speakers conceptually represent the number information of an NP is crucial in deciding whether reciprocity is indeed derived. This is why investigating reciprocal verbs has potential implications for L2 learners' representation and processing of conceptual number information.

2.4 Purpose of the Present Study

As reviewed above, although how L1 and L2 speakers conceptually represent number information in sentence processing has interested many researchers, L2 research has focused almost exclusively on number agreement. Previous studies revealed that L2 speakers processing for number agreement are less likely to be affected by conceptual

number than L1 speakers are unless they are highly proficient in the L2 (Hoshino et al., 2010) or their L1 has a number agreement system (Wei et al., 2015). However, the role of conceptual plurality may vary depending on the type of conceptual plurality, for example conceptual plurality present in collective nouns versus conceptual plurality derived from distributive effects (e.g., see Kusanagi, Tamura, & Fukuta, 2015 for the case of collective nouns). The difference between a conceptual number derived from collective nouns and one derived from distributive effects can be explained according to whether the constituents of the plural object are fully specified or unspecified. Our focus here was the former (see Patson [2014] for a comprehensive review of plurality).

Missing in L2 studies are 1) the application of a comprehension task as in recent L1 studies, and 2) investigation of conceptual plurality apart from number agreement. Of course, number agreement remains an interesting linguistic phenomenon, because speakers use both grammatical and conceptual information, which interface in distributive effects, in making number agreement. However, focusing on this phenomenon risks missing the broader picture. Focusing on processing of reciprocal verbs, in which conceptual number is inevitably involved in reaching a final interpretation, will broaden our understanding of how L2 learners represent conceptual number information and will move the field forward.

3. Method

The research question taken up by this study was: *Are Japanese EFL learners able to use conceptual plural information during online sentence processing?* To answer this research question, we examined the processing of reciprocal verbs.

Following the idea proposed by Ferreira and McClure (1997), Patson and Ferreira (2009) investigated whether reciprocal verbs with conjoined NPs enabled native speakers

of English to evade garden-path effects, by comparing the reading time of four types of sentences, shown below.

(7a) While the lifeguard and the swimming instructor embraced the child <u>fell into the pool</u>.

(7b) While the lifeguards embraced the child <u>fell into the pool</u>.

(7c) While the lifeguard and the swimming instructor trained the child <u>fell into the pool</u>.

(7d) While the lifeguards trained the child <u>fell into the pool</u>.

In (7ab), the verbs in the subordinate clauses are reciprocal verbs involving two or more people, and therefore, if the subject of the sentence carries plurality, they are used like transitive verbs. As discussed in section 2.3, the plurality in this case is conceptual, not grammatical.

When we look at (7a), the reciprocal verb *embraced* has a conjoined NP as its subject, and therefore, the following noun, *the child*, should be less likely processed as the direct object of *embraced*. If so, no garden-path effects should be found in (7a). In (7c), by contrast, the verb *trained* in the subordinate clause is an optionally transitive verb (OT verb), which can be interpreted either transitively or intransitively irrespective of the subject's number information. As a result, *the child* is more likely to be considered the direct object of the verb *trained*. The question is whether the same thing happens if the subject is a plural definite NP, like in (7bd), which also has plurality, but the constituent of the plural nouns—the exact number of lifeguards—is ambiguous compared to the case of a conjoined NP. Patson and Ferreira (2009) found that even L1 English speakers tended to be trapped in garden-path sentences like (7b–d) whereas they did not in (7a); thus,

17

Patson and Ferreira concluded that what made readers avoid the pitfalls of garden-path sentences was not the main effect of either the conjoined NP or the reciprocal verb but the interaction between them. Following this line, we also considered the type of noun—plural definite NP or conjoined NP—in our experiments. However, we did not include a singular subject NP condition because if the subject NP is singular, the sentence becomes ungrammatical (e.g., *the lifeguard embraced the child fell into the pool*).

Since our participants were Japanese EFL learners, we confirmed that they understood the characteristics of reciprocal verbs, using a written sentence completion task (SCT) and a self-paced reading task (SPRT).

The experiments' possible outcomes should be interpreted as follows. In the sentence completion task, if participants would tend to produce few direct objects of reciprocal verbs in subordinate clauses, it would suggest that they know reciprocal verbs do not need a direct object if the subject NP carries plurality. In the self-paced reading task, if participants read sentences with reciprocal verbs faster than those with optionally transitive verbs at and after they encountered the verb of the main clause, it would mean that they used the conceptual number information of the subject NP to interpret the NP right after the reciprocal verb as the subject of the main clause. Furthermore, the speed of processing was expected to differ depending on the type of subject NP—conjoined or PDD—because the conjoined NP more clearly denotes the constituent of the plural set.

3.1 Participants

Thirty-two Japanese learners of English participated in this study. They were either undergraduate ($n = 6$) or graduate students ($n = 26$) in Japanese universities, from various majors. Four participants were removed because their English proficiency was

found too low to engage in the SPRT. Fifty-eight percent of the participants had some experience living in English-speaking countries, for between 2 weeks and 54 months. Most had studied English since they were freshmen in junior high school, and some had also experienced weekly English language lessons in the fifth and sixth years of elementary school. The participants were considered relatively proficient EFL learners, with mean TOEIC score of 854.46 (SD = 82.58) / 990, roughly equivalent to B2 level on the Common European Framework Reference for Languages. They agreed to participate, receiving compensation of 1,000 Japanese yen. Detailed demographic information on participants, including self-reported English proficiency, is summarized in Table 1.

[Table 1 about here]

3.2 Materials and Procedures

This section discusses the materials used in the experiment as well as the procedure of the experiment. The experimental materials used in the SPRT will be described first because the materials of the SCT were based on these used in the SPRT. Note that in the analysis, result, and discussion sections, the SCT will always be discussed first because all the participants completed the SCT first and the SPRT afterward.

3.2.1 Self-paced reading task. Twenty test items were developed, each of which appeared in four different conditions (8a–d). In (8a) and (8c), the subject NP in a dependent clause was a conjoined NP, followed by either a reciprocal verb (8a) or an OT verb (8c). In contrast, the subject NP in the dependent clause in (8b) and (8d) was a PDD followed by either a reciprocal verb (8b) or an OT verb (8d).

19

(8a)As the mother and the father battled the child <u>played the guitar</u> in the room (Conj/recip)

(8b) As the parents battled the child<u> played the guitar</u> in the room. (PDD/recip)

(8c) As the mother and the father left the child <u>played the guitar</u> in the room. (Conj/OT)

(8d) As the parents left the child <u>played the guitar</u> in the room. (PDD/OT)

The 10 reciprocal verbs and 10 OT verbs presented in Table 2 were used as test items, following Patson and Ferreira (2009).[2] Although we referred to the test items made by Patson and Ferreira (2009), we did not use words that are often unfamiliar to EFL learners. The examples of those words were *salute*, *snuggle*, and *cuddle*. In addition, the sentence structure was also controlled for so that all the target verbs were followed by a determiner, a noun, and a prepositional phrase.

[Table 2 about here]

Additionally, 5 conjunctions (*when*, *while*, *as*, *after*, *because*) were distributed equally among the test items, along with 68 distractors (the test items are provided in Appendix). Some of the distractor items were such as *they had to teach the employees Chinese before sending them to China*, The participants were asked to answer a comprehension question (e.g., *were the employees to be sent to China*) after reading the distractor. Both examples presented here were taken from Jiang (2007). Participants were randomly assigned one of the four lists, meaning participants in different

conditions did not see the same test items.

The SPRT was developed using Hot Soup Processor ver. 3.2., which is a programming language freely available from http://hsp.tv/; it was conducted individually, in a quiet room. First, participants were asked to read a sentence randomly presented on a computer screen (Figure 1). Target sentences were presented in a moving-window style: Participants read the sentence word by word, moving to a new word by pressing a key. Though distracter items were followed by yes/no comprehension questions, no legitimate test items were followed by comprehension questions. Mean accuracy for comprehension questions was 85.7% (SD = 7.0%), or good to fair. To avoid fatigue effects, the 88 items (including distracters) were presented in two sessions; session order was counterbalanced on each of the four lists. The entire experiment, including the background questionnaire and an offline sentence completion task, took one hour.

[Figure 1 about here]

3.2.2 Sentence completion task. This task had two objectives: first, to ensure that participants could interpret reciprocal readings; second, to ensure that participants did not show any preference for transitive or intransitive interpretation of optionally transitive verbs. On the first point, if participants did not know that a reciprocal verb does not require an object noun if the subject noun carries plurality, they would be less likely to avoid the garden-path effect. Thus, it was necessary to verify that participants understood the argument structure of reciprocal verbs and could attend to reciprocal readings; if so, we could safely conclude that if no difference in RT latencies between reciprocal verbs with a conjoined NP subject and optionally transitive verbs with a

21

conjoined NP subject in the self-paced reading task, this was because participants were able to assign both agent and patient roles to the subject NP, avoiding the garden-path effect.

As for the second point, the aim in comparing reciprocal and optionally transitive verbs in the SPRT was to confirm that what blocks the garden-path effect is not transitivity but reciprocity. However, certain combinations of subject nouns and optionally transitive verbs may more likely lead to either transitive or intransitive interpretations. If so, this bias would affect online processing during self-paced reading, and thus verbs biased toward intransitive interpretation would likely block the garden-path effect. Therefore, we needed to ensure that participants processed optionally transitive verbs to the same extent as transitive and intransitive ones.

After the SPRT, participants tackled the SCT. They completed printed sentences (9a–d), using the same items as in the SPRT.

(9a) When the artist and the painter hugged_____

(9b) When the artists hugged _____

(9c) When the artist and the painter wrote _____

(9d) When the artists wrote _____

The same item list, comprising 20 sentences but without distracters, was used.[3] Each participant was assigned a different list from the one they had had in the SPRT, and thus did not see exactly the same sentences they had seen while doing the SPRT, avoiding the possibility of memorizing sentences. Additionally, each list contained the same number of test items across all four conditions, and thus, there was no serious danger that the participants' responses to the SCT would be influenced by the fact that they

completed the SPRT just beforehand.

One may wonder why the combination of singular NPs and reciprocal verbs were not tested in the SCT as well as in the SPRT, because it seems critical to demonstrate that the participants would show higher transitivity bias for reciprocal verbs with a singular subject than for those with a conjoined subject NP to determine whether they appreciate reciprocal readings or not. However, "reciprocal meaning" does not derive from a singular subject, given that reciprocity necessarily involves two (or more) people involved in the action denoted by the verb and that those people should be both agent and patient of the action. Thus, the only way to prove whether the participants appreciate reciprocal readings is to have them process the combination of plural subject NP and reciprocal verb and to investigate whether they add an object NP after the reciprocal verb. If they add an object NP, it means they do not read the sentence reciprocally but rather transitively. If not, it means they interpret the sentence reciprocally.

3.3 Analysis

3.3.1 Sentence completion task. The SCT responses were analyzed as follows. First, if the sentences were not complete, complex sentences, the responses were categorized as errors. If the participants seemed confused about whether to interpret the verb transitively or intransitively, those responses were also coded as errors (e.g., *after the leaders kissed to their children, they went to the battlefield as a national army*). In this example, *kissed* is used intransitively although it should have been transitive (e.g., *after the leaders kissed their children…*), which causes ungrammaticality. Second, how the verb in the subordinate clause was interpreted was coded as a transitive, intransitive,

or reciprocal reading. If the OT verb was followed by a direct object, the responses were coded as transitive; for responses to be coded as intransitive, the OT verb had to proceed to a prepositional phrase or a comma. If no direct object followed or *each other* followed, those responses were coded as reciprocal readings. Additionally, if adjuncts followed the reciprocal verbs (e.g., *as the mother and the father battled in the house….*), these responses were also coded as reciprocal readings. In contrast, if the post-verbal prepositional phrases did not refer to the person involved in the denoted action (e.g., *because the coach and the trainer argued about the methods of training….*), these responses were coded as intransitive. If the reciprocal verbs took direct objects (e.g., *As the waiters met their friends in the cafe…*), these were coded as transitive. Any grammatical errors or mistakes which were not relevant to the coding, such as morphosyntactic errors or spelling mistakes, were ignored. Coding examples are summarized in Table 3.

[Table 3 about here]

To see the differences in proportions, Poisson log-linear analyses were performed on the reciprocal verb items and OT verb items, respectively, using R 3.3.0 (R Core Team, 2016). Since no reciprocal reading was permitted for the sentences with OT verbs, the matrix was constructed as 2 (levels of noun type; reciprocal or PDD) x 2 (levels of interpretation type; intransitive or transitive) for OT verbs. In contrast, reciprocal verbs can be interpreted in three ways—reciprocally, transitively, or intransitively—and therefore, a 2 (reciprocal or PDD) x 3 (reciprocal, transitive, or intransitive) matrix was used. It should be noted that the error rate differed across each

condition, leading the sum frequency to differ also. To control the discrepancies, we added log-transformed total number of observations as an offset term of the Poisson log-linear model. The two categorical variables were contrast coded to avoid serious multicollinearity; if there was an interaction between the two factors, we proceeded to multiple comparison using the *lsmeans* package (Lenth, 2016).

3.3.2 Self-paced reading task. As for the analysis of the SPRT, reading time (RT) was analyzed in the target region, that is, the region where the participant encountered the target verb (reciprocal or OT), as well as in the two regions that followed it, in which the participants read the direct object of the target verb, to consider delayed effects; finally, one word before the target verb was also analyzed. The reason why we looked at the word before the target verb was to make sure that no RT difference was observed across the four conditions. It did not tell us anything about the conceptual plurality, and to understand the results of the SPRT correctly, we should examine the delay observed after the target verb was due to the garden-path effect. The analysis of RT was conducted as follows. First, we divided the RT data into four conditions (8a-d) and calculated the mean and standard deviation of each participant's RT in all regions. We considered responses below and above M +/- 3SD as outliers and removed them from further analysis. Responses below 200 milliseconds (ms) were also regarded as outliers, because word recognition and processing of word meaning are not likely to occur below 200 ms. Overall, 4.5% of the responses were removed as outliers.

After removing all the outliers, a series of generalized mixed-effects models (GLMMs) were applied using R 3.3.0 (R Core Team, 2016) and the *lme4* package (Bates, Maechler, Bolker, & Walker, 2015), so as to see the effects of the following three explanatory variables; type of verb (reciprocal or OT), type of NP (conjoined or

PDD), and an interaction term between these two variables. Additionally, the participant's English proficiency (TOEIC score) and word length for each region were added as covariates, although the latter was not added to the model for the region of one word after the target verb region because in all the conditions, the word length was three (*the*). To avoid convergence issues, TOEIC score was scaled before being entered into the model. A GLMM with cross-random effects (subject and item) was fitted with raw RT data as a response variable. The gamma distribution with identity link function was adopted on the presumption that the response variable (raw RT) fits gamma distribution because it is a continuous variable whose parameters are greater than zero (Lo & Andrews, 2015). Note that both exploratory variables were contrast coded (verb type: -.5 = OT, .5 = reciprocal; noun type: -.5 = PDD, .5 = conjoined), in accordance with Linck and Cunnings' (2015) recommendation.

Similar to traditional multiple regression, GLMM is also in danger of multicollinearity if the correlation between the explanatory variables is high. Thus, we checked VIF (variance inflation factor) for the best models in each region to make sure that no serious multicollinearity was found (See the "Supplementary Materials" for details).

If the GLMM analyses found an interaction between the type of nouns and verbs, we examined the simple main effects of both variables using the *lsmeans* package (Lenth, 2016).

4. Results

4.1 Sentence Completion Task

Table 4 breaks down by frequency the interpretations of the verbs in the four conditions, and Figure 2 graphically demonstrates their proportions. As can be seen,

26

whether the subject was a conjoined NP or a PDD, OT verbs were construed transitively or intransitively to the same degree. Thus, the participants did not have any preference regarding the target OT verbs used in the experiment. The result of log-linear analysis confirmed this tendency: There was no main effect of noun type (Estimate = 0.075, $SE =$ 0.159, $z = 0.476$, $p = .634$) or of verb category (Estimate < 0.001, $SE = 0.112$, $z = -0.004$, $p = .997$); nor was there any interaction between the two factors (Estimate = -0.151, $SE =$ 0.224, $z = -0.673$, $p = .501$). The results were also confirmed by stepwise backward model selection based on the Akaike Information Criterion (AIC). The best model chosen was a null model which included neither the main effect of the type of noun nor the main effect of the coded verb category (see "Supplementary Materials" for further information).

[Table 4 about here]

[Figure 2 about here]

Looking at the reciprocal verbs, we see that they were more likely to be read reciprocally than either transitively or intransitively. However, the proportion of reciprocal readings appeared to be influenced by the type of subject NP: If the subject NP was conjoined, the participants were more likely to prefer a reciprocal reading. This observation was confirmed by the log-linear analysis. The best model chosen by stepwise backward selection contained the interaction between the noun type and verb category, suggesting that frequency differences between some combination of noun type and verb type (e.g., conjoined NP with transitive verb, PDD with intransitive verb, etc.) do exist.

To examine these frequency differences, multiple comparisons were carried out. Their results showed that when the subject was a conjoined NP, participants produced more reciprocal than intransitive verbs (Estimate = -1.841, $SE = 0.241$, $z = -7.647$, p

27

< .001) and also more reciprocal than transitive verbs (Estimate = 2.271, *SE* = 0.291, *z* = 7.797, *p* < .001); however, there was no frequency difference between intransitive and transitive verbs (Estimate = 0.431, *SE* = 0.356, *z* = 1.209, *p* = .448). Similarly, when a plural definite noun stood as the subject, the participants produced more reciprocal than intransitive verbs (Estimate = -0.892, *SE* = 0.204, *z* = -4.383, *p* < .001) and more reciprocal than transitive verbs (Estimate = 0.781, *SE* = 0.196, *z* = 3.989, *p* < .001).

4.2 Self-Paced Reading Task

 Table 5 summarizes the mean and standard deviation of RTs for each condition; Figure 3 is a graphical representation of mean RT profile.

[Table 5 about here]

[Figure 3 about here]

 As mentioned in section 3.3, GLMM was carried out in four critical regions. Since our focus was an interaction term between type of noun and type of verb, we developed a model including both of these variables and the interaction term. We also added TOEIC score, which was z-transformed, as a covariate, to control the effect of proficiency differences.

 For each region, the random effect structures were decided as follows: First, a model with maximal random structures (that is, with all the slopes and intercepts of all the explanatory variables) was developed. Second, we removed random slopes one by one and developed several models with simpler random structures. Finally, we compared the AICs of all the converged models and chose the model with the lowest AIC (See "Supplementary Materials" for detailed information on each model). Note that in the target verb region, the two models produced almost exactly the same AIC

(6934.074 and 6934.137); therefore, in this region, we also checked the Bayesian

Information Criterion (BIC), and selected the model with the lower BIC.

The best model as justified by AIC in the region of one word before the target

verb region demonstrates that there is an interaction between the type of noun and the

type of verb (Table 6). A simple main effects test revealed that sentences including

conjoined NPs and OT verbs were read faster than those with PDDs and OT verbs

(Estimate = -76.179, SE = 24.403, z = -3.122, p = .002). No other comparison reached

statistical significance, although RT differences between the combination of conjoined

NPs and OT verbs and that of conjoined NPs and reciprocal verbs were close to the

significance threshold (Estimate = -34.013, SE = 18.344, z = -1.854, p = .064) (see

Supplementary materials for the complete tables of the simple main effects test).

[Table 6 about here]

Table 7 is a summary of the best model in the target verb region. In this region,

main effects of both noun type (Estimate = 56.606, SE = 17.138, t = 3.303, p < .001)

and verb type (Estimate = -32.914, SE = 16.057, t = -2.050, p = .040) were found;

however, there was no significant interaction between them (Estimate = -8.381, SE =

26.478, t = -0.317, p = .752).

[Table 7 about here]

Table 8 summarizes the results of GLMM in the next region, one word after the

target verb. In this region, there was a main effect of verb type (Estimate = -57.874, SE

= 26.830, t = -2.157, p = .031), but neither the main effect of noun type nor the

29

interaction term was significant (noun type: Estimate = 40.381, *SE* = 32.719, *t* = 1.234, *p* = .217; interaction: Estimate = 21.785, *SE* = 26.528, *t* = 0.821, *p* = .412).

[Table 8 about here]

The model selected based on the AIC in the last region of interest, two words after the target verb, confirmed that no main effect of either noun type or verb type was found (noun type: Estimate = 19.43, *SE* = 17.48, *t* = 1.111, *p* = .266; verb type: Estimate = -21.84, *SE* = 18.87, *t* = -1.157, *p* = .247). However, there was a significant interaction between the two variables (Estimate = 45.13, *SE* = 22.57, *t* = 2.000, *p* = .046). Table 9 summarizes the results of GLMM in the region two words after the target verb.

[Table 9 about here]

A simple main effects test further revealed that if the verb in the subordinate clause was reciprocal, sentences in which a conjoined NP served as subject were processed faster than those with a plural definite noun as subject (Estimate = -33.710, *SE* = 16.409, *z* = -2.054, *p* = .040), whereas no RT difference resulting from subject noun type was found when the verb was OT (Estimate = 2.688, *SE* = 15.877, *z* = 0.169, *p* = .866). Looking at the simple main effect of verb type, conjoined NPs with reciprocal verbs were read faster than those with OT verbs (Estimate = 49.939, *SE* = 23.768, *z* = 2.101, *p* = .036); in contrast, no RT difference was found between plural definite nouns with OT verbs and those with reciprocal verbs (Estimate = 13.541, *SE* = 24.164, *z* = 0.560, *p* = .575). Figure 4 graphically represents the interaction between type of noun and type of verb.

[Figure 4 about here]

To control the possible effect of English language proficiency, TOEIC score was added to GLMM models in all the regions of interest; however, the main effects of the TOEIC score did not reach statistically significant levels in any of the regions, which implied that English language proficiency did not have much impact on the variance of the RT latencies.

5. Discussion

5.1 Findings of the Present Study

5.1.1 Sentence completion task. First, we analyzed the data obtained through the SCT to confirm that the participants did not show any bias in the interpretation of optionally transitive verbs. The results suggested that the optionally transitive verbs used in this study successfully induced transitive interpretations to the same extent as intransitive interpretations, meaning that participants demonstrated no bias in the interpretation of OT verbs regardless of whether the subject was a conjoined NP or a plural definite description.

Another objective of the SCT was to show the participants capable of reciprocal readings, in which the subjects of the reciprocal verb play both agent and patient roles in the action denoted by the verb. The results of the SCT in reciprocal verb conditions show that whether the subject noun type was conjoined or a PDD, the participants interpreted the sentences reciprocally much more frequently than intransitively or transitively. However, the type of noun did influence the likelihood of reciprocal reading: Participants were more inclined to read reciprocally when the subject was conjoined than when the subject was a plural definite noun. This might indicate that a

31

conjoined NP is more likely to induce reciprocal reading..

5.1.2 Self-paced reading task. To summarize the results of the SPRT, in the first region of interest, sentences with OT verbs and conjoined NPs were unexpectedly read faster than those with PDDs, but there was no significant RT difference between OT verbs with conjoined NPs and reciprocal verbs with conjoined NPs.[4] Nonetheless, the expected RT differences were observed in the target verb region: Sentences with reciprocal verbs were read faster than those with OT verbs in both conjoined NP and PDD conditions, although the main effect of noun type indicated that irrespective of verb type, the sentences with conjoined NPs were read faster than those with PDDs. This indicates the possibility that if the subject is a PDD, learners might have difficulty inducing reciprocal interpretation. In the region covering the one word after the target region, the main effect of noun type disappeared, but the main effect of verb type persisted, suggesting that RT delay was observed only in the OT verb sentences. However, in the next region, two words after the target verb region, the RT trend changed: The participants read fastest in the conjoined NP with reciprocal verb condition, and the PDD with reciprocal verb condition was no longer read faster than the OT verb conditions.

5.2 Processing and Representation of Plurality

Our research question was "Are Japanese EFL learners able to use conceptual plural information during online sentence processing?" The evidence presented here suggests that the answer is yes. Before discussing this in more detail, let us consider the results of the sentence completion task, which confirmed that the participants possessed the knowledge that reciprocal verbs do not need a direct object if the number feature of the subject carries plurality. This result allowed us to conclude that if the processing

tendency in the self-paced reading task was to differ depending on verb type, it had to result from the characteristics of the reciprocal verb. In fact, sentences with reciprocal verbs were read faster than those with OT verbs. This result is to be expected, because the probability of taking a direct object is lower for reciprocal verbs than for OT verbs, which was confirmed by the observation that in the SCT the participants were far less likely to write direct objects after reciprocal verbs.

The SCT results also indicated that the conjoined NP is more likely than the plural definite noun to induce reciprocal reading, since reciprocal reading requires readers to access the individuals within the plural sets (Patson & Ferreira, 2009; Patson & Warren, 2010), and the conjoined NP explicitly denotes the individuals in the plural sets while the plural definite noun does not. Thus, the indication in the findings that the combination of reciprocal verb and conjoined NP made participants more likely to read reciprocally than that of reciprocal verb and plural definite noun is plausible. This tendency is also compatible to some extent with the results of the self-paced reading task: Although it seemed that participants interpreted sentences with reciprocal verbs reciprocally regardless of noun type, they appeared to have processing difficulty in the case where a plural definite noun was the subject of a reciprocal verb, as reflected by the fact that RT slowed when participants encountered the object noun of the main verb, two words after the target verb region. The only condition that showed no RT delay among the several regions of interest was the combination of conjoined NP and reciprocal verb, indicating that a conjoined NP, which explicitly denotes the individuals in plural sets, might help participants induce reciprocal readings more easily. Nevertheless, we cannot be 100% sure that the participants assigned reciprocal reading to the reciprocal verbs, because we did not directly measure the participants'

interpretation of the verbs in the self-paced reading task (SPRT). If we had done so, the participants would have noticed that the focus of the SPRT was the interpretation of the verbs. Therefore, we do not know the participants' preference toward transitive reading in the SPRT; however, if we look at the results of the sentence completion task (SCT), we can see that most of the time, the participants showed reciprocal interpretation if the verb of the subordinate clause was a reciprocal verb, although the percentage was higher when the subjects of the reciprocal verbs were conjoined subjects. Even though the SCT was an offline task, we can reasonably infer that the participants must have preferred reciprocal reading in processing reciprocal verbs in the SPRT.

The difference between conjoined NP and plural definite nouns may, in part, be explained by L1 transfer effects, as suggested by Shibuya and Wakabayashi (2008). In Japanese, no bound morpheme is attached to nouns to specify plurality, but quantifiers can be attached (19ab).

(19a) kodomo-ga rouka-de hanashite-iru

(The) child/children-ga[NOM] the hallway-de[LOC] talk-iru[PROG]

'(The) child/children is/are talking in the hallway.'

(19b) kodomo-ga san-nin rouka-de hanashite-iru

(The) child/children-ga[NOM] three-nin[CL] the hallway-de[LOC] talk-iru[PROG]

'(The) three children are talking in the hallway.'

In other words, Japanese does not require the processing of bound morphemes, unlike English, and this might have caused difficulty for the Japanese EFL learners in the current experiment when they attempted to process conceptual plurality present in plural

definite nouns.

The present study's results, as summarized above, seem to contradict some of the previous L2 research, which showed L2 speakers having difficulty accessing conceptual plural information in a sentence production task (e.g., Hoshino et al., 2010; Wei et al., 2015). Two possible explanations are worth discussing here. First, one big difference between the previous literature and the present study is the mode of language being considered: production vs. comprehension. Though L1 research like that cited in the literature review section has shown that L1 speakers use conceptual number information during sentence comprehension (e.g., Kreiner et al., 2013), this might not hold true in light of the present results because L2 speakers' performance is more vulnerable to disruption than that of L1 speakers, and is sometimes inconsistent across different tasks. Clearly, future research needs to investigate and compare the accessibility of conceptual number information in both production and comprehension, across L1 and especially L2 speakers.

The other, and the more critical, difference between the previous research and the present study is that the present study did not investigate number agreement phenomena. Researchers investigating the representation and processing of conceptual number information through subject–verb number agreement are interested in the interface between conceptual and grammatical number processing, and researchers who have demonstrated L2 learners' inability to use conceptual number in making number agreement in online tasks have posited that conceptual number does not invade grammatical processing (Hoshino et al., 2010, 2012, Wei et al., 2015). Since our study did not examine number agreement process, its results do not inevitably contradict the evidence previously accumulated. Rather, the present study can add a novel viewpoint

to those of previous L2 studies investigating conceptual number information: EFL learners whose first language does not have obligatory morphological number marking system succeed in accessing conceptual plural information in online sentence processing if grammatical number agreement is not concerned. As reviewed earlier, reciprocal verbs call not for grammatical number, but conceptual number (Gleitman et al., 1996; Fiengo & Lasnik, 1973); thus, it might be that L2 learners are able to access conceptual number information in online processing but that this information is not "strong" enough to invade the grammatical number agreement process.

The availability of conceptual number information could be explained by the two-stage agreement process (Hartsuiker & Barkhuysen, 2006) and the required cognitive resources. According to Hartsuiker and Barkhuysen (2006), the first stage—number mapping between conceptual representation and functional representation—is not vulnerable to resource limitations, whereas the later stage—integrating number information—does suffer if sufficient cognitive resources are not available. Following this account, Hoshino et al. (2010) insisted that the reason why low-proficiency L2 speakers in their study did not show sensitivity to conceptual number is because the low-proficiency L2 speakers failed in the second stage due to their limited cognitive resources. Thus, Hoshino et al. (2010) assumed that their low-proficiency participants might have succeeded in mapping conceptual number to functional representation but failed to integrate conceptual number information in the later stage. Therefore, it should be noted that the participants in the present study who succeeded in accessing conceptual plurality in reciprocal sentences might not show sensitivity to conceptual number in number agreement, as Hoshino et al. (2010, 2012) argued.

Last, let us recall and consider that reciprocal constructions in Japanese and

English both require the readers to access conceptual plurality. In the literature review, we introduced Japanese reciprocal constructions, focusing on V+*aw*, and explained that in Japanese too, speakers would be expected to access conceptual plurality to make a reciprocal interpretation. Unlike English, Japanese does not necessarily mark plurality of nouns; but as we saw in section 2.3, even if the subject NP is unmarked for number, V+*aw* makes the subject NP conceptually plural, so that the sentence can be made understandable. Though it is only a tentative speculation at this point, this could be one reason that Japanese EFL learner participants were able to access conceptual plurality of subject NP in reading English reciprocal sentences. Since the present study did not include other L2 or L1 comparison groups to look for possible differences in L1 effects, further investigation is necessary to assess this possibility.

5.3 Limitations and Implications for Future Research

Here we present a number of limitations of the present study that may affect its interpretation. First, although much of the previous research has applied the SPRT to investigate various types of garden-path effect (e.g., Juffs, 1998; Juffs & Harrington, 1996), one of the limitations of this task is that we cannot reliably determine the process of reanalysis. In reading garden-path sentences, the comprehender is presumed to move backward after encountering interpretive breakdown to reparse the sentence in a correct way. However, the method used in this study did not allow the participants to move backward in this way, because it could have made the analysis of RT in each region more complicated and chaotic. In this sense, an eye-tracking procedure might be preferable in that it enables us to observe regressions (reader's backward eye movements). It should be noted in this regard, however, that Patson and Warren (2014)

replicated the findings of Patson and Ferreira's (2009) eye-movement experiments using a self-paced reading task, which may help address concern about this limitation.

Second, it must be acknowledged that not all the test items were followed by comprehension questions, although comprehension questions did follow distracter items to help the participants focus on meaning during the experiment. In this sense, it was inevitably unclear whether the participants succeeded in ambiguity resolution. The lack of comprehension questions after target items is related to the nature of the self-paced reading task used in this study. Due to the unavailability of backward reading and reanalysis, it cannot be ruled out that participants did not reach a final appropriate interpretation. Thus, whether there was any RT delay or not does not fully reveal the success of ambiguity resolution. However, asking whether the participants comprehended the sentences correctly may have been rather unfair, because they might have failed to understand the sentences due to the prohibition on reparsing them; future studies should compensate for this limitation.

Third, one may point out that the plausibility of the verb in the subordinate clause and the following NP combinations might have been problematic. It should be acknowledged that some of the test items accidentally included implausible or infrequent verb + NP structures: Those are *argued the student*, *negotiated the manager/man*, *battled the child/the employer*, *recovered the editor/manager*, *protested the referee/the employer*, and *write somebody*. Among the six less plausible phrases, four are optionally transitive (*negotiate*, *recover*, *protest*, and *write*). These four OT verbs would have induced transitive reading due to the lower likelihood of them taking human being as their direct object. But if so, the sentences with OT verbs would have been likely to show smaller garden-path effects, because the NP following the OT

38

would be more likely to be interpreted as the subject of the main clause, which would block the garden-path effect. Nevertheless, the sentences with OTs were read more slowly than those with reciprocal verbs, thereby showing the garden-path effect. Still, the experimental materials should be revised and improved for future research to address this issue.

Lastly, including native speakers of English as a control group would have been worthwhile, given that it would have allowed us to compare the processing tendency of L1 and L2 speakers of English. However, interpreting the results of L1–L2 comparison in the same tasks needs caution, particularly when the L2 learners are not highly proficient, as often in EFL environments. In these cases, usually, test materials are tailored to learners, for instance to avoid low-frequency vocabulary and complex sentence structures, which are difficult for L2 learners to process. The resulting easiness might allow L1 speakers to engage in heuristic processing, because L1 speakers do not find these items difficult to process. As a result, we might not be able to capture L1 speakers' real processing behavior. Bearing this caution in mind, future studies need to examine similarities and dissimilarities between L1 and L2 speakers of English with regard to the use of conceptual plural information in tasks like those used in our study and in Patson and Ferreira (2009).

Similarly, and with focus on the learner factors, it should be acknowledged that not all of the variables that could potentially influence the results (e.g., age and study abroad experience) were taken into account in the analysis, although the participants' L2 language proficiency scores were examined in analyzing the data. The impact that the other variables have upon the processing of conceptual plural information will be worth investigating in future research.

6. Concluding Remarks

The purpose of the present study was to investigate native-Japanese-speaking L2 English speakers' representation and processing of conceptual plurality apart from number agreement, which has been the approach taken by the bulk of the previous research (Foote, 2010; Hoshino et al., 2010, 2012; Kusnagi et al., 2015; Wei et al., 2015). To achieve this objective, we investigated L2 speakers' comprehension process from the viewpoint of reciprocal verbs, whose processing requires accessing the conceptual plurality of the subject NP. We confirmed through the written sentence completion task that our participants understood that reciprocal verbs do not need a direct object when the subject NP has plurality, while the results of the self-paced reading task suggest that the participants succeeded in accessing conceptual plurality and did not show RT delay in reciprocal conditions compared to the conditions where the participants read optionally transitive verbs, in which retrieving conceptual plurality is not necessary for understanding. Additionally, explicitly denoting plurality of NP by conjoining two singular NPs (e.g., *the boy and the girl*) appeared to help the learners access conceptual plurality, similar to the case of L1 speakers (Patson & Ferreira, 2009). This could be evidence that L2 speakers are capable of using conceptual plurality in online sentence processing if we are not concerned about whether conceptual number information overrides grammatical number, which was the focus of the previous L2 literature (Foote, 2010; Hoshino et al., 2010, 2012; Jackson et al., 2018; Wei et al., 2015). Though several limitations we mentioned in the previous section should be kept in mind, we hope the present findings will be viewed as helpful to broadening the understanding of the nature of conceptual representation of number information in L2 speakers.

Appendix. Test items for the experiment

1a When the producer and the editor fought the actor cancelled the offer of the
   program.
1b When the editors fought the actor cancelled the offer of the program.
1c When the producer and the editor criticized the actor cancelled the offer of the
   program.
1d When the editors criticized the actor cancelled the offer of the program.
2a When the artist and the painter hugged the son played the violin with the teacher.
2b When the artists hugged the son played the violin with the teacher.
2c When the artist and the painter wrote the son played the violin with the teacher.
2d When the artists wrote the son played the violin with the teacher.
3a When the doctor and the nurse dated the chef cooked the dish in the restaurant.
3b When the doctors dated the chef cooked the dish in the restaurant.
3c When the doctor and the nurse paid the chef cooked the dish in the restaurant.
3d When the doctors paid the chef cooked the dish in the restaurant.
4a When the manager and the secretary kissed the worker entered the room with the
   colleagues.
4b When the managers kissed the worker entered the room with the colleagues.
4c When the manager and the secretary investigated the worker entered the room with
   the colleagues.
4d When the managers investigated the worker entered the room with the colleagues.
5a While the professor and the lecturer argued the student sang the song in the
   classroom.
5b While the professors argued the student sang the song in the classroom.
5c While the professor and the lecturer investigated the student sang the song in the
   classroom.
5d While the professors investigated the student sang the song in the classroom.
6a While the boy and the girl dated the performer played the piano on the stage.
6b While the teenagers dated the performer played the piano on the stage.
6c While the boy and the girl paid the performer played the piano on the stage.
6d While the teenagers paid the performer played the piano on the stage.
7a While the actor and the actress embraced the woman took the photograph in the
   theater.
7b While the actors embraced the woman took the photograph in the theater.
7c While the actor and the actress emailed the woman took the photograph in the
   theater.
7d While the actors emailed the woman took the photograph in the theater.
8a While the French and the Spanish hugged the girl watched the dog in the park.
8b While the Europeans hugged the girl watched the dog in the park.
8c While the French and the Spanish searched the girl watched the dog in the park.
8d While the Europeans searched the girl watched the dog in the park.
9a As the waiter and the waitress met the manager gave the promotion to the employee.
9b As the waiters met the manager gave the promotion to the employee.
9c As the waiter and the waitress negotiated the manager gave the promotion to the
   employee.
9d As the waiters negotiated the manager gave the promotion to the employee.
10a As the wife and the husband divorced the woman published the article on the

newspaper.

10b As the lovers divorced the woman published the article on the newspaper.

10c As the wife and the husband wrote the woman published the article on the
    newspaper.

10d As the lovers wrote the woman published the article on the newspaper.

11a As the mayor and the councilor fought the journalist reported the argument on the
    internet.

11b As the politicians fought the journalist reported the argument on the internet.

11c As the mayor and the councilor criticized the journalist reported the argument on
    the internet.

11d As the politicians criticized the journalist reported the argument on the internet.

12a As the mother and the father battled the child played the guitar in the room.

12b As the parents battled the child played the guitar in the room.

12c As the mother and the father left the child played the guitar in the room.

12d As the parents left the child played the guitar in the room.

13a After the writer and the novelist married the editor heard the news on the radio.

13b After the writers married the editor heard the news on the radio.

13c After the writer and the novelist recovered the editor heard the news on the radio.

13d After the writers recovered the editor heard the news on the radio.

14a After the runner and the cyclist met the boy called the mother on the phone.

14b After the athletes met the boy called the mother on the phone.

14c After the runner and the cyclist searched the boy called the mother on the phone.

14d After the athletes searched the boy called the mother on the phone.

15a After the singer and the guitarist married the manager held the interview at the
    company.

15b After the musicians married the manager heard the interview at the company.

15c After the singer and the guitarist recovered the manager held the interview at the
    company.

15d After the musicians recovered the manager held the interview at the company.

16a After the king and the queen kissed the baby read the book in the bed.

16b After the leaders kissed the baby read the book in the bed.

16c After the king and the queen left the baby read the book in the bed.

16d After the leaders left the baby read the book in the bed.

17a Because the novelist and the poet divorced the man sent the letter to the family.

17b Because the writers divorced the man sent the letter to the family.

17c Because the novelist and the poet negotiated the man sent the letter to the family.

17d Because the writers negotiated the man sent the letter to the family.

18a Because the musician and the comedian embraced the man took his phone from the
    pocket.

18b Because the entertainers embraced the man took his phone from the pocket.

18c Because the musician and the comedian emailed the man took his phone from the
    pocket.

18d Because the entertainers emailed the man took his phone from the pocket.

19a Because the coach and the trainer argued the referee canceled the game on the way.

19b Because the coaches argued the referee canceled the game on the way.

19c Because the coach and the trainer protested the referee canceled the game on the
    way.

19d Because the coaches protested the referee canceled the game on the way.

20a Because the engineer and the mechanic battled the employer called the chief by the
     phone.
20b Because the engineers battled the employer called the chief by the phone.
20c Because the engineer and the mechanic protested the employee called the chief by
     the phone.
20d Because the engineers protested the employer called the chief by the phone.

Notes

[1] The situation becomes complicated if *each other* is added, because, for instance, *the group meets each other* sounds odd, but *the girls meet each other* does not. This is because *meet* is used differently and has a different meaning across these sentences. In the case of collective singular nouns, *meet* means 'have a gathering or an assembly', whereas *meet* in *the girls meet each other* denotes 'come face to face by chance or arrangement'. Therefore, *each other* cannot go along with *the group*. That is, this issue has nothing to do with the relationship between conceptual plurality and reciprocal verbs, and so we will not discuss the issue further because it is beyond the focus of the present study. See Fiengo and Lasnik (1973) for the semantics of *each other*.

[2] One may wonder whether the frequency of the use of the verbs selected in this study could have been biased toward either reciprocal use or transitive use. Nonetheless, the 10 reciprocal verbs and 10 optionally transitive (OT) verbs used in the present study were chosen on the basis of the verbs used in Patson and Ferreira (2009), whose norming study demonstrated that "the transitivity bias of the verbs are essentially the same" (p.468). Second, even if there are some verbs that have high transitive bias and those verbs might have influenced the participants' sentence processing, the GLMM analysis took into account the item variance by estimating by-item random intercepts. In addition, our GLMM analysis showed that adding by-item random slopes did not improve the model, which implied that the garden-path effects were essentially the same among all the verbs.

[3] Still, however, the small number of the items and the lack of distractors included in the

SCT might be problematic in a sense that the participants saw similar items constantly and, therefore, each response might not be independent. Nevertheless, as we stated in the objectives of the SCT in section 3.2.2, the purpose of this task was to ensure that the participants were aware that reciprocal verbs do not require object NP if the subject is plural. The other objective was to ensure that the optionally transitive verbs selected for the experiment were truly optionally transitive. For these purposes, we think that the negative influence of the small number of the test items without distractors was negligible. The results of the SCT were just as we expected, and they correspond to the results of the SPRT.

[4] Unfortunately, there was an interaction found in this region, suggesting that the sentences including conjoined NP and OT were read faster. This result was unexpected, and the cause of this unexpected RT tendency remains unclear. One possible reason could be the main effect of the noun type, as can be seen from Figure 3. In processing the test items including conjoined NPs, the participants had read a few more words before encountering the target verb than in processing the items with the plural definite description. That is, the participants had more time to process the sentences in the case of the conjoined NP items.

References

Bates, D., Maechler, M., Bolker, B., & Walker, S. (2015). *lme4: Linear mixed-effects models using Eigen and S4.* [R package version 1.1-12] Retrieved from https://cran.r-project.org/package=lme4

Bock, K., & Eberhard, K. M. (1993). Meaning, sound and syntax in English number agreement. *Language and Cognitive Processes, 8,* 57–99. doi:10.1080/01690969308406949

Bock, K., Eberhard, K. M., Cutting, J. C., Meyer, A. S., & Schriefers, H. (2001). Some attractions of verb agreement. *Cognitive Psychology, 43,* 83–128. doi:10.1006/cogp.2001.0753

Bock, K., & Miller, C. A. (1991). Broken agreement. *Cognitive Psychology, 23,* 45–93. doi:10.1016/0010-0285(91)90003-7

Bock, K., Nicol, J. L., & Cutting, J. C. (1999). The ties that bind: creating number agreement in speech. *Journal of Memory and Language, 40,* 330–346. doi:10.1006/jmla.1998.2616

Eberhard, K. M. (1997). The marked effect of number on subject – verb agreement. *Journal of Memory and Language, 36,* 147–164.

Eberhard, K. M. (1999). The accessibility of conceptual number to the processes of subject–verb agreement in English. *Journal of Memory and Language, 41,* 560–578. doi:10.1006/jmla.1999.2662

Eberhard, K. M., Cutting, J. C., & Bock, K. (2005). Making syntax of sense: number agreement in sentence production. *Psychological Review, 112,* 531–559. doi:10.1037/0033-295X.112.3.531

Ferreira, F., & McClure, K. (1997). Parsing of garden-path sentences with reciprocal

verbs. *Language and Cognitive Processes, 12,* 273–306.

doi:10.1080/016909697386862

Fiengo, R., & Lasnik, H. (1973). The logical structure of reciprocal sentences in

English. *Foundations of Language, 9,* 447–468.

Foote, R. (2010). Age of acquisition and proficiency as factors in language production:

Agreement in bilinguals. *Bilingualism: Language and Cognition, 13,* 99–118.

doi:10.1017/S136672890999040X

Gleitman, L. R., Gleitman, H., Miller, C., & Ostrin, R. (1996). Similar, and similar

concepts. *Cognition, 58,* 321–376. doi:10.1016/0010-0277(95)00686-9

Hartsuiker, R. J., & Barkhuysen, P. N. (2006). Language production and working

memory: The case of subject-verb agreement. *Language and Cognitive*

Processes, 21, 181–204. doi:10.1080/01690960400002117

Hoshino, N., Dussias, P. E., & Kroll, J. F. (2010). Processing subject–verb agreement in

a second language depends on proficiency. *Bilingualism: Language and*

Cognition, 13, 87–98. doi:10.1017/S1366728909990034

Hoshino, N., Kroll, J. F., & Dussias, P. E. (2012). Psycholinguistic perspectives on

second language speech production. In M. Sanz & J. M. Igoa (Eds.), *Applying*

language science to language pedagogy: Contributions of linguistics and

psycholinguistics to second language teaching. (pp. 107–127). Newcastle, UK:

Cambridge Scholars Publishing.

Humphreys, K. R., & Bock, K. (2005). Notional number agreement in English.

Psychonomic Bulletin & Review, 12, 689–95. doi:10.3758/BF03196759

Jiang, N. (2007). Selective integration of Linguistic knowledge in adult second

language learning. *Language Learning, 57,* 1–33. doi:10.1111/j.1467-9922.2007.00397.x

Jackson, C. N., Mormer, E., & Brehm, L. (2018). The production of subject-verb agreement among Swedish and Chinese second language speakers of English. *Studies in Second Language Acquisition*. Advance Online Publication. doi:10.1017/S0272263118000025

Juffs, A. (1998). Main verb versus reduced relative clause ambiguity resolution in L2 sentence processing. *Language Learning, 48,* 107–147. doi:10.1111/1467-9922.00034

Juffs, A., & Harrington, M. (1996). Garden path sentences and error data in second language sentence processing. *Language Learning, 46,* 283–323. doi:10.1111/j.1467-1770.1996.tb01237.x

Kaup, B., Kelter, S., & Habel, C. (2002). Representing referents of plural expressions and resolving plural anaphors. *Language and Cognitive Processes, 17,* 405–450. doi:10.1080/01690960143000272

Kreiner, H., Garrod, S., & Sturt, P. (2013). Number agreement in sentence comprehension: The relationship between grammatical and conceptual factors. *Language and Cognitive Processes, 28,* 829–874. doi:10.1080/01690965.2012.667567

Kusanagi, K., Tamura, Y., & Fukuta, J. (2015). The notional number attraction in English as a foreign language: A self-paced reading study. *Journal of the Japan Society for Speech Sciences, 16,* 77–96.

Lo, S., & Andrews, S. (2015). To transform or not to transform : Using Generalized Linear Mixed Models to analyse reaction time data. *Frontiers in Psychology, 6,*

1–16. doi:10.3389/fpsyg.2015.01171

Lenth, R. (2016). *lsmeans*. [R package version 2.25] Retrieved from https://cran.r-project.org/package=lsmeans

Linck, J. A., & Cunnings, I. (2015). The utility and application of mixed-effects models in second language research. *Language Learning, 65,* 185–207. doi:10.1111/lang.12117

Nakanishi, K., & Tomioka, S. (2004). Japanese plurals are exceptional. *Journal of East Asian Linguistics, 13,* 113–140. doi:10.1023/B:JEAL.0000019058.46668.c1

Nicol, J. L., Forster, K. I., & Veres, C. (1997). Subject–verb agreement processes in comprehension. *Journal of Memory and Language, 36,* 569–587. doi:10.1006/jmla.1996.2497

Nicol, J., & Greth, D. (2003). Production of subject-verb agreement in Spanish as a second language. *Experimental Psychology, 50,* 196–203. doi:10.1026//1617-3169.50.3.196

Nicol, J. L., Teller, M., & Greth, D. (2001). Production of verb agreement in monolingual, bilingual, and second-language speakers. In J. L. Nicol (Ed.), *One mind, two languages: Bilingual sentence processing* (pp. 117–133). Maiden: Blackwell Publishing.

Nishigauchi, T. (1992). Syntax of reciprocals in Japanese. *Journal of East Asian Linguistics, 1,* 157–196. doi:10.1007/BF00130235

Patson, N. D. (2014). The processing of plural expressions. *Linguistics and Language Compass, 8,* 319–329. https://doi.org/10.1111/lnc3.12085

Patson, N. D., & Ferreira, F. (2009). Conceptual plural information is used to guide early parsing decisions: Evidence from garden-path sentences with reciprocal

verbs. *Journal of Memory and Language, 60,* 464–486.

doi:10.1016/j.jml.2009.02.003

Patson, N. D., George, G., & Warren, T. (2014). The conceptual representation of

number. *The Quarterly Journal of Experimental Psychology, 67,* 1349–65.

doi:10.1080/17470218.2013.863372

Patson, N. D., & Warren, T. (2010). Evidence for distributivity effects in

comprehension. *Journal of Experimental Psychology. Learning, Memory, and*

Cognition, 36, 782–789. doi:10.1037/a0018783

Patson, N. D., & Warren, T. (2011). Building complex reference objects from dual sets.

Journal of Memory and Language, 64, 443–459. doi:10.1016/j.jml.2011.01.005

Pearlmutter, N. J., Garnsey, S. M., & Bock, K. (1999). Agreement processes in sentence

comprehension. *Journal of Memory and Language, 41,* 427–456.

doi:10.1006/jmla.1999.2653</

R Core Team (2016). R: A language and environment for statistical computing. R

Foundation for Statistical Computing, Vienna, Austria. Retrieved from

http://www.R-project.org/

Shibuya, M., & Wakabayashi, S. (2008). Why are L2 learners not always sensitive to

subject-verb agreement? *EUROSLA Yearbook, 8,* 235–258.

doi:10.1075/eurosla.8.13shi

Wei, X., Chen, B., Liang, L., & Dunlap, S. (2015). Native language influence on the

distributive effect in producing second language subject–verb agreement. *The*

Quarterly Journal of Experimental Psychology, 68, 2370–2383.

doi:10.1080/17470218.2015.1014821

Table 1.
Demographic Information of the Participants.

	M	SD	Mdn	Minimum	Maximum	Skew	Kurtosis
TOEIC[a]	854.46	82.58	860.00	700.00	990.00	-0.17	-1.07
Age[b]	24.70	5.30	23.00	20.00	40.00	1.64	1.60
Experience of studying abroad[c]	11.36	13.28	9.50	0.50	54.00	1.89	3.28
Years of learning English[a]	14.00	6.14	12.00	8.00	36.00	1.99	4.03
Starting age[b]	10.52	4.13	11.00	2.00	24.00	0.62	2.54
Self-reported proficiency scores[a]							
Reading	3.36	0.99	3.50	1.00	5.00	-0.72	0.18
Writing	3.00	0.94	3.00	1.00	4.00	-0.26	-1.37
Listening	3.71	1.05	4.00	1.00	5.00	-0.55	-0.26
Speaking	3.00	1.25	3.00	1.00	5.00	-0.22	-0.96
Vocabulary	2.75	0.75	3.00	1.00	4.00	-0.09	-0.53
Grammar	3.29	0.81	3.50	2.00	4.00	-0.53	-1.33

Note. [a]*n* = 28, [b]*n* = 27, [c]*n* = 18. Starting age of learning English was calculated by subtracting the years of learning English from the age. One participant did not report his age so his starting age could not be calculated. The self-reported proficiency scale was measured by 5 point Likert scale.

Table 2.
The List of Reciprocal Verbs and Optionally Transitive Verbs Used in the Experiment.

Reciprocal verbs	Optionally Transitive Verbs
argue	criticize
battle	email
date	investigate
divorce	leave
embrace	negotiate
fight	pay
hug	protest
kiss	recover
marry	search
meet	write

Table 3.
Examples of Coding in the Sentence Completion Task.

Verb Type	Category	Sample Sentences from the data
OT	transitive	Because the engineer and the mechanic protested the working schedule for this year, the chef of the factory really worried about that.
	intransitive	As the parents left, the son felt sad too.
Reciprocal	transitive	When the artists hugged the dog, he looked happy.
	intransitive	Because the coach and the trainer argued about the methods of training, the new policy was established.
		As the parents battled with his son, he got away from his home.
	reciprocal	When the managers kissed in the room, the employee walked into there with his colleagues.
		After the writer and the novelist married, they wrote a novel together.
	Error	*When the managers investigated the working attitude of their employees.
		*After the leaders kissed to their children, they went to the battlefield as a national army.

Table 4.

Proportion of Verb Interpretations in the Sentence Completion Task (percentage in parentheses).

	Reciprocal		OT	
	conj	PDD	conj	PDD
intransitive	20 (12.50)	34 (21.25)	77 (48.13)	82 (51.25)
transitive	13 (8.13)	38 (23.75)	83 (51.88)	76 (47.50)
reciprocal	126 (78.75)	83 (51.88)	0 (0)	0 (0)
error	1 (0.63)	5 (3.13)	0 (0)	2 (1.25)
All	160 (100)	160 (100)	160 (100)	160 (100)

Note. Conj = conjoined NPs; PDD = plural definite descriptions; OT = optionally transitive verbs.

Table 5.
Mean RTs (ms) and SDs (in Parentheses) in the Self-paced Reading Task.

	V	the	N	targetV	D	N
Conj/recip	617	531	543	600	498	543
	(212)	(142)	(182)	(248)	(116)	(163)
PDD/recip	758	516	594	721	550	593
	(428)	(116)	(226)	(369)	(219)	(250)
Conj/OT	679	505	535	643	561	607
	(351)	(121)	(147)	(230)	(224)	(238)
PDD/OT	723	518	604	697	561	558
	(250)	(143)	(183)	(229)	(183)	(154)

Note. Conj = conjoined NPs; PDD = plural definite descriptions; recip = reciprocal verbs; OT = optionally transitive verbs.

Table 6.
Results from GLMM in the One Word Before Target V Region.

| | Fixed effects | | | | Random effects | |
| | | | | | By Subject | By Items |
Parameters	Estimate	*SE*	*t*	*p*	*SD*	*SD*
Intercept	498.888	24.834	20.089	$<.001$	99.295	38.057
Verb Type	6.609	14.714	0.449	.653	–	–
Noun Type	48.775	21.749	2.243	.025	96.151	–
TOEIC	-15.372	25.98	-0.592	.554	–	–
Word Length	18.445	5.437	3.393	.001	–	–
Verb x Noun	-54.808	23.131	-2.369	.018	–	–

Note. Number of observation = 536, N = 28, K = 20. Model formula: RT ~ Noun +Verb + Noun : Verb + TOEIC + Word Length + (1 + Noun | Subject) + (1 | Item)

Table 7.

Results from GLMM in the Target V Region.

| | Fixed effects | | | | Random effects | |
| | | | | | By Subject | By Items |
Parameters	Estimate	*SE*	*t*	*p*	*SD*	*SD*
Intercept	482.378	36.029	13.389	< .001	142.350	34.128
Verb Type	-33.173	16.187	-2.049	.040	–	–
Noun Type	55.359	17.170	3.224	.001	–	–
TOEIC	-35.876	24.417	-1.469	.142	–	–
Word Length	37.785	6.775	5.577	< .001	–	–
Verb x Noun	-14.170	27.809	-0.510	.610	–	–

Note. Number of observation = 501, $N = 28$, $K = 20$. Model formula: RT ~ Noun + Verb + Noun : Verb +TOEIC + Word Length + (1 | Subject) + (1 | Item).

Table 8.
Results from GLMM in the Region D.

| | Fixed effects | | | | Random effects | |
| | | | | | By Subject | By Items |
Parameters	Estimate	*SE*	*t*	*p*	*SD*	*SD*
Intercept	560.512	40.600	13.806	< .001	97.241	19.318
Verb Type	-57.874	26.830	-2.157	.031	80.769	–
Noun Type	40.381	32.719	1.234	.217	88.795	–
TOEIC	-1.629	20.387	-0.08	.936	–	–
Verb x Noun	21.785	26.528	0.821	.412	–	–

Note. Number of observation = 547, *N* = 28, *K* = 20. Model formula: RT ~ Noun + Verb + Noun : Verb + TOEIC + (1 + Noun + Verb | Subject) + (1 | Item).

Table 9.
Results from GLMM in the Region N.

| | Fixed effects | | | | Random effects | |
| | | | | | By Subject | By Items |
Parameters	Estimate	*SE*	*t*	*p*	*SD*	*SD*
Intercept	308.076	25.564	12.051	< .001	72.363	26.804
Verb Type	-31.740	21.941	-1.447	.148	77.281	39.701
Noun Type	15.511	12.949	1.198	.231	–	–
TOEIC	7.704	19.633	0.392	.695	18.413	–
Word Length	49.483	7.456	6.637	< .001	20.698	–
Verb x Noun	36.398	19.286	1.887	.059	–	

Note. Number of observation = 532, *N* = 28, *K* = 20. Model formula: RT ~ Noun + Verb + Noun : Verb + TOEIC + Word Length + (1 + Verb + TOEIC + Word Length | Subject) + (1 + Verb | Item).
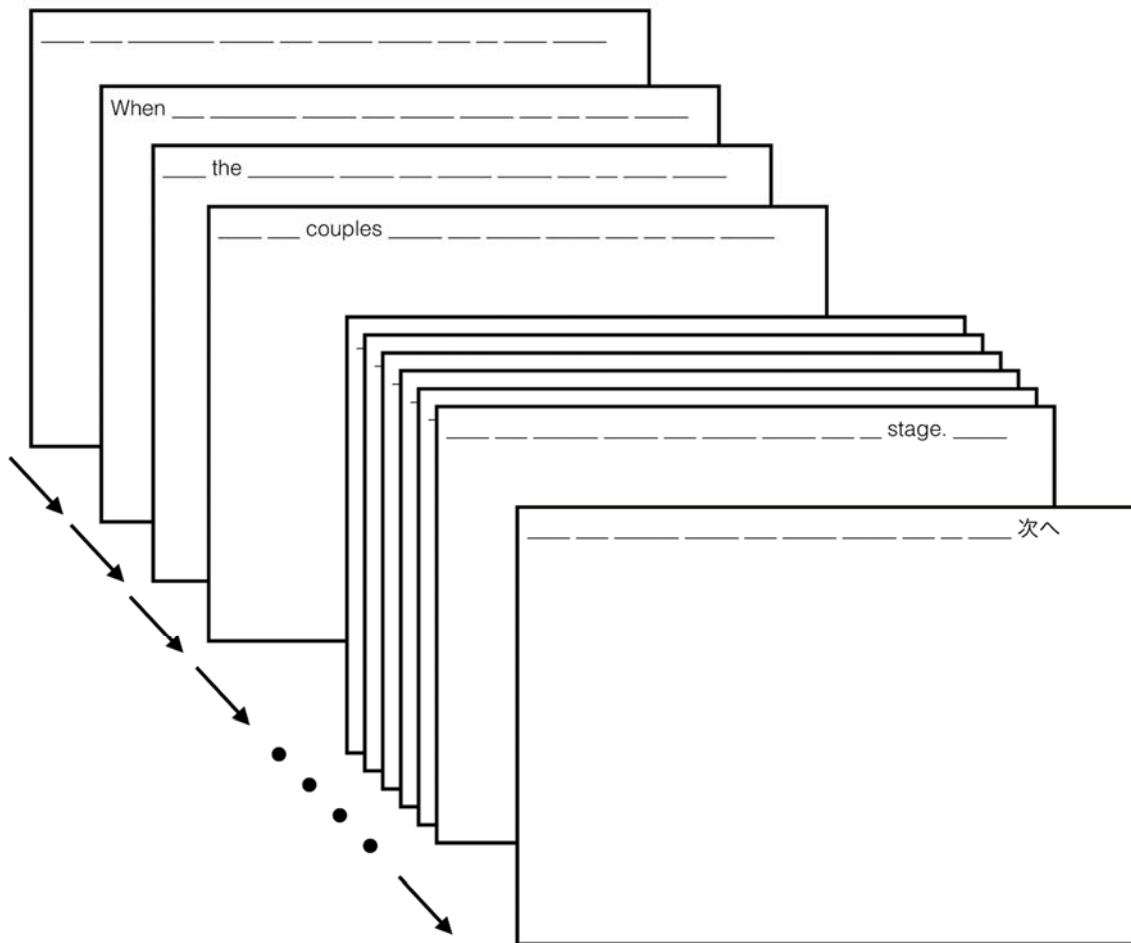
Figure 1. Schematic of the self-paced reading experiment. In order to avoid the rap-up effect, the last region included the Japanese translation of "going to the next". In the analysis, this last region was excluded in calculating mean RT of the participants.
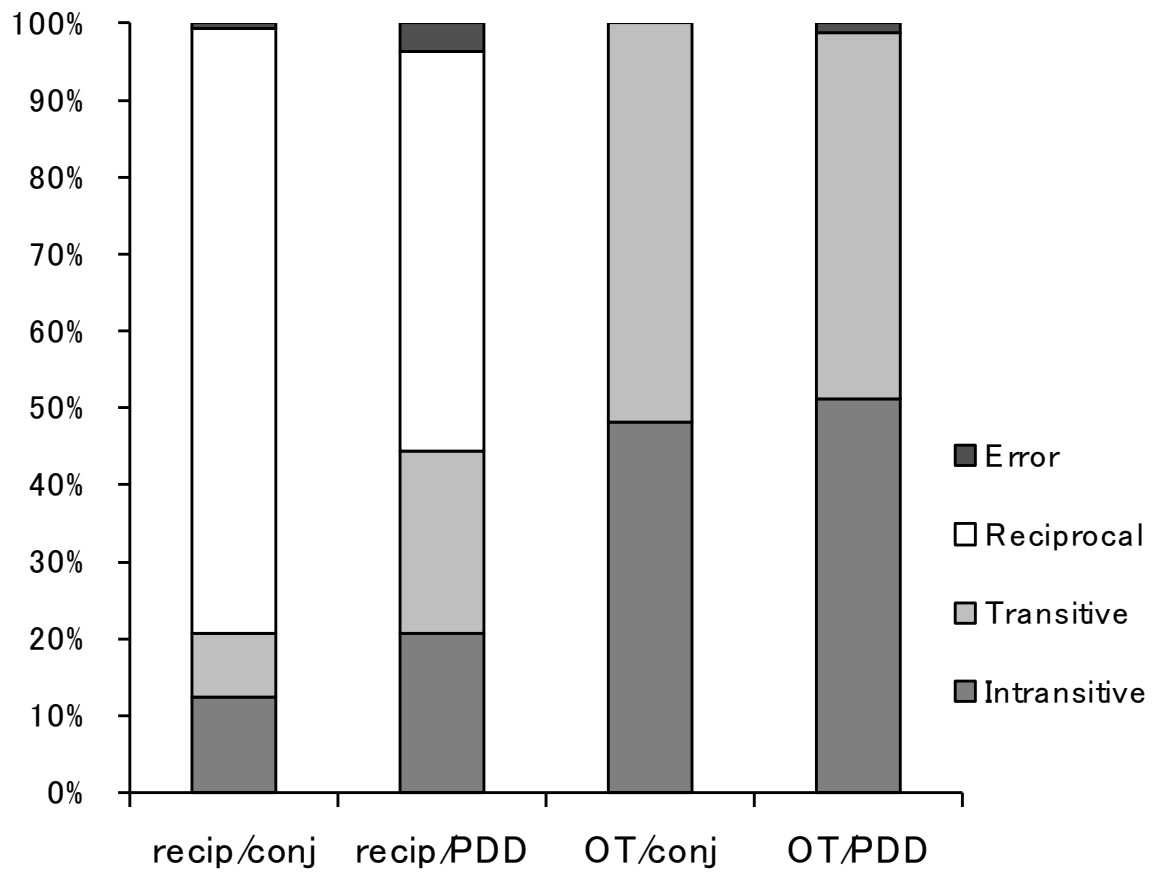
Figure 2. The proportion of the interpretation of the verb in the sentence completion task. Conj = conjoined NPs; PDD = plural definite descriptions; recip = reciprocal verbs; OT = optionally transitive verbs.
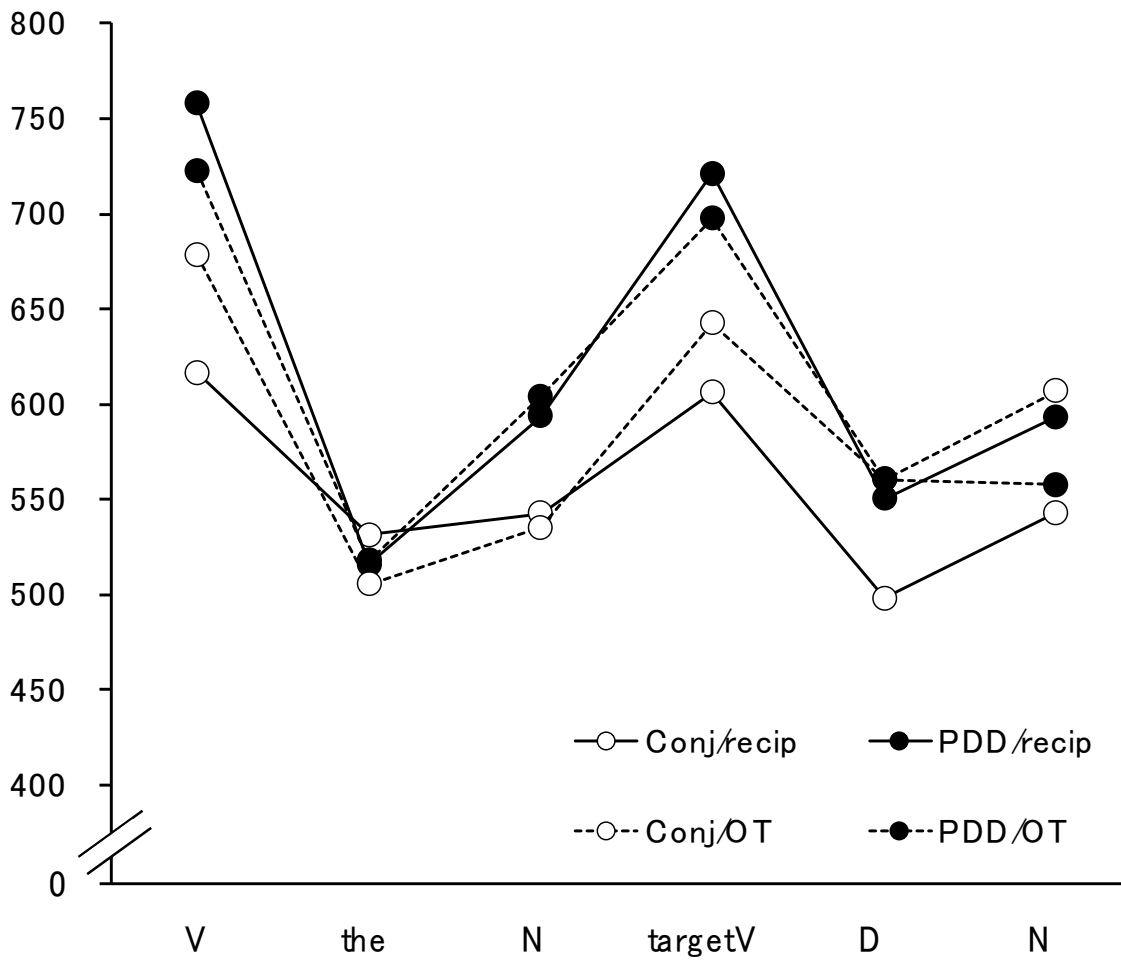
Figure 3. Mean RT profile in all the four conditions. Conj = conjoined NPs; PDD = plural definite descriptions; recip = reciprocal verbs; OT = optionally transitive verbs.
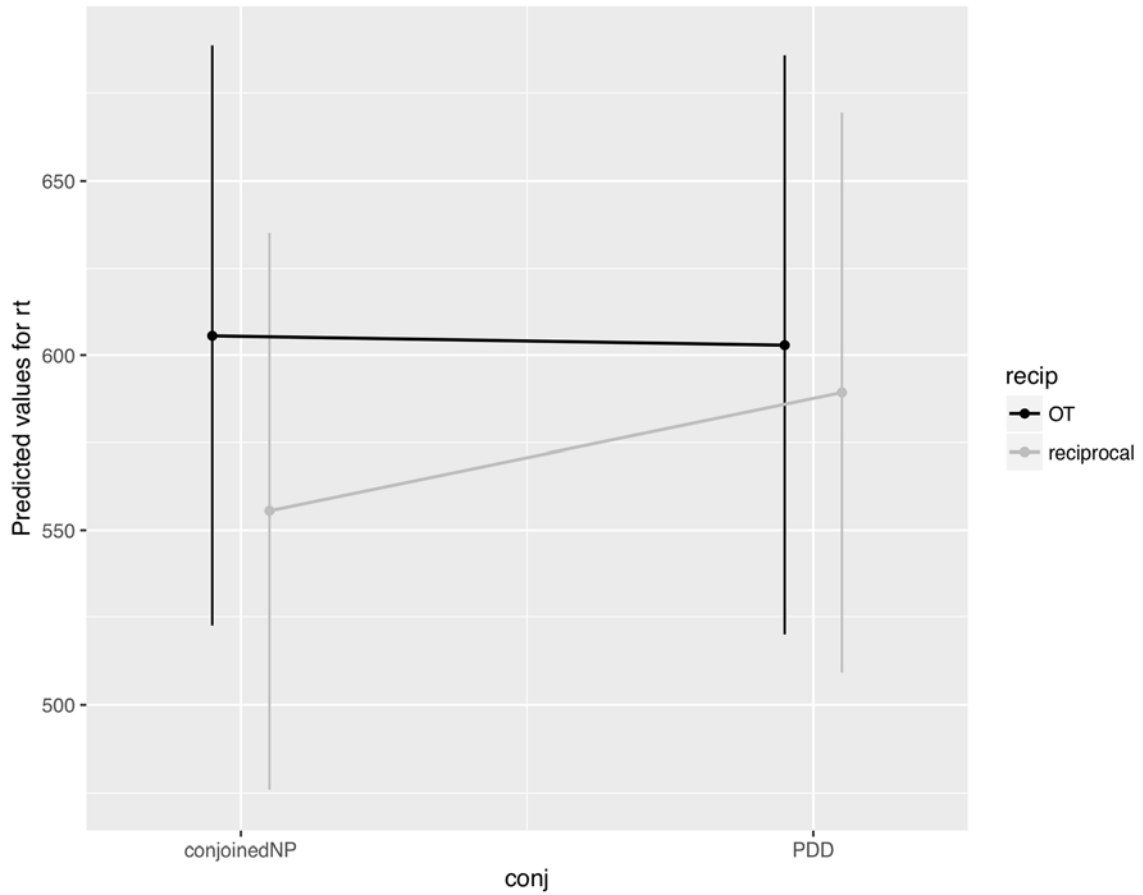
Figure 4. Interaction plot of the RT in the last interested region of the self-paced reading task. The black lines indicate optionally transitive verbs and gray lines indicate reciprocal verbs.

Supplementary Materials

The below are the R codes and the detailed analysis procedures for the present experiments.

Supplementary Materials 1.

R code for the analysis of sentence completion task

SCT Poisson Log-linear

Authors

January 5, 2018

Possion Log-linear

Package preparation

If you haven't installed the packages yet, please first install the packages.

```
install.packages("stats")
install.packages("tidyr")
install.packages("dplyr")
install.packages("car")
install.packages("sjPlot")
install.packages("lsmeans")
install.packages("MASS")
```

Then read the necessary packages

```
library(stats)
library(tidyr)
library(dplyr)
library(car)
library(sjPlot)
library(lsmeans)
library(MASS)
```

Reading the data

```
sct.all<-read.table("SCT-table.csv",header=T,sep=",")
print(sct.all)

##      Verb Noun Category Freq
## 1  Recip conj     Intr   20
## 2  Recip conj    Trans   13
## 3  Recip conj    Recip  126
## 4  Recip conj    Error    1
## 5  Recip  PDD     Intr   34
## 6  Recip  PDD    Trans   38
```

```
## 7   Recip   PDD     Recip    83
## 8   Recip   PDD     Error     5
## 9       OT  conj     Intr    77
## 10      OT  conj    Trans    83
## 11      OT  conj    Recip     0
## 12      OT  conj    Error     0
## 13      OT   PDD     Intr    82
## 14      OT   PDD    Trans    76
## 15      OT   PDD    Recip     0
## 16      OT   PDD    Error     2
```

Analysis for reciprocal verbs

Preparing data sets

Exctracting the data for reciprocal verbs

```
sct.all%>%
  filter(Verb=="Recip")->dat.recip
print(dat.recip)

##       Verb Noun Category Freq
## 1 Recip conj     Intr   20
## 2 Recip conj    Trans   13
## 3 Recip conj    Recip  126
## 4 Recip conj    Error    1
## 5 Recip  PDD     Intr   34
## 6 Recip  PDD    Trans   38
## 7 Recip  PDD    Recip   83
## 8 Recip  PDD    Error    5
```

We are not going to use error data. However, it will inevitablly have an impact on the sum frequency of the observation. That is, the more the error data is, the less the sum frequency is. To control a different number of the sum frequency, we are going to use the number of observation as an offset term in the poisson loglinear analysis.

```
#Exclude the error data
dat.recip%>%
  filter(Category != "Error")->recip.NoError
```

You can see that there is one error observation in [Recip-conj] condition and 5 error observations in [Recip-PDD] condition among each 160 obvervations. Therefore, the sum frequency for the [Recip-conj] condition is 160-1 = 159, and for the [Recip-PDD] condition is 160-5 = 155. We add the sum frequency into Obs variable

```
recip.NoError$Obs<-c(rep(159,3),rep(155,3))
print(recip.NoError)
```

```
##     Verb Noun Category Freq Obs
## 1 Recip conj     Intr   20 159
## 2 Recip conj    Trans   13 159
## 3 Recip conj    Recip  126 159
## 4 Recip  PDD     Intr   34 155
## 5 Recip  PDD    Trans   38 155
## 6 Recip  PDD    Recip   83 155
```

Change coding

Since it is very likely that we face multicolinearlity issue with dummy coding of the categorical variable, we are going to change it to contrast coding.

```
#For two levels
c2<-contr.treatment(2)
my.coding2<-matrix(rep(1/2,2),ncol=1)
my.simple2<-c2-my.coding2
contrasts(recip.NoError$Noun)<-my.simple2

#For three levels
#We first need to drop the empty level (Error) from the Category varia
ble
recip.NoError$Category<-droplevels(recip.NoError$Category)
c3<-contr.treatment(3)
c3

##   2 3
## 1 0 0
## 2 1 0
## 3 0 1

my.coding3<-matrix(rep(1/3,6),ncol=2)
my.simple3<-c3-my.coding3
contrasts(recip.NoError$Category)<-my.simple3
```
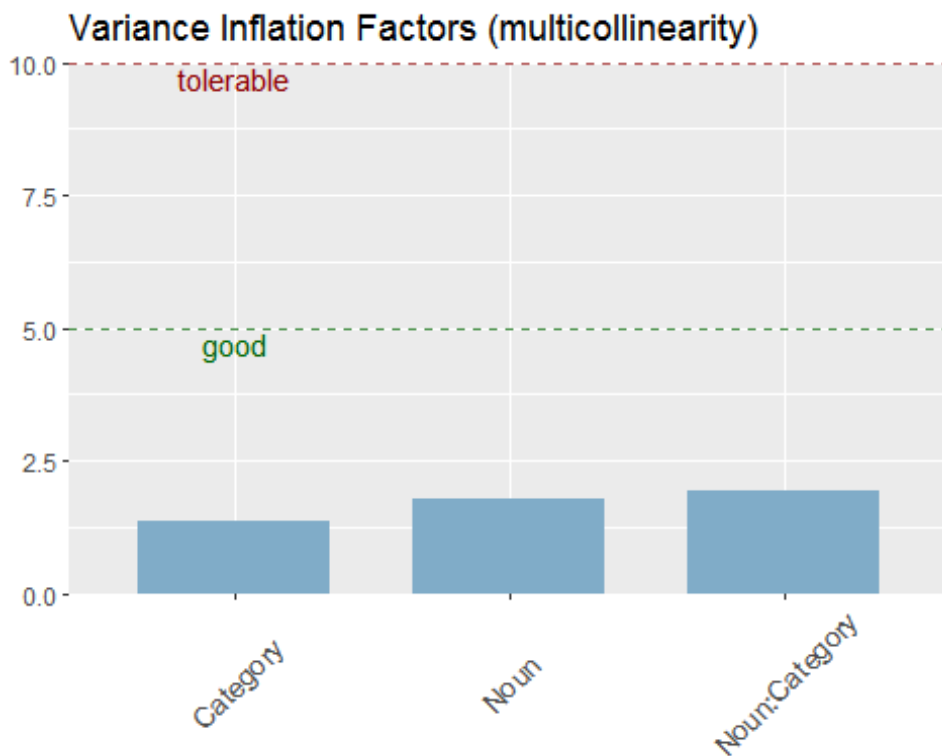
Log-linear regreggion by glm
```
model1<-glm(Freq~Noun+Category+Noun:Category, offset = log(Obs), famil
y = poisson, data = recip.NoError)
vif(model1)

##                    GVIF Df GVIF^(1/(2*Df))
## Noun           1.767144  1        1.329340
## Category       1.357462  2        1.079399
## Noun:Category  1.916803  2        1.176642

sjp.glm(model1,type = "vif") #check VIF visually
```

Variance Inflation Factors (multicollinearity)

Seek the best model by step wise procedure.

```
stepAIC(model1)

## Start:  AIC=45.04
## Freq ~ Noun + Category + Noun:Category
##
##                 Df Deviance    AIC
## <none>                0.000 45.041
## - Noun:Category  2   25.331 66.372

##
## Call:  glm(formula = Freq ~ Noun + Category + Noun:Category, family
 = poisson,
##     data = recip.NoError, offset = log(Obs))
##
## Coefficients:
##     (Intercept)            Noun2         Category2         Category3

##         -1.3929           0.4208            1.3665           -0.1598

## Noun2:Category2  Noun2:Category3
##         -0.9481           0.5420
##
## Degrees of Freedom: 5 Total (i.e. Null);  0 Residual
## Null Deviance:        169.6
## Residual Deviance: 5.995e-15     AIC: 45.04
```

The full model with interaction term was chosen as the best model, so let us now see the results of poisson loglinear analysis

```
summary(model1)

##
## Call:
## glm(formula = Freq ~ Noun + Category + Noun:Category, family = pois
son,
##     data = recip.NoError, offset = log(Obs))
##
## Deviance Residuals:
## [1]  0  0  0  0  0  0
##
## Coefficients:
##                 Estimate Std. Error z value Pr(>|z|)
## (Intercept)     -1.39287    0.07503 -18.565  < 2e-16 ***
## Noun2            0.42075    0.15005   2.804  0.00505 **
## Category2        1.36651    0.15764   8.669  < 2e-16 ***
## Category3       -0.15978    0.21369  -0.748  0.45463
## Noun2:Category2 -0.94807    0.31527  -3.007  0.00264 **
## Noun2:Category3  0.54201    0.42738   1.268  0.20472
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for poisson family taken to be 1)
##
##     Null deviance: 1.6959e+02  on 5  degrees of freedom
## Residual deviance: 5.9952e-15  on 0  degrees of freedom
## AIC: 45.041
##
## Number of Fisher Scoring iterations: 3
```

We found there is a significant interaction between the Noun type and the Category. We visualize the interaction by sjp.int function.

Visualization
```
sjp.int(model1,show.ci = T,plevel = .05,jitter.ci = T)
```

Interaction effect of Noun and Category on Freq
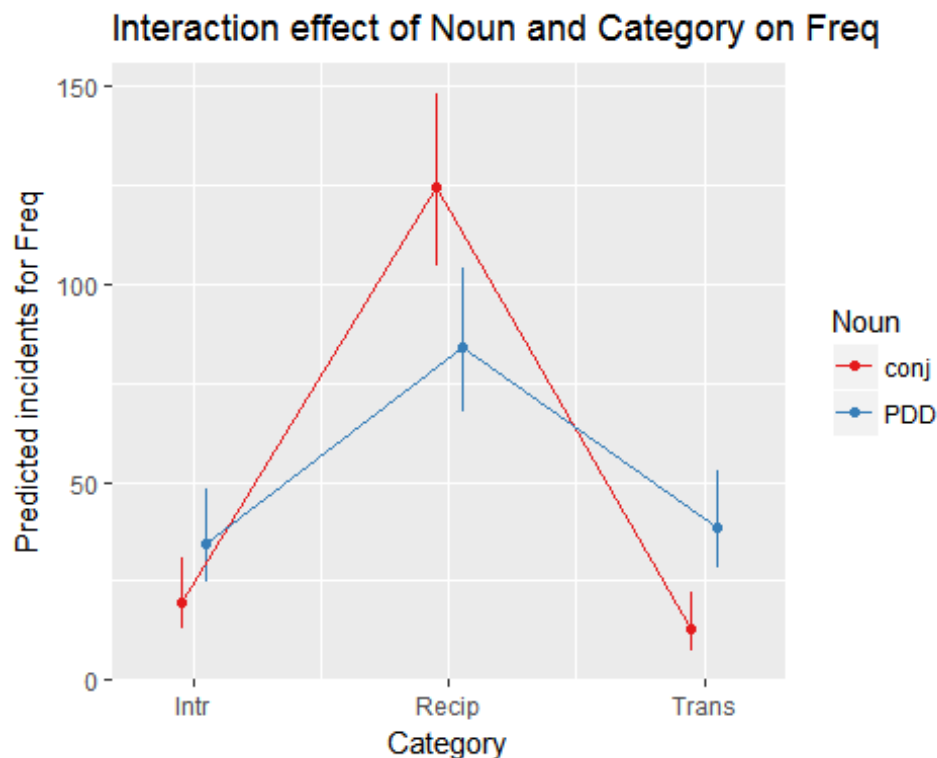
It seems that the frequency of reciprocal verbs and transitive verbs differs between conjoined NP and plural definite nouns.To look at the freqnecy differences, we carry out multiple comparison using least square means.

Multiple Comparison

```
#library(lsmeans)
lsmeans(model1,pairwise~Category|Noun)$contrasts

## Noun = conj:
##  contrast        estimate        SE df z.ratio p.value
##  Intr - Recip  -1.8405496 0.2407000 NA  -7.647  <.0001
##  Intr - Trans   0.4307829 0.3562627 NA   1.209  0.4477
##  Recip - Trans  2.2713325 0.2913067 NA   7.797  <.0001
##
## Noun = PDD:
##  contrast        estimate        SE df z.ratio p.value
##  Intr - Recip  -0.8924801 0.2036172 NA  -4.383  <.0001
##  Intr - Trans  -0.1112256 0.2360668 NA  -0.471  0.8849
##  Recip - Trans  0.7812544 0.1958673 NA   3.989  0.0002
##
## Results are given in the log (not the response) scale.
## P value adjustment: tukey method for comparing a family of 3 estima
tes

lsmeans(model1,pairwise~Noun|Category)$contrasts

## Category = Intr:
##  contrast     estimate        SE df z.ratio p.value
```

```
##  conj - PDD -0.5561073 0.2818009 NA  -1.973  0.0484
##
## Category = Recip:
##  contrast      estimate        SE df z.ratio p.value
##  conj - PDD  0.3919622 0.1413673 NA   2.773  0.0056
##
## Category = Trans:
##  contrast      estimate        SE df z.ratio p.value
##  conj - PDD -1.0981159 0.3213081 NA  -3.418  0.0006
##
## Results are given in the log (not the response) scale.
```

In summary, we found:

- Intransitive verbs: PDD > conj
- Reciprocal verbs: conj > PDD
- Transitive verbs: PDD > conj

and

- conjoined NP
    - Intransitive < Reciprocal
    - Intransitive = Transitive
    - Reciprocal > Transitive
- Plural definite nouns (PDD)
    - Intransitive < Reciprocal
    - Intransitive = Transitive
    - Reciprocal > Transitive

Analysis for Optionally Transitive Verbs

Now, let us analyze the case of optionally transitive (OT) verbs

```
sct.all%>%
  filter(Verb=="OT")->dat.ot
print(dat.ot)

##    Verb Noun Category Freq
## 1   OT conj     Intr   77
## 2   OT conj    Trans   83
## 3   OT conj    Recip    0
## 4   OT conj    Error    0
## 5   OT  PDD     Intr   82
## 6   OT  PDD    Trans   76
## 7   OT  PDD    Recip    0
## 8   OT  PDD    Error    2
```

As we did above, we exclude the error data. Also, there are strctural zeros of reciprocal verbs, so we also delete those rows.

```
#Exclude the error data
dat.ot%>%
  filter(Category != "Error" & Category != "Recip")->ot.NoError
print(ot.NoError)

##    Verb Noun Category Freq
## 1   OT conj     Intr   77
## 2   OT conj    Trans   83
## 3   OT  PDD     Intr   82
## 4   OT  PDD    Trans   76
```

You can see that there is no error observation in [OT-conj] condition but 2 error observations are found in [OT-PDD] condition among each 160 obvervations. Therefore, the sum frequency for the [OT-conj] condition is 160, and for the [OT-PDD] condition is 160-2 = 158. We add the sum frequency into Obs variable

```
ot.NoError$Obs<-c(rep(160,2),rep(158,2))
print(ot.NoError)

##    Verb Noun Category Freq Obs
## 1   OT conj     Intr   77 160
## 2   OT conj    Trans   83 160
## 3   OT  PDD     Intr   82 158
## 4   OT  PDD    Trans   76 158
```

Change coding

Since it is very likely that we face multicolinearlity issue with dummy coding of the categorical variable, we are going to change it to contrast coding.

```
#For two levels
contrasts(ot.NoError$Noun)<-my.simple2
contrasts(ot.NoError$Noun)<-my.simple2
```

Log-linear regression by glm

```
model2<-glm(Freq~Noun*Category,offset = log(Obs),data=ot.NoError,family = poisson)
summary(model2)

##
## Call:
## glm(formula = Freq ~ Noun * Category, family = poisson, data = ot.NoError,
##     offset = log(Obs))
##
## Deviance Residuals:
## [1]  0  0  0  0
##
## Coefficients:
```

```
##                     Estimate Std. Error z value Pr(>|z|)
## (Intercept)        -0.6936221  0.0793444  -8.742   <2e-16 ***
## Noun2               0.0754926  0.1586887   0.476    0.634
## CategoryTrans      -0.0004754  0.1122366  -0.004    0.997
## Noun2:CategoryTrans -0.1510211  0.2244731  -0.673    0.501
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for poisson family taken to be 1)
##
##     Null deviance:  4.5296e-01  on 3  degrees of freedom
## Residual deviance: -8.8818e-16  on 0  degrees of freedom
## AIC: 32.86
##
## Number of Fisher Scoring iterations: 2
```

```r
vif(model2)
```

```
##          Noun     Category Noun:Category
##      2.001901     1.001466      2.000991
```

```r
sjp.int(model2,show.ci=T,jitter.ci = T)
```


Interaction effect of Noun and Category on Freq
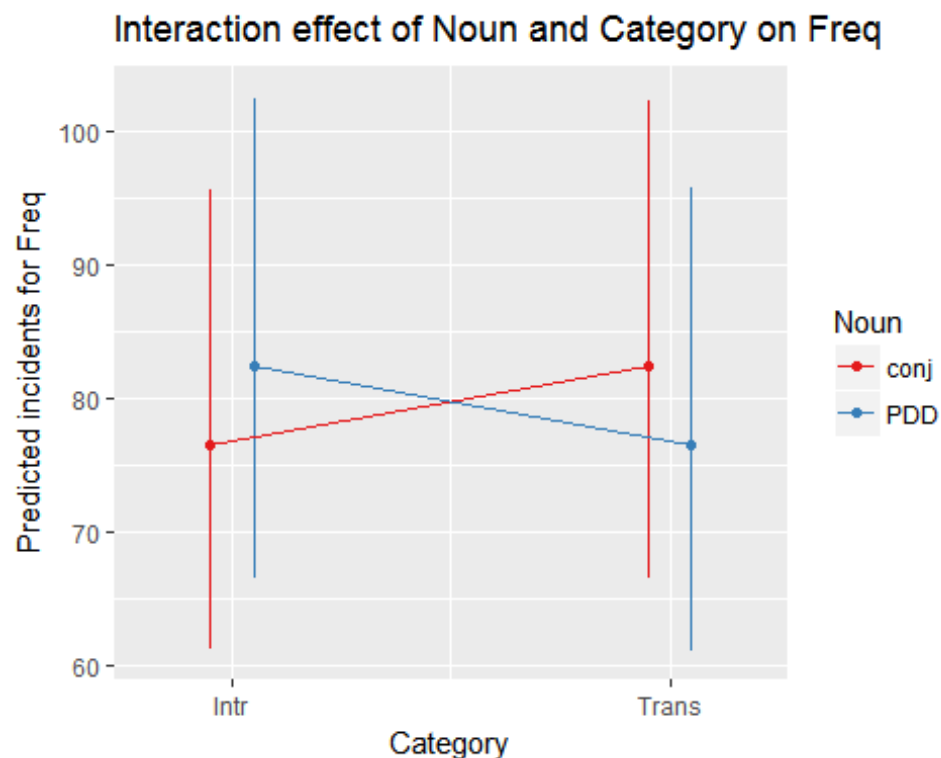
We can see that there is no interaction between the noun type and the category. Now, we reduce the terms by backward procedure.

```r
stepAIC(model2,direction = "backward")
```

```
## Start:  AIC=32.86
## Freq ~ Noun * Category
```

```
## 
##                   Df Deviance    AIC
## - Noun:Category  1  0.45296 31.313
## <none>              0.00000 32.860
## 
## Step:  AIC=31.31
## Freq ~ Noun + Category
## 
##             Df Deviance    AIC
## - Noun       1  0.45296 29.313
## - Category   1  0.45296 29.313
## <none>          0.45296 31.313
## 
## Step:  AIC=29.31
## Freq ~ Category
## 
##             Df Deviance    AIC
## - Category   1  0.45296 27.313
## <none>          0.45296 29.313
## 
## Step:  AIC=27.31
## Freq ~ 1
## 
## 
## Call:  glm(formula = Freq ~ 1, family = poisson, data = ot.NoError,
## 
##     offset = log(Obs))
## 
## Coefficients:
## (Intercept)
##     -0.6931
## 
## Degrees of Freedom: 3 Total (i.e. Null);  3 Residual
## Null Deviance:       0.453
## Residual Deviance: 0.453      AIC: 27.31
```

The result of model selection shows that neither factor explains the frequency differences, suggesting that the frequency is evenly distributed.

```r
model3<-stepAIC(model2,direction = "backward")
```

```
## Start:  AIC=32.86
## Freq ~ Noun * Category
## 
##                   Df Deviance    AIC
## - Noun:Category  1  0.45296 31.313
## <none>              0.00000 32.860
## 
## Step:  AIC=31.31
## Freq ~ Noun + Category
## 
##             Df Deviance    AIC
```

```
## - Noun       1   0.45296 29.313
## - Category   1   0.45296 29.313
## <none>           0.45296 31.313
##
## Step:  AIC=29.31
## Freq ~ Category
##
##              Df Deviance    AIC
## - Category   1   0.45296 27.313
## <none>           0.45296 29.313
##
## Step:  AIC=27.31
## Freq ~ 1
```

```
summary(model3)
```

```
##
## Call:
## glm(formula = Freq ~ 1, family = poisson, data = ot.NoError,
##     offset = log(Obs))
##
## Deviance Residuals:
##       1        2        3        4
## -0.3375   0.3333   0.3354  -0.3397
##
## Coefficients:
##             Estimate Std. Error z value Pr(>|z|)
## (Intercept) -0.69315    0.05608  -12.36   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for poisson family taken to be 1)
##
##     Null deviance: 0.45296  on 3  degrees of freedom
## Residual deviance: 0.45296  on 3  degrees of freedom
## AIC: 27.313
##
## Number of Fisher Scoring iterations: 3
```

Visualization of Odds Ratio

```
sjp.glm(model2)
```

76

Freq
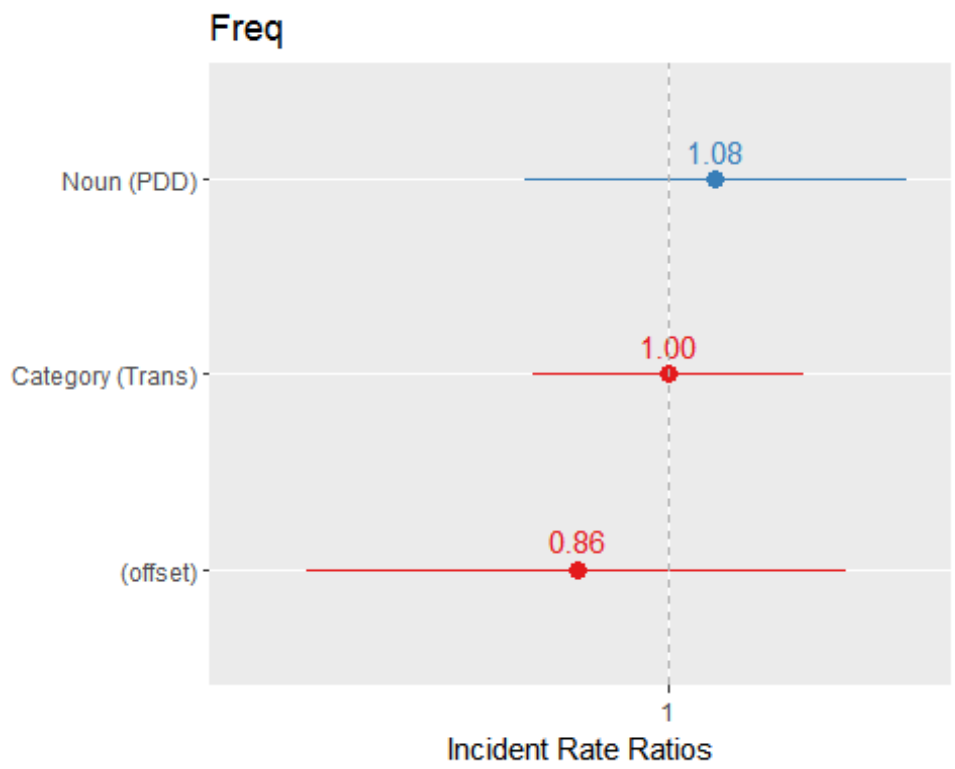
Supplementary Materials 2.

R code for the analysis of self-paced reading task.

Japanese EFL Learners' Online Sentence Processing

Authors

January 5, 2018

This document explains the GLMM analysis of Authors (2018) submitted to Applied Psycholinguistics.

Reading Time Analysis

Preparing required packages

```
#install.packages("lmer4")
#install.packages("effects")
#install.packages("dplyr")
#install.packages("sjplot")
library(lme4)
library(effects)
library(dplyr)
library(sjPlot)
library(lsmeans)
#useful code by Jaeger to calculate vif in glmer
source("https://raw.githubusercontent.com/aufrank/R-hacks/master/mer-utils.R")
```

Preparing data sets

```
first.noun<-read.csv("first-noun-28_20170109.csv",header=T) #the head noun before the target verb (the subject noun of hte main clause)
target.verb<-read.csv("target-verb-28_20170109.csv",header=T) #the target verb (the verb of the main clause)
aft.verb1<-read.csv("one-word-aft-verb-28_20170109.csv",header=T) #The following region of the target verb (One word after the target verb, which is either definite or indefinite article)
aft.verb2<-read.csv("two-words-aft-verb-28_20170109.csv",header=T) #The following region of the target verb (Two words after the target verb, which is the head noun of the object NP of the main verb)
```

Checking the data sets

```
head(first.noun)

##   condition item region  stimuli participant   rt        recip
 conj
## 1         a    3      8     chef           1  397 reciprocal conjoi
```

```
nedNP
## 2          a    5      8   student         1 1493 reciprocal conjoi
nedNP
## 3          a   13      8    editor         1  406 reciprocal conjoi
nedNP
## 4          a   18      8       man         1  438 reciprocal conjoi
nedNP
## 5          a   20      8 employer         1  270 reciprocal conjoi
nedNP
## 6          b    8      5      girl         1 1345 reciprocal
   PDD
##   TOEIC  c.TOEIC
## 1   805 45.89286
## 2   805 45.89286
## 3   805 45.89286
## 4   805 45.89286
## 5   805 45.89286
## 6   805 45.89286
```

str(first.noun)

```
## 'data.frame':    560 obs. of  10 variables:
##  $ condition  : Factor w/ 4 levels "a","b","c","d": 1 1 1 1 1 2 2 2
 2 2 ...
##  $ item       : int  3 5 13 18 20 8 9 10 11 16 ...
##  $ region     : int  8 8 8 8 8 5 5 5 5 5 ...
##  $ stimuli    : Factor w/ 18 levels "actor","baby",..: 4 16 6 11 8
9 12 17 10 2 ...
##  $ participant: int  1 1 1 1 1 1 1 1 1 1 ...
##  $ rt         : int  397 1493 406 438 270 1345 1459 382 1200 566
 ...
##  $ recip      : Factor w/ 2 levels "OT","reciprocal": 2 2 2 2 2 2 2
 2 2 2 ...
##  $ conj       : Factor w/ 2 levels "conjoinedNP",..: 1 1 1 1 1 2 2
2 2 2 ...
##  $ TOEIC      : int  805 805 805 805 805 805 805 805 805 805 ...
##  $ c.TOEIC    : num  45.9 45.9 45.9 45.9 45.9 ...
```

summary(first.noun)

```
##  condition      item            region        stimuli     participant

##  a:140    Min.   : 1.00   Min.   :5.0   man    : 56   Min.   : 1.0
0
##  b:140    1st Qu.: 5.75   1st Qu.:5.0   manager: 56   1st Qu.: 9.7
5
##  c:140    Median :10.50   Median :6.5   woman  : 56   Median :16.5
0
##  d:140    Mean   :10.53   Mean   :6.5   actor  : 28   Mean   :16.7
5
##           3rd Qu.:15.25   3rd Qu.:8.0   baby   : 28   3rd Qu.:24.2
5
```

```
##             Max.   :20.00   Max.   :8.0   boy    : 28   Max.   :32.0
0
##                                          (Other):308

##         rt               recip            conj        TOEIC

##  Min.   : 202.0   OT      :280   conjoinedNP:280   Min.   :600.0

##  1st Qu.: 374.8   reciprocal:280   PDD     :280   1st Qu.:800.0

##  Median : 521.5                                  Median :860.0

##  Mean   : 576.5                                  Mean   :850.9

##  3rd Qu.: 693.8                                  3rd Qu.:911.2

##  Max.   :2071.0                                  Max.   :990.0

##  NA's   :24

##     c.TOEIC
##  Min.   :-139.107
##  1st Qu.: -60.357
##  Median :  -9.107
##  Mean   :   0.000
##  3rd Qu.:  50.893
##  Max.   : 250.893
##
```

head(target.verb)

```
##   condition item region   stimuli participant   rt        recip
  conj
## 1         a    3      9    cooked           1   NA reciprocal conjo
inedNP
## 2         a    5      9      sang           1  851 reciprocal conjo
inedNP
## 3         a   13      9     heard           1  754 reciprocal conjo
inedNP
## 4         a   18      9      took           1  396 reciprocal conjo
inedNP
## 5         a   20      9    called           1   NA reciprocal conjo
inedNP
## 6         c    1      9 cancelled           1 2497         OT conjo
inedNP
##   TOEIC  c.TOEIC
## 1   805 45.89286
## 2   805 45.89286
## 3   805 45.89286
## 4   805 45.89286
```

```
## 5    805 45.89286
## 6    805 45.89286
```

str(target.verb)

```
## 'data.frame':    560 obs. of  10 variables:
##  $ condition  : Factor w/ 4 levels "a","b","c","d": 1 1 1 1 1 3 3 3
 3 3 ...
##  $ item       : int  3 5 13 18 20 1 4 7 14 17 ...
##  $ region     : int  9 9 9 9 9 9 9 9 9 9 ...
##  $ stimuli    : Factor w/ 16 levels "called","canceled",..: 4 13 7
15 1 3 5 15 1 14 ...
##  $ participant: int  1 1 1 1 1 1 1 1 1 1 ...
##  $ rt         : int  NA 851 754 396 NA 2497 368 2318 600 329 ...
##  $ recip      : Factor w/ 2 levels "OT","reciprocal": 2 2 2 2 2 1 1
 1 1 1 ...
##  $ conj       : Factor w/ 2 levels "conjoinedNP",..: 1 1 1 1 1 1 1
1 1 1 ...
##  $ TOEIC      : int  805 805 805 805 805 805 805 805 805 805 ...
##  $ c.TOEIC    : num  45.9 45.9 45.9 45.9 45.9 ...
```

summary(target.verb)

```
##   condition       item            region          stimuli      participa
nt
##   a:140     Min.   : 1.00   Min.   :6.0   played   : 84   Min.   :
1.00
##   b:140     1st Qu.: 5.75   1st Qu.:6.0   called   : 56   1st Qu.:
9.75
##   c:140     Median :10.50   Median :7.5   took     : 56   Median :1
6.50
##   d:140     Mean   :10.53   Mean   :7.5   heard    : 36   Mean   :1
6.75
##             3rd Qu.:15.25   3rd Qu.:9.0   canceled : 28   3rd Qu.:2
4.25
##             Max.   :20.00   Max.   :9.0   cancelled: 28   Max.   :3
2.00
##                                           (Other)  :272

##        rt             recip              conj          TOEIC

##   Min.   : 202.0   OT       :280   conjoinedNP:280   Min.   :600.0

##   1st Qu.: 406.0   reciprocal:280   PDD        :280   1st Qu.:800.0

##   Median : 564.0                                      Median :860.0

##   Mean   : 667.1                                      Mean   :850.9

##   3rd Qu.: 786.0                                      3rd Qu.:911.2

##   Max.   :2829.0                                      Max.   :990.0
```

81

```
##  NA's   :59

##      c.TOEIC
## Min.   :-139.107
## 1st Qu.: -60.357
## Median :  -9.107
## Mean   :   0.000
## 3rd Qu.:  50.893
## Max.   : 250.893
##
```

head(aft.verb1)

```
##   condition item region stimuli participant  rt      recip         c
onj
## 1         a    3     10     the           1 381 reciprocal conjoine
dNP
## 2         a    5     10     the           1 459 reciprocal conjoine
dNP
## 3         a   13     10     the           1 440 reciprocal conjoine
dNP
## 4         a   18     10     his           1 756 reciprocal conjoine
dNP
## 5         a   20     10     the           1 322 reciprocal conjoine
dNP
## 6         c    1     10     the           1 968         OT conjoine
dNP
##   TOEIC  c.TOEIC
## 1   805 45.89286
## 2   805 45.89286
## 3   805 45.89286
## 4   805 45.89286
## 5   805 45.89286
## 6   805 45.89286
```

str(aft.verb1)

```
## 'data.frame':    560 obs. of  10 variables:
##  $ condition  : Factor w/ 4 levels "a","b","c","d": 1 1 1 1 1 3 3 3
 3 3 ...
##  $ item       : int  3 5 13 18 20 1 4 7 14 17 ...
##  $ region     : int  10 10 10 10 10 10 10 10 10 10 ...
##  $ stimuli    : Factor w/ 2 levels "his","the": 2 2 2 1 2 2 2 2 2 2
 ...
##  $ participant: int  1 1 1 1 1 1 1 1 1 1 ...
##  $ rt         : int  381 459 440 756 322 968 775 1413 394 760 ...
##  $ recip      : Factor w/ 2 levels "OT","reciprocal": 2 2 2 2 2 1 1
 1 1 1 ...
##  $ conj       : Factor w/ 2 levels "conjoinedNP",..: 1 1 1 1 1 1 1
1 1 1 ...
```

```
## $ TOEIC     : int  805 805 805 805 805 805 805 805 805 805 ...
## $ c.TOEIC   : num  45.9 45.9 45.9 45.9 45.9 ...
```

summary(aft.verb1)

```
##  condition       item            region      stimuli    participant
##  a:140     Min.   : 1.00   Min.   : 7.0   his: 28   Min.   : 1.00
##  b:140     1st Qu.: 5.75   1st Qu.: 7.0   the:532   1st Qu.: 9.75
##  c:140     Median :10.50   Median : 8.5             Median :16.50
##  d:140     Mean   :10.53   Mean   : 8.5             Mean   :16.75
##            3rd Qu.:15.25   3rd Qu.:10.0             3rd Qu.:24.25
##            Max.   :20.00   Max.   :10.0             Max.   :32.00
##
##        rt                 recip              conj            TOEIC

##  Min.   : 233.0   OT        :280   conjoinedNP:280   Min.   :600.0

##  1st Qu.: 382.0   reciprocal:280   PDD        :280   1st Qu.:800.0

##  Median : 448.0                                      Median :860.0

##  Mean   : 541.3                                      Mean   :850.9

##  3rd Qu.: 585.0                                      3rd Qu.:911.2

##  Max.   :2520.0                                      Max.   :990.0

##  NA's   :13


##     c.TOEIC
##  Min.   :-139.107
##  1st Qu.: -60.357
##  Median :  -9.107
##  Mean   :   0.000
##  3rd Qu.:  50.893
##  Max.   : 250.893
##
```

head(aft.verb2)

```
##   condition item region stimuli participant  rt      recip          c
onj
## 1         a    3     11    dish           1 393 reciprocal conjoine
dNP
## 2         a    5     11    song           1 376 reciprocal conjoine
dNP
## 3         a   13     11    news           1 315 reciprocal conjoine
dNP
## 4         a   18     11   phone           1 467 reciprocal conjoine
dNP
## 5         a   20     11   chief           1 360 reciprocal conjoine
dNP
```

```
## 6         c    1    11    offer           1 809         OT conjoine
dNP
##   TOEIC  c.TOEIC
## 1   805 45.89286
## 2   805 45.89286
## 3   805 45.89286
## 4   805 45.89286
## 5   805 45.89286
## 6   805 45.89286
```

str(aft.verb2)

```
## 'data.frame':    560 obs. of  10 variables:
##  $ condition  : Factor w/ 4 levels "a","b","c","d": 1 1 1 1 1 3 3 3
 3 3 ...
##  $ item       : int  3 5 13 18 20 1 4 7 14 17 ...
##  $ region     : int  11 11 11 11 11 11 11 11 11 11 ...
##  $ stimuli    : Factor w/ 20 levels "argument","article",..: 5 19 1
2 14 4 13 18 15 11 10 ...
##  $ participant: int  1 1 1 1 1 1 1 1 1 1 ...
##  $ rt         : int  393 376 315 467 360 809 508 1083 2780 500 ...
##  $ recip      : Factor w/ 2 levels "OT","reciprocal": 2 2 2 2 2 1 1
 1 1 1 ...
##  $ conj       : Factor w/ 2 levels "conjoinedNP",..: 1 1 1 1 1 1 1 1
1 1 1 ...
##  $ TOEIC      : int  805 805 805 805 805 805 805 805 805 805 ...
##  $ c.TOEIC    : num  45.9 45.9 45.9 45.9 45.9 ...
```

summary(aft.verb2)

```
##  condition       item          region        stimuli       participa
nt
##  a:140    Min.   : 1.00   Min.   : 8.0   argument: 28   Min.   :
1.00
##  b:140    1st Qu.: 5.75   1st Qu.: 8.0   article : 28   1st Qu.:
9.75
##  c:140    Median :10.50   Median : 9.5   book    : 28   Median :1
6.50
##  d:140    Mean   :10.53   Mean   : 9.5   chief   : 28   Mean   :1
6.75
##           3rd Qu.:15.25   3rd Qu.:11.0   dish    : 28   3rd Qu.:2
4.25
##           Max.   :20.00   Max.   :11.0   dog     : 28   Max.   :3
2.00
##                                          (Other) :392


##       rt              recip             conj           TOEIC


##  Min.   : 200.0   OT        :280   conjoinedNP:280   Min.   :600.0


##  1st Qu.: 381.0   reciprocal:280   PDD        :280   1st Qu.:800.0
```

```
##  Median : 502.5                                      Median :860.0

##  Mean   : 572.8                                      Mean   :850.9

##  3rd Qu.: 672.0                                      3rd Qu.:911.2

##  Max.   :2780.0                                      Max.   :990.0

##  NA's   :28

##      c.TOEIC
##  Min.   :-139.107
##  1st Qu.: -60.357
##  Median :  -9.107
##  Mean   :   0.000
##  3rd Qu.:  50.893
##  Max.   : 250.893
##
```

Adding the word length

```
first.noun$Wlength<-nchar(as.character(first.noun$stimuli), type="char
s")
target.verb$Wlength<-nchar(as.character(target.verb$stimuli), type="ch
ars")
aft.verb1$Wlength<-nchar(as.character(aft.verb1$stimuli), type="chars
")
aft.verb2$Wlength<-nchar(as.character(aft.verb2$stimuli), type="chars
")
```

Scaling TOEIC score and centering word length

```
#TOEIC score
first.noun$s.TOEIC<-scale(first.noun$TOEIC)
target.verb$s.TOEIC<-scale(target.verb$TOEIC)
aft.verb1$s.TOEIC<-scale(aft.verb1$TOEIC)
aft.verb2$s.TOEIC<-scale(aft.verb2$TOEIC)

#Word length
first.noun$c.Wlength<-mean(first.noun$Wlength)-first.noun$Wlength
target.verb$c.Wlength<-mean(target.verb$Wlength)-target.verb$Wlength
aft.verb1$c.Wlength<-mean(aft.verb1$Wlength)-aft.verb1$Wlength
aft.verb2$c.Wlength<-mean(aft.verb2$Wlength)-aft.verb2$Wlength
```

Change coding

```
#First make all the variable factor
first.noun$recip<-as.factor(first.noun$recip)
target.verb$recip<-as.factor(target.verb$recip)
aft.verb1$recip<-as.factor(aft.verb1$recip)
aft.verb2$recip<-as.factor(aft.verb2$recip)
first.noun$conj<-as.factor(first.noun$conj)
target.verb$conj<-as.factor(target.verb$conj)
```

```
aft.verb1$conj<-as.factor(aft.verb1$conj)
aft.verb2$conj<-as.factor(aft.verb2$conj)

c<-contr.treatment(2)
my.coding<-matrix(rep(1/2,2),ncol=1)
my.simple<-c-my.coding
my.simple

##      2
## 1 -0.5
## 2  0.5

contrasts(first.noun$recip)<-my.simple
contrasts(first.noun$conj)<-my.simple
contrasts(target.verb$recip)<-my.simple
contrasts(target.verb$conj)<-my.simple
contrasts(aft.verb1$recip)<-my.simple
contrasts(aft.verb1$conj)<-my.simple
contrasts(aft.verb2$recip)<-my.simple
contrasts(aft.verb2$conj)<-my.simple
```

GLMM

Analysis 1 (The first noun)

Note that only converged models are presented here.

```
analysis1 <-list()
analysis1[[1]]<-glmer(rt ~ recip*conj+s.TOEIC+Wlength+(1+conj+recip+Wl
ength|participant)+(1+conj+s.TOEIC|item),data = first.noun,family = Ga
mma(link = "identity"),glmerControl(optimizer = "bobyqa",optCtrl = lis
t(maxfun=2e5)))
#summary(analysis1[[1]])
#vif.mer(analysis1[[1]])
#sjp.int(analysis1[[1]],show.ci = T)

analysis1[[2]]<-glmer(rt ~ recip*conj+s.TOEIC+Wlength+(1+conj+Wlength|
participant)+(1+recip+conj|item),data = first.noun,family = Gamma(link
 = "identity"),glmerControl(optimizer = "bobyqa",optCtrl = list(maxfun
=2e5)))
#summary(analysis1[[2]])
#vif.mer(analysis1[[2]])
#sjp.int(analysis1[[2]],show.ci = T)

analysis1[[3]]<-glmer(rt ~ recip*conj+s.TOEIC+Wlength+(1+conj+recip|pa
rticipant)+(1+conj|item),data = first.noun,family = Gamma(link = "iden
tity"),glmerControl(optimizer = "bobyqa",optCtrl = list(maxfun=2e5)))
#summary(analysis1[[3]])
#vif.mer(analysis1[[3]])
#sjp.int(analysis1[[3]],show.ci = T)

analysis1[[4]]<-glmer(rt ~ recip*conj+s.TOEIC+Wlength+(1+conj|particip
```

```
ant)+(1|item),data = first.noun,family = Gamma(link = "identity"),glme
rControl(optimizer = "bobyqa",optCtrl = list(maxfun=2e5)))
#summary(analysis1[[4]])
#vif.mer(analysis1[[4]])
#sjp.int(analysis1[[4]],show.ci = T)

analysis1[[5]]<-glmer(rt ~ recip*conj+s.TOEIC+Wlength+(1+recip|partici
pant)+(1|item),data = first.noun,family = Gamma(link = "identity"),glm
erControl(optimizer = "bobyqa",optCtrl = list(maxfun=2e5)))
#summary(analysis1[[5]])
#vif.mer(analysis1[[4]])
#sjp.int(analysis1[[4]],show.ci = T)

analysis1[[6]]<-glmer(rt ~ recip*conj+s.TOEIC+Wlength+(1|participant)+
(1|item),data = first.noun,family = Gamma(link = "identity"),glmerCont
rol(optimizer = "bobyqa",optCtrl = list(maxfun=2e5)))
#summary(analysis1[[5]])
#vif.mer(analysis1[[5]])
#sjp.int(fit1.first.noun,show.ci = T)
```

Model Comparison of the random effects

```
sapply(analysis1,AIC)%>% data.frame

##             .
## 1 7229.137
## 2 7225.682
## 3 7229.027
## 4 7230.229
## 5 7244.121
## 6 7242.728

sapply(analysis1,AIC)%>% which.min

## [1] 2
```

The model2 showed the lowest AIC. Thus, let us look at the results of the model4

Checking the results of analysis1

```
summary(analysis1[[4]])

## Generalized linear mixed model fit by maximum likelihood (Laplace
##   Approximation) [glmerMod]
##  Family: Gamma  ( identity )
## Formula:
## rt ~ recip * conj + s.TOEIC + Wlength + (1 + conj | participant) +

##    (1 | item)
##    Data: first.noun
## Control:
## glmerControl(optimizer = "bobyqa", optCtrl = list(maxfun = 2e+05))
##
##      AIC      BIC   logLik deviance df.resid
```

```
##    7230.2    7277.4   -3604.1    7208.2        525
##
## Scaled residuals:
##      Min       1Q   Median      3Q      Max
## -1.7284  -0.6127  -0.1735   0.3581   5.6057
##
## Random effects:
##  Groups       Name         Variance  Std.Dev. Corr
##  participant (Intercept) 9859.4974 99.2950
##              conj2        9244.9698 96.1508  0.22
##  item        (Intercept) 1448.3427 38.0571
##  Residual                   0.1639  0.4048
## Number of obs: 536, groups:  participant, 28; item, 20
##
## Fixed effects:
##               Estimate Std. Error t value Pr(>|z|)
## (Intercept)    498.888     24.834  20.089  < 2e-16 ***
## recip2           6.609     14.714   0.449 0.653333
## conj2           48.775     21.749   2.243 0.024922 *
## s.TOEIC        -15.372     25.980  -0.592 0.554055
## Wlength         18.445      5.437   3.393 0.000693 ***
## recip2:conj2   -54.808     23.131  -2.369 0.017813 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##             (Intr) recip2 conj2  s.TOEI Wlngth
## recip2       0.019
## conj2        0.139  0.001
## s.TOEIC     -0.060  0.088  0.061
## Wlength     -0.458  0.021  0.027  0.048
## recip2:cnj2 -0.005  0.040  0.022 -0.007 -0.001
```
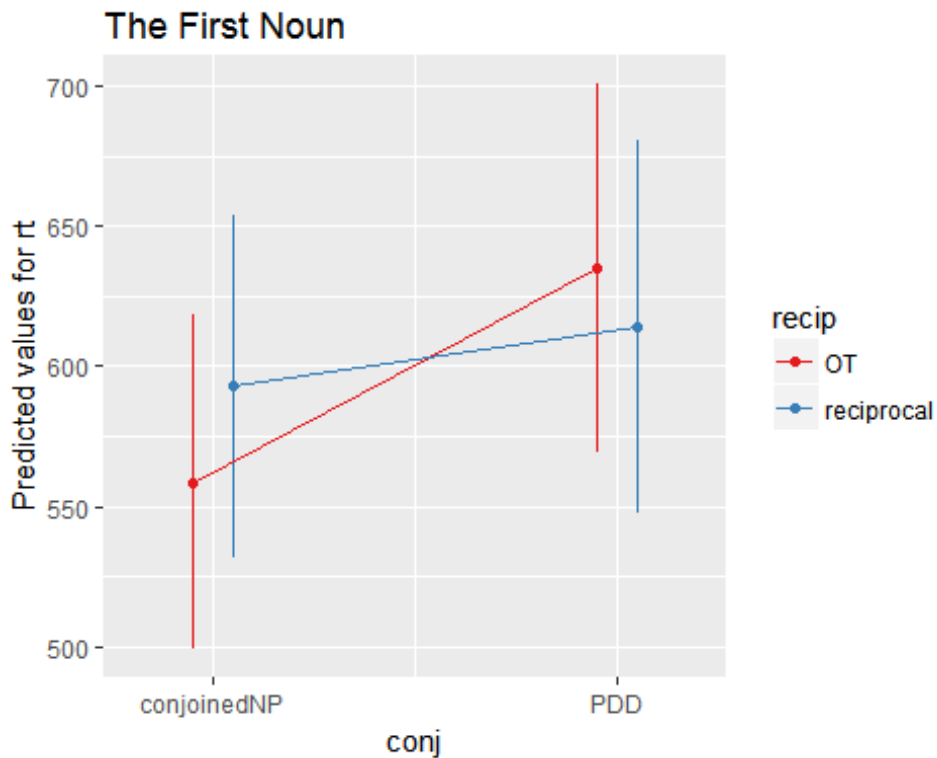
vif.mer(analysis1[[4]]) *#Checking vif for multicollinearity*

```
##      recip2        conj2      s.TOEIC      Wlength recip2:conj2
##    1.009863     1.004917     1.013816     1.003116     1.002283
```

sjp.int(analysis1[[4]],show.ci = T,jitter.ci = T, title = "The First N
oun")

The First Noun

 We can see that there is an interaction between the type of noun and the type of verb; therefore, we move on to the test of simple main effects to see the RT differences in more detail.

Simple main effects

```
lsmeans::lsmeans(analysis1[[4]],pairwise~conj|recip) #simple main effe
ct of noun type

## $lsmeans
## recip = OT:
##  conj         lsmean       SE df asymp.LCL asymp.UCL
##  conjoinedNP 558.7840 30.30428 NA  499.3887  618.1793
##  PDD         634.9631 33.36675 NA  569.5655  700.3607
##
## recip = reciprocal:
##  conj         lsmean       SE df asymp.LCL asymp.UCL
##  conjoinedNP 592.7966 30.97375 NA  532.0892  653.5040
##  PDD         614.1680 33.88136 NA  547.7618  680.5743
##
## Results are given on the identity (not the response) scale.
## Confidence level used: 0.95
##
## $contrasts
## recip = OT:
##  contrast           estimate       SE df z.ratio p.value
##  conjoinedNP - PDD -76.17908 24.40314 NA  -3.122  0.0018
##
## recip = reciprocal:
```

```
##  contrast              estimate        SE df z.ratio p.value
##  conjoinedNP - PDD -21.37141 24.86104 NA  -0.860  0.3900
```

```
lsmeans::lsmeans(analysis1[[4]],pairwise~recip|conj) #simple main effe
ct of verb type
```

```
## $lsmeans
## conj = conjoinedNP:
##  recip           lsmean        SE df asymp.LCL asymp.UCL
##  OT           558.7840 30.30428 NA   499.3887   618.1793
##  reciprocal 592.7966 30.97375 NA   532.0892   653.5040
##
## conj = PDD:
##  recip           lsmean        SE df asymp.LCL asymp.UCL
##  OT           634.9631 33.36675 NA   569.5655   700.3607
##  reciprocal 614.1680 33.88136 NA   547.7618   680.5743
##
## Results are given on the identity (not the response) scale.
## Confidence level used: 0.95
##
## $contrasts
## conj = conjoinedNP:
##  contrast           estimate        SE df z.ratio p.value
##  OT - reciprocal -34.01257 18.34401 NA  -1.854  0.0637
##
## conj = PDD:
##  contrast           estimate        SE df z.ratio p.value
##  OT - reciprocal  20.79510 19.07959 NA   1.090  0.2758
```

Analysis 2 (The target verb)

Note that only converged models are presented here.

```
analysis2 <-list()
analysis2[[1]]<-glmer(rt ~ recip*conj+s.TOEIC+Wlength+(1+conj+Wlength+
s.TOEIC|participant)+(1+conj|item),data = target.verb,family = Gamma(l
ink = "identity"),glmerControl(optimizer = "bobyqa",optCtrl = list(max
fun=2e5)))
#summary(analysis2[[1]])
#vif.mer(analysis2[[1]])
#sjp.int(analysis2[[1]],show.ci = T)

analysis2[[2]]<-glmer(rt ~ recip*conj+s.TOEIC+Wlength+(1+recip+conj+s.
TOEIC|participant)+(1+s.TOEIC|item),data = target.verb,family = Gamma
(link = "identity"),glmerControl(optimizer = "bobyqa",optCtrl = list(m
axfun=2e5)))
#summary(analysis2[[2]])
#vif.mer(analysis2[[2]])
#sjp.int(analysis2[[2]],show.ci = T)
```

```
analysis2[[3]]<-glmer(rt ~ recip*conj+s.TOEIC+Wlength+(1+recip+conj|pa
rticipant)+(1+recip+conj|item),data = target.verb,family = Gamma(link
= "identity"),glmerControl(optimizer = "bobyqa",optCtrl = list(maxfun=
2e5)))
#summary(analysis2[[3]])
#vif.mer(analysis2[[3]])
#sjp.int(analysis2[[3]],show.ci = T)

analysis2[[4]]<-glmer(rt ~ recip*conj+s.TOEIC+Wlength+(1+conj|particip
ant)+(1+conj|item),data = target.verb,family = Gamma(link = "identity
"),glmerControl(optimizer = "bobyqa",optCtrl = list(maxfun=2e5)))
#summary(analysis2[[4]])
#vif.mer(analysis2[[4]])
#sjp.int(analysis2[[4]],show.ci = T)

analysis2[[5]]<-glmer(rt ~ recip*conj+s.TOEIC+Wlength+(1+conj|particip
ant)+(1|item),data = target.verb,family = Gamma(link = "identity"),glm
erControl(optimizer = "bobyqa",optCtrl = list(maxfun=2e5)))
#summary(analysis2[[5]])
#vif.mer(analysis2[[5]])
#sjp.int(analysis2[[5]],show.ci = T)

analysis2[[6]]<-glmer(rt ~ recip*conj+s.TOEIC+Wlength+(1|participant)+
(1|item),data = target.verb,family = Gamma(link = "identity"),glmerCon
trol(optimizer = "bobyqa",optCtrl = list(maxfun=2e5)))
#summary(analysis2[[6]])
#vif.mer(analysis2[[5]])
#sjp.int(analysis2[[5]],show.ci = T)
```

Model Comparison of the random effects

```
sapply(analysis2,AIC)%>% data.frame

##             .
## 1 6935.350
## 2 6945.613
## 3 6947.110
## 4 6938.030
## 5 6934.074
## 6 6934.137

sapply(analysis2,AIC)%>% which.min

## [1] 5
```

Model5 and Model6 showed similar AIC; therefore, let us check BIC.

```
sapply(analysis2,BIC)%>% data.frame

##             .
## 1 7019.682
## 2 7029.945
## 3 7027.226
## 4 6992.846
```

```
## 5 6980.456
## 6 6972.086
```

```
sapply(analysis2,BIC)%>% which.min
```

```
## [1] 6
```

The model6 shows the lowest BIC. Thus, let us look at the results of the model6

Checking the results of analysis2
```
summary(analysis2[[6]])
```

```
## Generalized linear mixed model fit by maximum likelihood (Laplace
##    Approximation) [glmerMod]
##  Family: Gamma  ( identity )
## Formula: rt ~ recip * conj + s.TOEIC + Wlength + (1 | participant)
+ (1 |
##     item)
##    Data: target.verb
## Control:
## glmerControl(optimizer = "bobyqa", optCtrl = list(maxfun = 2e+05))
##
##      AIC      BIC   logLik deviance df.resid
##   6934.1   6972.1  -3458.1   6916.1      492
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -1.6299 -0.6105 -0.1609  0.3911  5.0803
##
## Random effects:
##  Groups      Name        Variance  Std.Dev.
##  participant (Intercept) 2.026e+04 142.3501
##  item        (Intercept) 1.165e+03  34.1282
##  Residual                1.837e-01   0.4286
## Number of obs: 501, groups:  participant, 28; item, 20
##
## Fixed effects:
##              Estimate Std. Error t value Pr(>|z|)
## (Intercept)   482.378     36.029  13.389  < 2e-16 ***
## recip2        -33.173     16.187  -2.049  0.04042 *
## conj2          55.359     17.170   3.224  0.00126 **
## s.TOEIC       -35.876     24.417  -1.469  0.14175
## Wlength        37.785      6.775   5.577 2.44e-08 ***
## recip2:conj2  -14.170     27.809  -0.510  0.61036
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##          (Intr) recip2 conj2  s.TOEI Wlngth
## recip2   -0.040
## conj2    -0.051 -0.013
## s.TOEIC   0.020  0.018 -0.002
```

```
## Wlength      -0.447  0.017  0.010  0.010
## recip2:cnj2  0.125  0.028 -0.040 -0.085 -0.099
```

```
vif.mer(analysis2[[6]]) #Checking vif for multicollinearity
```

```
##       recip2        conj2      s.TOEIC       Wlength recip2:conj2
##     1.001770     1.001794     1.007725     1.010396     1.019776
```

```
sjp.int(analysis2[[6]],show.ci = T,jitter.ci = T, title = "Target Verb
  Region")
```
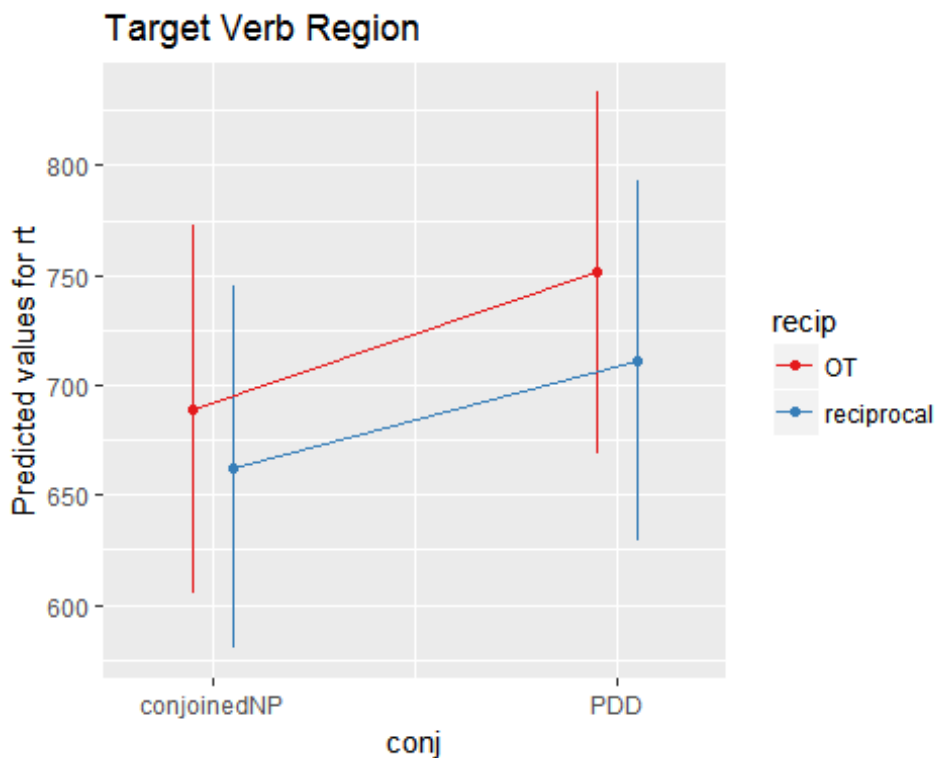

We can see that there are main effects of the type of noun and the type of verb.

Analysis 3 (One word after the target verb)

Note that only converged models are presented here. Here, we don't need to include word length as a covariate because all the word lengths are equal.

```
analysis3 <-list()
analysis3[[1]]<-glmer(rt ~ recip*conj+s.TOEIC+(1+recip+conj+s.TOEIC|pa
rticipant)+(1+recip+conj+s.TOEIC|item),data = aft.verb1,family = Gamma
(link = "identity"),glmerControl(optimizer = "bobyqa",optCtrl = list(m
axfun=2e5)))
#summary(analysis3[[1]])
#vif.mer(analysis3[[1]])
#sjp.int(analysis3[[1]],show.ci = T)

analysis3[[2]]<-glmer(rt ~ recip*conj+s.TOEIC+(1+recip+conj+s.TOEIC|pa
```

```
rticipant)+(1+recip+conj|item),data = aft.verb1,family = Gamma(link =
"identity"),glmerControl(optimizer = "bobyqa",optCtrl = list(maxfun=2e
5)))
#summary(analysis3[[2]])
#vif.mer(analysis3[[2]])
#sjp.int(analysis3[[2]],show.ci = T)

analysis3[[3]]<-glmer(rt ~ recip*conj+s.TOEIC+(1+recip+conj|participan
t)+(1+recip+conj|item),data = aft.verb1,family = Gamma(link = "identit
y"),glmerControl(optimizer = "bobyqa",optCtrl = list(maxfun=2e5)))
#summary(analysis3[[3]])
#vif.mer(analysis3[[3]])
#sjp.int(analysis3[[3]],show.ci = T)

analysis3[[4]]<-glmer(rt ~ recip*conj+s.TOEIC+(1+recip+conj|participan
t)+(1|item),data = aft.verb1,family = Gamma(link = "identity"),glmerCo
ntrol(optimizer = "bobyqa",optCtrl = list(maxfun=2e5)))
#summary(analysis3[[4]])
#vif.mer(analysis3[[4]])
#sjp.int(analysis3[[4]],show.ci = T)

analysis3[[5]]<-glmer(rt ~ recip*conj+s.TOEIC+(1+recip|participant)+(1
|item),data = aft.verb1,family = Gamma(link = "identity"),glmerControl
(optimizer = "bobyqa",optCtrl = list(maxfun=2e5)))
#summary(analysis3[[5]])
#vif.mer(analysis3[[5]])
#sjp.int(analysis3[[5]],show.ci = T)

analysis3[[6]]<-glmer(rt ~ recip*conj+s.TOEIC+(1|participant)+(1|ite
m),data = aft.verb1,family = Gamma(link = "identity"),glmerControl(opt
imizer = "bobyqa",optCtrl = list(maxfun=2e5)))
#summary(analysis3[[6]])
#vif.mer(analysis3[[6]])
#sjp.int(analysis3[[6]],show.ci = T)
```

Model Comparison of the random effects

```
sapply(analysis3,AIC)%>% data.frame

##            .
## 1 7259.965
## 2 7255.048
## 3 7248.273
## 4 7245.063
## 5 7252.035
## 6 7263.054

sapply(analysis3,AIC)%>% which.min

## [1] 4
```

The model4 shows the lowest AIC. Thus, let us look at the results of the model4

Checking the results of analysis3
```
summary(analysis3[[4]])

## Generalized linear mixed model fit by maximum likelihood (Laplace
##    Approximation) [glmerMod]
##   Family: Gamma  ( identity )
## Formula: rt ~ recip * conj + s.TOEIC + (1 + recip + conj | particip
ant) +
##      (1 | item)
##    Data: aft.verb1
## Control:
## glmerControl(optimizer = "bobyqa", optCtrl = list(maxfun = 2e+05))
##
##      AIC      BIC   logLik deviance df.resid
##   7245.1   7301.0  -3609.5   7219.1      534
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -1.4703 -0.5621 -0.2297  0.2429  5.2294
##
## Random effects:
##  Groups      Name        Variance  Std.Dev. Corr
##  participant (Intercept) 9455.7327 97.2406
##              recip2       6523.6131 80.7689  -0.53
##              conj2        7884.6199 88.7954   0.28  0.10
##  item        (Intercept)  373.1694 19.3176
##  Residual                   0.1539  0.3923
## Number of obs: 547, groups:  participant, 28; item, 20
##
## Fixed effects:
##             Estimate Std. Error t value Pr(>|z|)
## (Intercept)  560.512     40.600  13.806   <2e-16 ***
## recip2       -57.874     26.830  -2.157    0.031 *
## conj2         40.381     32.719   1.234    0.217
## s.TOEIC       -1.629     20.387  -0.080    0.936
## recip2:conj2  21.785     26.528   0.821    0.412
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##             (Intr) recip2 conj2  s.TOEI
## recip2      -0.631
## conj2        0.340 -0.130
## s.TOEIC      0.030 -0.052 -0.068
## recip2:cnj2 -0.018  0.044 -0.237 -0.050

vif.mer(analysis3[[4]]) #Checking vif for multicollinearity

##      recip2        conj2      s.TOEIC recip2:conj2
##    1.021007     1.084435     1.012960     1.064667

sjp.int(analysis3[[4]],show.ci = T,jitter.ci = T)
```

Interaction effect of recip and conj on rt
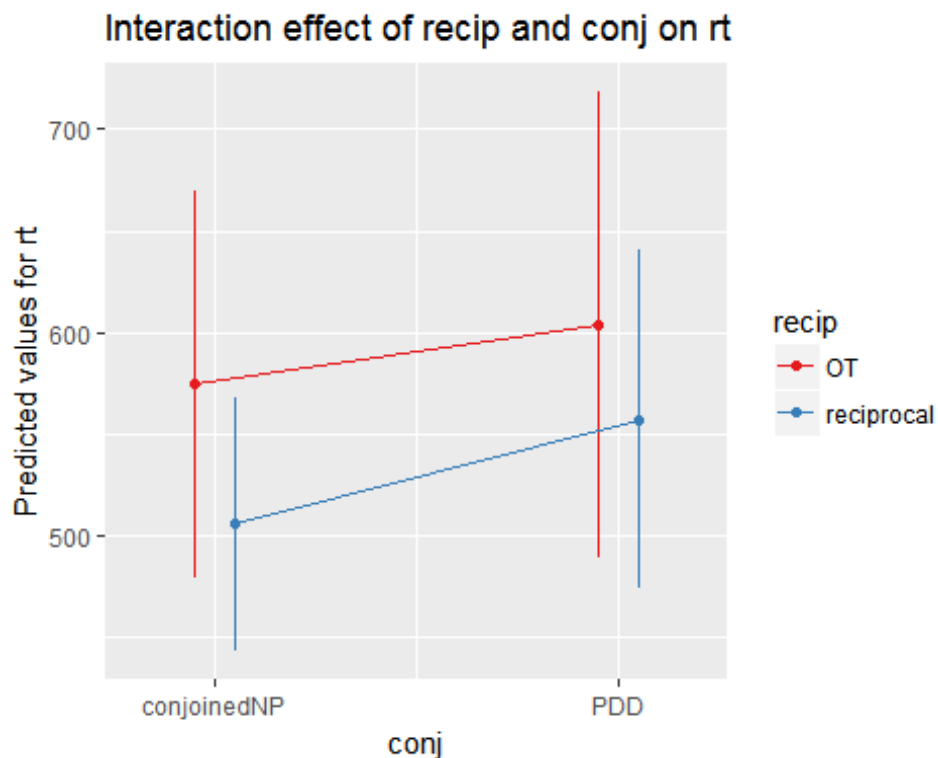
We can see that there is a main effect of the type of verb.

Analysis 4 (Two words after the target verb)

Note that only converged models are presented here.

```
analysis4 <-list()
analysis4[[1]]<-glmer(rt ~ recip*conj+s.TOEIC+Wlength+(1+conj+recip+s.
TOEIC|participant)+(1+s.TOEIC+recip|item),data = aft.verb2,family = Ga
mma(link = "identity"),glmerControl(optimizer = "bobyqa",optCtrl = lis
t(maxfun=2e5)))
#summary(analysis4[[1]])
#vif.mer(analysis4[[1]])
#sjp.int(analysis4[[1]],show.ci = T)

analysis4[[2]]<-glmer(rt ~ recip*conj+s.TOEIC+Wlength+(1+recip+s.TOEIC
+Wlength|participant)+(1+recip|item),data = aft.verb2,family = Gamma(l
ink = "identity"),glmerControl(optimizer = "bobyqa",optCtrl = list(max
fun=2e5)))
#summary(analysis4[[2]])
#vif.mer(analysis4[[2]])
#sjp.int(analysis4[[2]],show.ci = T)

analysis4[[3]]<-glmer(rt ~ recip*conj+s.TOEIC+Wlength+(1+recip+conj|pa
rticipant)+(1+conj|item),data = aft.verb2,family = Gamma(link = "ident
ity"),glmerControl(optimizer = "bobyqa",optCtrl = list(maxfun=2e5)))
#summary(analysis4[[3]])
```

```
#vif.mer(analysis4[[3]])
#sjp.int(analysis4[[3]],show.ci = T)

analysis4[[4]]<-glmer(rt ~ recip*conj+s.TOEIC+c.Wlength+(1+recip+conj|
participant)+(1+recip|item),data = aft.verb2,family = Gamma(link = "id
entity"),glmerControl(optimizer = "bobyqa",optCtrl = list(maxfun=2e
5)))
#summary(analysis4[[4]])
#vif.mer(analysis4[[4]])
#sjp.int(analysis4[[4]],show.ci = T)

analysis4[[5]]<-glmer(rt ~ recip*conj+s.TOEIC+c.Wlength+(1+conj|partic
ipant)+(1|item),data = aft.verb2,family = Gamma(link = "identity"),glm
erControl(optimizer = "bobyqa",optCtrl = list(maxfun=2e5)))
#summary(analysis4[[5]])
#vif.mer(analysis4[[5]])
#sjp.int(analysis4[[5]],show.ci = T)

analysis4[[6]]<-glmer(rt ~ recip*conj+s.TOEIC+c.Wlength+(1+recip|parti
cipant)+(1|item),data = aft.verb2,family = Gamma(link = "identity"),gl
merControl(optimizer = "bobyqa",optCtrl = list(maxfun=2e5)))
#summary(analysis4[[5]])
#vif.mer(analysis4[[5]])
#sjp.int(analysis4[[5]],show.ci = T)

analysis4[[7]]<-glmer(rt ~ recip*conj+s.TOEIC+c.Wlength+(1|participan
t)+(1|item),data = aft.verb2,family = Gamma(link = "identity"),glmerCo
ntrol(optimizer = "bobyqa",optCtrl = list(maxfun=2e5)))
#summary(analysis4[[6]])
#vif.mer(analysis4[[6]])
#sjp.int(analysis4[[6]],show.ci = T)
```

Model Comparison of the random effects

```
sapply(analysis4,AIC)%>% data.frame

##              .
## 1 7083.393
## 2 7068.016
## 3 7076.139
## 4 7076.632
## 5 7080.466
## 6 7078.103
## 7 7079.770

sapply(analysis4,AIC)%>% which.min

## [1] 2
```

The model2 shows the lowest AIC. Thus, let us look at the results of the model4

## Checking the results of analysis4

```
summary(analysis4[[2]])
```

97

```
## Generalized linear mixed model fit by maximum likelihood (Laplace
##   Approximation) [glmerMod]
##  Family: Gamma  ( identity )
## Formula: rt ~ recip * conj + s.TOEIC + Wlength + (1 + recip + s.TOE
IC +
##     Wlength | participant) + (1 + recip | item)
##    Data: aft.verb2
## Control:
## glmerControl(optimizer = "bobyqa", optCtrl = list(maxfun = 2e+05))
##
##      AIC      BIC   logLik deviance df.resid
##   7068.0   7153.5  -3514.0   7028.0      512
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -1.5961 -0.5359 -0.1274  0.3361  7.9537
##
## Random effects:
##  Groups      Name        Variance  Std.Dev. Corr
##  participant (Intercept) 5236.3565 72.3627
##              recip2      5972.3391 77.2809   0.54
##              s.TOEIC      339.0369 18.4130  -0.27 -0.68
##              Wlength      428.3996 20.6978  -0.45 -0.41 -0.38
##  item        (Intercept)  718.4374 26.8037
##              recip2      1576.1839 39.7012  0.10
##  Residual                   0.1405  0.3748
## Number of obs: 532, groups:  participant, 28; item, 20
##
## Fixed effects:
##              Estimate Std. Error t value Pr(>|z|)
## (Intercept)  308.076     25.564  12.051  < 2e-16 ***
## recip2       -31.740     21.941  -1.447   0.1480
## conj2         15.511     12.949   1.198   0.2310
## s.TOEIC        7.704     19.633   0.392   0.6948
## Wlength       49.483      7.456   6.637  3.2e-11 ***
## recip2:conj2  36.398     19.286   1.887   0.0591 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##            (Intr) recip2 conj2  s.TOEI Wlngth
## recip2      0.144
## conj2       0.025  0.003
## s.TOEIC    -0.047 -0.068  0.009
## Wlength    -0.419 -0.161 -0.014 -0.065
## recip2:cnj2 0.075  0.022  0.034  0.017 -0.031
```

```r
vif.mer(analysis4[[2]]) #Checking vif for multicollinearity
```

```
##      recip2        conj2      s.TOEIC       Wlength recip2:conj2
##    1.033407     1.001400     1.010943     1.033453     1.002709
```

```
sjp.int(analysis4[[2]],show.ci = T,jitter.ci = T,geom.colors = c("blac
k","grey"),title = "")
```
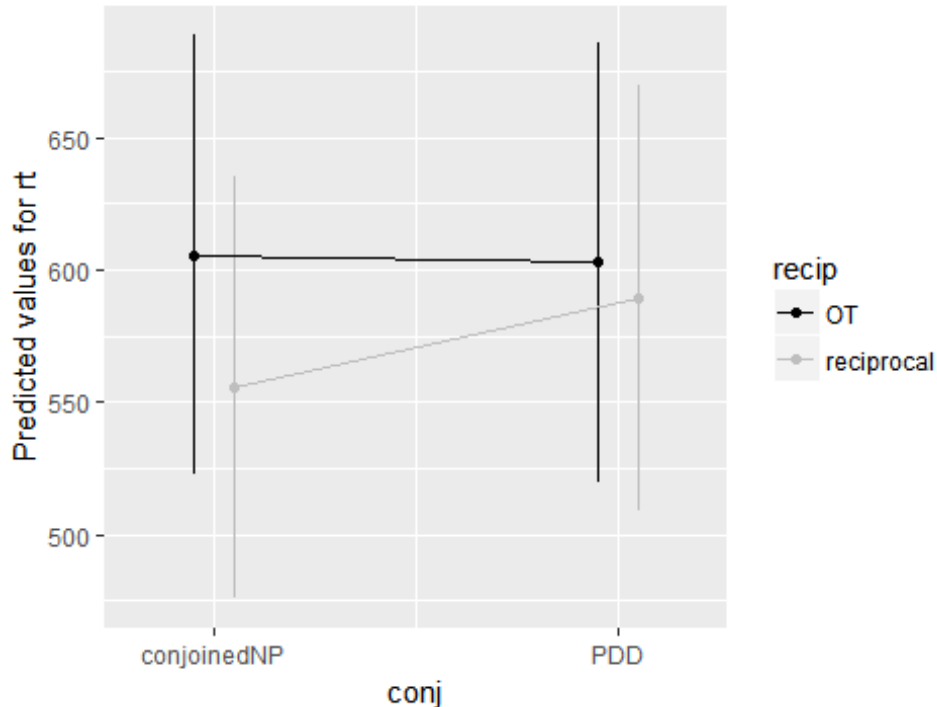

 We can see that there is a tendency toward an interaction between the type of noun and the type of verb; therefore, we move on to the test of simple main effects to see the RT differences in more detail.

Simple main effects
```
lsmeans::lsmeans(analysis4[[2]],pairwise~conj|recip) #simple main effe
ct of noun type

## $lsmeans
## recip = OT:
##  conj          lsmean       SE df asymp.LCL asymp.UCL
##  conjoinedNP 605.5126 42.27044 NA  522.6640  688.3611
##  PDD         602.8246 42.19938 NA  520.1153  685.5338
##
## recip = reciprocal:
##  conj          lsmean       SE df asymp.LCL asymp.UCL
##  conjoinedNP 555.5736 40.52824 NA  476.1398  635.0075
##  PDD         589.2837 40.76163 NA  509.3924  669.1751
##
## Results are given on the identity (not the response) scale.
## Confidence level used: 0.95
##
## $contrasts
## recip = OT:
##  contrast           estimate       SE df z.ratio p.value
##  conjoinedNP - PDD    2.6880 15.87654 NA   0.169  0.8656
```

```
## 
## recip = reciprocal:
##  contrast         estimate       SE df z.ratio p.value
##  conjoinedNP - PDD -33.7101 16.40888 NA  -2.054  0.0399

lsmeans::lsmeans(analysis4[[2]],pairwise~recip|conj) #simple main effe
ct of verb type

## $lsmeans
## conj = conjoinedNP:
##  recip          lsmean        SE df asymp.LCL asymp.UCL
##  OT          605.5126 42.27044 NA   522.6640  688.3611
##  reciprocal 555.5736 40.52824 NA   476.1398  635.0075
## 
## conj = PDD:
##  recip          lsmean        SE df asymp.LCL asymp.UCL
##  OT          602.8246 42.19938 NA   520.1153  685.5338
##  reciprocal 589.2837 40.76163 NA   509.3924  669.1751
## 
## Results are given on the identity (not the response) scale.
## Confidence level used: 0.95
## 
## $contrasts
## conj = conjoinedNP:
##  contrast         estimate       SE df z.ratio p.value
##  OT - reciprocal 49.93891 23.76805 NA   2.101  0.0356
## 
## conj = PDD:
##  contrast         estimate       SE df z.ratio p.value
##  OT - reciprocal 13.54081 24.16358 NA   0.560  0.5752
```