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Online processing of subject-initial non-canonical sentences: Interaction of syntax with information structure

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Many languages allow flexible word orders, and how humans parse and comprehend them has been one of the central questions in psycholinguistics. Mounting evidence has suggested that not only syntactic factors (e.g., the formation of a filler–gap dependency) but also discourse-related factors (e.g., the discourse status of phrases) influence the processing of non-canonical word orders. However, far too little attention has been paid to *subject-initial* non-canonical word orders, leaving it unclear how these two factors interact during the processing of such structures. Given this background, we conducted two self-paced reading experiments in Japanese, focusing on inchoative constructions involving a theme subject and a causer adjunct. Experiment 1 showed that the pre-verbal phrase was read more quickly in causer–theme sentences than in theme–causer sentences. We attributed this processing asymmetry to a filler–gap dependency between the sentence-initial theme subject and its original position in the theme–causer sentences. Experiment 2 revealed that this reading-time difference diminished but did not entirely disappear under the condition that a phrase marked as discourse-given appeared first. This pattern aligns well with previous findings concerning the processing of object-initial non-canonical word orders. Taken together, we conclude that syntactic and discourse factors interact in the processing of subject-initial non-canonical sentences, just as they do in the processing of object-initial ones. This study also proposes what we call a *sentence-pair* method for the examination of the phrase-by-phrase processing of mono-clausal, structurally simple sentences. Thus, this paper makes not only empirical and theoretical contributions but also a methodological contribution to psycholinguistics.

1 Introduction: Flexible word orders and sentence processing

1.1 Processing of sentences with non-canonical word order

Many languages permit flexible word orders. For instance, Japanese transitive sentences may have either Subject-Object-Verb (SOV) or Object-Subject-Verb (OSV) word orders to express the event of Hanako eating pizza, as illustrated by (1). The SOV word order is canonical while the OSV word order is non-canonical, derived by scrambling the object over the subject (Hoji, 1985; Saito, 1985). Scrambling is a type of optional movement of a constituent (Ross, 1967). It is semantically vacuous, in the sense that the basic sentence and its scrambled counterpart are truth-conditionally equivalent.

(1) a. SOV:
Hanako-ga piza-o tabe-ta.
Hanako-NOM pizza-ACC eat-PST

b. OSV:
Piza-o Hanako-ga tabe-ta.
pizza-ACC Hanako-NOM eat-PST
'Hanako ate pizza.'

An important question in the field of psycholinguistics is how humans parse and comprehend sentences with alternative word orders, such as SOV and OSV sentences in Japanese. Numerous sentence processing studies have tackled this question, suggesting that non-canonical sentences incur a higher processing load than their canonical counterparts across different languages (e.g., Bader & Meng, 1999, 2023; Erdocia et al., 2009; Frazier & d'Arcais, 1989; Jeong et al., 2025; Kim et al., 2009; Koizumi et al., 2014; Mazuka, 2002; Miyamoto & Takahashi, 2002b; Ono et al., 2020; Rösler et al., 1998; Tamaoka et al., 2005, 2024; Weyerts et al., 2002). The observed processing asymmetry follows from the assumption that, all other things being equal, syntactically complex sentences are harder to process than their simple counterparts (e.g., Gibson, 1998; Hawkins, 2004; Koizumi, 2023; Marantz, 2005; Pritchett & Whitman, 1995). More concretely, an optional movement like scrambling introduces an additional filler–gap dependency between a moved phrase (i.e., filler) and its original position (i.e., gap); hence, non-canonical sentences are syntactically more complex and, accordingly, computationally more costly to represent than their canonical counterparts.

Other than syntactic complexity, several factors have been identified and investigated that impact the processing of flexible word order sentences (Kaiser & Trueswell, 2004; Koizumi, 2023; Miyamoto & Takahashi, 2002b; Tamaoka et al., 2005). One such factor to be investigated in the current study is *information structure*: how new information and old information are ordered in a sentence.[1] Many studies have examined the interaction between syntax and information structure

[1] This definition of information structure is far from comprehensive. One of the other possible definitions is how topic and focus are ordered in a clause. The definition provided in the main text suffices for this study.

in the processing of flexible word order sentences (e.g., Bader & Meng, 2023; Jeong et al., 2025; Kahraman & Hirose, 2018; Kaiser & Trueswell, 2004; Koizumi & Imamura, 2017; Miyamoto et al., 2014; Slioussar, 2011; Yano & Koizumi, 2018, 2021; Yano et al., 2019). Although their details are different, these studies adopt the view that a non-canonical sentence is a marked option, and its use is associated with a discourse requirement that old information comes before new information in a sentence (Aissen, 1992; Birner & Ward, 2009; Kuno, 1978, 1995). For instance, Kaiser and Trueswell (2004) hypothesized that non-canonical sentences would become easier to process when they had a given–new order. Consistent with this hypothesis, their self-paced reading experiment revealed that an appropriate context alleviated the processing asymmetry between non-canonical OVS sentences and canonical SVO sentences in Finnish. Specifically, they found a significant interaction at the second NP (*jänistä* in (3a) vs. *hiiri* in (3b)) such that the reading time was longer in OVS sentences than in SVO sentences only when the first phrase was not introduced in the preceding context (2).

(2) Context sentences:
Lotta etsi eilen sieniä metsässä. Hän huomasi heinikossa
Lotta looked.for yesterday mushrooms forest.in s/he.NOM noticed grass.in
{hiiren/jäniksen} joka liikkui varovasti eteenpäin.
{mouse-ACC/hare-ACC} that was.moving carefully forward
'Lotta looked for mushrooms in the forest yesterday. She noticed {a hare /a mouse} moving forward carefully in the grass.'

(3) Target sentence:
a. SVO:
Hiiri seurasi jänistä ja linnut lauloivat.
mouse-NOM followed hare-PART and birds were.singing
b. OVS:
Jänistä seurasi hiiri ja linnut lauloivat.
hare-PART followed mouse-NOM and birds were.singing.
'The mouse followed the hare and birds were singing.'

The findings from the other studies cited above are largely consistent with those from Kaiser and Trueswell (2004). These previous results underscore the point that the putative processing cost associated with non-canonical sentences stems not only from syntax but also from information structure.

It is important to note that previous studies have seldom found evidence that contextual support completely eliminates or overrides the processing asymmetry between canonical and non-canonical sentences (cf. Funasaki & Yano, 2025). This indicates that information structure is not the sole factor determining the processing difference under consideration.

1.2 Processing of *subject-initial* non-canonical sentences

Although most of the previous research examined the processing of *object-initial* non-canonical sentences (e.g., OSV sentences in Japanese), at least three studies focused on *subject-initial* non-canonical sentences, namely, Yasunaga et al. (2015), Yano et al. (2019), and Asami and Tomioka (2025). We review them in order below.

Yasunaga et al. (2015) conducted an event-related potential (ERP) experiment in Kaqchikel (a Mayan language spoken in Guatemala). In Kaqchikel, VOS sentences are canonical while SVO sentences are non-canonical, derived by fronting the subject to sentence-initial position (García Matzar & Rodríguez Guaján, 1997). Yasunaga and colleagues found a P600 effect at the third phrase in SVO sentences (i.e., O) relative to the corresponding phrase in VOS sentences (i.e., S) during the comprehension of Kaqchikel sentences. Importantly, this effect was detected even though the experimental sentences were preceded by a non-verbal context – a picture depicting the participants involved in the sentences. This result was comparable to that of another ERP experiment in which the same sentences were presented out of the blue (Yano et al., 2017). Yasunaga and colleagues attributed the observed P600 effect to the processing of the filler–gap dependency between the sentence-initial subject and its original position after the object (i.e., S_1VOt_1). Their claim is consistent with the traditional view that this ERP component reflects the processing cost related to filler–gap dependency formation (e.g., Kaan et al., 2000; Phillips et al., 2005; Ueno & Kluender, 2003).

However, the experimental studies in Yano et al. (2019) found different patterns in Seediq (an Austronesian language spoken in Taiwan). In Seediq, VOS sentences are canonical, while SVO sentences are non-canonical, derived by preposing the subject to clause-initial position (Tsukida, 2009). Their first experiment showed that in the absence of the context, the third phrase in SVO sentences (i.e., O) elicited a larger P600 in comparison to the corresponding phrase in VOS sentences (i.e., S). Crucially, their second experiment demonstrated that a non-verbal context – a picture similar to that used in Yasunaga et al. (2015) – substantially alleviated the processing cost observed in their first experiment. Based on these results, Yano and colleagues claimed that the processing cost indexed by the P600 has to do with a discourse-related factor rather than a syntactic one, contra Yasunaga et al. (2015) (also Kaan et al., 2000; Phillips et al., 2005; Ueno & Kluender, 2003). They then concluded that the processing cost associated with non-canonical SVO sentences in Seediq is related to a discourse-related factor.

The findings from Yasunaga et al. (2015) and Yano et al. (2019) do not fit well with each other. One possible interpretation of these conflicting results is that a single picture might serve as a sufficient context for non-canonical SOV sentences in Seediq, but not in Kaqchikel, for some independent reason (we will come back to this point in 5.1). Even if this consideration is on the right track, we should be cautious about the interpretation of the results in Yano et al. (2019). It would be too hasty to conclude from their ERP results that contextual support completely

eliminated the processing cost for the non-canonical SOV sentences in Seediq, because as suggested by Yano and colleagues themselves (p. 414), the P600 might only reflect a conflict between syntactic structure and information structure (see also Yano, 2019; Yano & Koizumi, 2018). If this interpretation of the P600 is correct, the findings from Yano et al. (2019) are not informative about the processing cost associated with a syntactic factor per se. Therefore, further research is necessary to see whether syntax still impacts the processing of discourse-licensed, subject-initial non-canonical sentences.

The findings from Asami and Tomioka (2025) represent a case in point. They examined the processing of inchoative sentences in Japanese that contain a nominative-marked theme subject and a postpositional causer adjunct. They found that it took less time to process causer–theme sentences like (4a) than theme–causer sentences like (4b). They interpreted this result as indicating that the former are canonical while the latter are non-canonical, derived by moving the theme subject over the causer adjunct.

(4) a. Causer–Theme:
Kazi-de ie-ga yak-e-ta.
fire-due.to house-NOM be.burned.down-INCH-PST

b. Theme–Causer:
Ie-ga kazi-de yak-e-ta.
house-NOM fire-due.to be.burned.down-INCH-PST
'A house burned down due to fire.'

Importantly, they also revealed that the processing cost for non-canonical theme–causer sentences was reduced when the sentence-initial theme subject was marked as discourse-given with the demonstrative *sono* 'that'.

(5) $\text{Theme}_{\text{given}}$–Causer:
Sono-ie-ga kazi-de yak-e-ta.
that-house-NOM fire-due.to be.burned.down-INCH-PST
'That house burned down due to fire.'

It was also reported that the causer–theme order was processed faster than the theme–causer order even when the fronted subject was interpreted as discourse-given. These findings indicate that both syntax and information structure play a role in the processing of subject-initial non-canonical sentences. However, there is a methodological limitation in this study. It employed a speeded forced-choice task (e.g., Asami, 2024; Chujo, 1983; Koizumi & Tamaoka, 2010; Tamaoka et al., 2005). In this task, a sentence is presented in full, and only the total time the participants take to read the whole sentence is measured. This methodology is useful for examining whether a particular word order takes longer to process than the other(s) (Tamaoka & Koizumi, 2006), but it is not very informative about the time course of sentence processing (Miyamoto & Nakamura,

2005). Therefore, the findings from Asami and Tomioka (2025) cannot tell us at which point in the sentence syntax and information structure interact during comprehension.

To be fair to the three studies reviewed above, it is important to emphasize that no single experimental methodology can offer a perfect picture of human sentence processing. It is essential to examine evidence from several experimental methods with different measures (i.e., a multiple-methods approach; Kaiser & Trueswell, 2004, p. 130). In light of this, the current study used a moving-window, self-paced reading task – a widely-adopted methodology to investigate cognitive processes behind online reading (Just et al., 1982) – to shed light on the time course of the interaction between syntax and information structure in the processing of subject-initial non-canonical sentences. We examined the phrase-by-phrase processing of inchoatives with a theme subject and a causer adjunct in Japanese, expanding on Asami and Tomioka (2025).

2 Sentence-pair method and current study

Departing from standard self-paced reading studies, this study proposes a *sentence-pair* method.[2] In this method, a participant reads two unrelated mono-clausal sentences phrase by phrase in a row in each trial (e.g., (6)).

(6) Sensee-ga gakusee-o home-ta rasii. Kazi-de ie-ga
teacher-NOM student-ACC praise-PST I.hear fire-due.to house-NOM
yak-e-ta rasii.
be.burned.down-INCH-PST I.hear
'I hear that a teacher praised a student. I hear that a house burned down due to fire.'

The rationale behind our proposal is to address concerns arising from previous sentence-processing studies in Japanese. We elaborate on it below before reporting our experiments.

Several earlier self-paced reading studies failed to detect a reading-time difference between canonical and non-canonical sentences (Mazuka, 2002; Miyamoto & Takahashi, 2002a; Nakayama, 1995; Tamaoka et al., 2003; Yamashita, 1997). As a result, many researchers concluded that this task might not be suitable for examining the online processing of non-canonical sentences, especially if the experimental stimuli are mono-clausal, simple sentences (Mazuka, 2002; Miyamoto & Nakamura, 2005; Tamaoka & Koizumi, 2006; Tamaoka et al., 2003; Witzel & Witzel, 2016). One possible reason for this failure is that participants read each sentence by pressing a button at a constant rhythm; as a result, the measured reading times varied little (Tamaoka et al., 2003, p. 449). According to Tamaoka and Koizumi (2006, pp. 214–217), this tendency became extreme with simple active sentences: participants pressed a button three or four times at a constant pace. Another possible reason is that the experimental sentences used in earlier

[2] We are grateful to an anonymous reviewer for suggesting the term *sentence-pair*.

studies were structurally so simple, even if they were not mono-clausal, that they could not make participants read more carefully than usual; as a consequence, the experiments could not detect the subtle but real processing difference under consideration (Miyamoto, 2008, pp. 232–234).

Notably, other self-paced reading studies successfully found evidence of a processing difference between canonical and non-canonical sentences. These experiments used structurally complex sentences (Aoshima et al., 2004; Mazuka, 2002; Miyamoto & Takahashi, 2002b, 2004) or passages consisting of two clauses (Koizumi & Imamura, 2017; Miyamoto et al., 2014) as experimental stimuli. In this study, we did not follow the first set of studies for the following reasons. Consider (7). This is an example item adopted from Miyamoto and Takahashi (2002b, 171–172, (4)), which examined how the ordering of dative-marked and accusative-marked objects would affect the processing of ditransitive constructions in Japanese. This kind of sentence is very hard to parse and comprehend, even for native speakers of Japanese. The difficulty is evidenced by the low accuracy (around 65%) in a secondary comprehension question task embedded within the self-paced reading experiment (Miyamoto & Takahashi, 2002b, p. 173).

(7) Ofisu-de shokuin-ga {ocha-o/kakarichoo-ni} {kakarichoo-ni/ocha-o} dasi-ta
office-at employee-NOM {tea-ACC/manager-DAT} {manager-DAT/tea-ACC} serve-PST
josei-o teineini home-ta-to Aihara-san-ga hanasi-tei-ta.
woman-ACC politely praise-PST-COMP Aihara-Mr/Ms-NOM say-PROG-PST
'At the office, Mr./Ms. Aihara said that the employee politely praised the woman who had served tea to the manager.'

The rationale behind Miyamoto and Takahashi's use of complex items like (7) was to "force participants to read carefully and intently store words in working memory" under the assumption that a greater working memory load requires the participants to pay close attention during reading (Miyamoto & Takahashi, 2002b, p. 171). Their rationale is understandable, considering the concerns about the use of simple sentences mentioned above. For current purposes, however, the use of complex items is not ideal. Placing additional irrelevant phrases within a clause could perturb the ordering of given and new information. In addition, it is far from obvious what counts as structurally complex enough to detect the processing asymmetry between non-canonical and canonical sentences. For these reasons, this study did not use structurally complex sentences as experimental stimuli.

Instead, we followed the second set of studies, which used passages consisting of two simple sentences as experimental items (Koizumi & Imamura, 2017; Miyamoto et al., 2014). These studies focused on the effect of discourse context on the processing of non-canonical sentences. In their design, the first sentence served as a context for the second target sentence. We reason that these studies succeeded in detecting relevant processing-time differences because presenting two sentences in each trial effectively disrupted rhythmic button-pressing behavior and imposed

additional cognitive demands, thereby increasing sensitivity to subtle processing costs. Departing from these previous studies, however, we employed sentence pairs consisting of two unrelated sentences, with a filler item as the first sentence and a target item as the second (e.g., (6)). We made this decision because it was particularly challenging to manipulate contextual factors for inchoative constructions with a theme subject and a causer adjunct. Specifically, it was difficult to create contextually natural sentences containing an open slot flexible enough to accommodate either a theme or a causer phrase. For transitive sentences such as those used as target sentences in Miyamoto et al. (2014) and Koizumi and Imamura (2017) (e.g., *Kuroki-ga Kaneda-o mukae-ta.* 'Kuroki welcomed Kaneda.'), it is relatively straightforward to construct context sentences that introduce either the agent subject or the patient object (e.g., *Gaimusho-no jikan-wa {Kuroki/Kaneda}-da.* 'It is {Kuroki/Kaneda} who is the vice president of the Ministry of Foreign Affairs.'), thereby allowing for controlled manipulation of discourse status. Given the difficulty of constructing comparable contexts for inchoative constructions, the use of a context sentence was impractical for the present experiments. We therefore inserted an unrelated filler sentence as the first sentence in each sentence pair.

Unlike the use of structurally complex sentences, the current sentence-pair method allows us to use simple sentences by themselves with only two modifications: (i) the addition of an unrelated sentence as the first sentence and (ii) the insertion of a sentence-final phrase like *rasii* 'I hear' to take into account an end-of-sentence wrap-up effect. Since Miyamoto et al. (2014) and Koizumi and Imamura (2017) successfully detected the relevant processing asymmetry with passages, we reasoned that our sentence-pair method would enable us to detect an otherwise undetectable processing-time difference while circumventing the above-mentioned concerns about the use of structurally complex sentences.

Using the sentence-pair method, we conducted two self-paced reading experiments targeting inchoative constructions in Japanese. We hypothesized that if syntactic and discourse factors interact in the processing of subject-initial non-canonical sentences as they do in the processing of object-initial ones, the processing asymmetry between non-canonical subject-initial sentences and their canonical counterparts (i.e., theme–causer vs. causer–theme sentences) should be reduced, if not completely eliminated, when they follow the preferred information structure (i.e., given information comes before new information).

To preview our key findings, Experiment 1 showed that the pre-verbal phrase was read more quickly in causer–theme sentences than in theme–causer sentences, consistent with the view that the former are canonical and the latter are non-canonical (Asami & Tomioka, 2025). Experiment 2 revealed that this processing asymmetry was substantially reduced when the sentences followed the preferred information structure. Nevertheless, a processing advantage for the canonical causer–theme order was still detected. These findings are in line with previous results on the processing of object-initial non-canonical sentences, supporting the view that both syntactic and discourse factors contribute to the processing of subject-initial non-canonical sentences.

3 Experiment 1

Experiment 1 examined the online processing of two word order variants of inchoatives with a theme subject and a causer adjunct in Japanese (i.e., causer–theme vs. theme–causer). Adopting the view that causer–theme sentences are canonical, while theme–causer sentences are non-canonical (Asami & Tomioka, 2025), we predicted that filler–gap dependency formation would slow down the processing time at the second phrase in the theme–causer sentences relative to the causer–theme sentences (i.e., causer vs. theme), because this is where readers can detect the non-canonical structure.[3]

3.1 Methods

3.1.1 Participants

The target number of participants was 96. We recruited 110 native speakers of Japanese on Lancers (https://www.lancers.jp), a crowdsourcing platform in Japan. They were paid ¥350 (approximately 2.5 US dollars) for their participation. Fourteen participants were excluded from the data analysis because they had less than 80% accuracy in the experimental task.

To address concerns about the quality of data collected via a crowdsourcing platform, we implemented the following participation requirements and exclusion criteria. Participants were eligible if they were native speakers of Japanese and had an approval rating of 95% or higher on Lancers. To be included in the analysis, participants were required to achieve over 80% accuracy and have less than 10% missing data across all items. Reading times shorter than 100 ms or longer than 2500 ms were treated as missing data. Participants were compensated regardless of whether their data were ultimately included in the analysis.

3.1.2 Materials and design

The experiment had a within-subjects design and manipulated word order with two levels (causer–theme vs. theme–causer). We adopted 24 sets of experimental items (48 items in total) from the first experiment in Asami and Tomioka (2025). Examples of each condition are provided in (8). Slashes indicate the segment boundaries used in the self-paced reading task. Theme phrases and causer adjuncts consisted of inanimate nouns. Unlike Asami and Tomioka (2025), we added *rasii* 'I hear' to the end of each sentence to take into account an end-of-sentence wrap-up effect.

(8) a. Causer–Theme:

Kazi-de	/	ie-ga	/	yak-e-ta	/	rasii.
fire-due.to		house-NOM		be.burned.down-INCH-PST		I.hear

[3] An implicit assumption that we adopt throughout this paper is that humans comprehend a sentence piece by piece as they read or hear it, rather than waiting for the end of the sentence before beginning to understand it (i.e., incrementality of human sentence processing; e.g., Altmann & Kamide, 1999; Altmann & Mirković, 2009; Kamide et al., 2003; Van Berkum et al., 2005).

b. Theme–Causer:
Ie-ga / kazi-de / yak-e-ta / rasii.
house-NOM fire-due.to be.burned.down-INCH-PST I.hear
'I hear that a house burned down due to fire.'

We created 24 sets of sentence pairs using the experimental items as second sentences. The first sentences in the pairs were unrelated filler items. The fillers were various types of acceptable four-phrase constructions with the sentence-final phrase *rasii* 'I hear' as the fourth phrase, to maintain consistency with the experimental sentences. The constructions that we used were as follows: canonical active transitives (N = 7), scrambled active transitives (N = 5), passives (N = 4), negative transitives containing the negative polarity item (NPI) *sika* 'only' (N = 4), and intransitives with an adjunct (N = 4). We provide examples of each construction in (9) below. Each set of experimental sentences was paired with the same filler sentence across all conditions, ensuring that the first sentence remained identical regardless of the word order of the second sentence (e.g., the filler sentence in (9a) preceded the target sentence in (8), regardless of conditions).

(9) a. Active transitive:
Sensee-ga / gakusee-o / home-ta / rasii.
teacher-NOM student-ACC praise-PST I.hear
'I hear that a teacher praised a student.'

b. Passive:
Hannin-ga / keesatu-ni / taihos-are-ta / rasii.
criminal-NOM police.officer-by arrest-PASS-PST I.hear
'I hear that a criminal was arrested by a police officer.'

c. Scrambled active transitive:
Ziroo-o / sensee-ga / yon-da / rasii.
Ziro-ACC teacher-NOM call-PST I.hear
'I hear that a teacher called Ziro.'

d. Negative transitive with the NPI *sika* 'only':
Gakusee-sika / hookokusyo-o / kak-anakat-ta / rasii.
student-only report-ACC write-NEG-PST I.hear
'I hear that only a student wrote a report.'

e. Intransitive with an adjunct:
Sinnichi-ga / yukkuri / hasit-ta / rasii.
Sinnichi-NOM slowly run-PST I.hear
'I hear that Sinnichi ran slowly.'

Each phrase in the experimental sentence pair was labeled as in (10). Starting from the left, we refer to each phrase as P(hrase)1, P2, P3, etc. P1 was always '+' (see 3.1.3). P2, P3, P4, and P5 constituted a filler sentence, while P6, P7, P8, and P9 formed an experimental sentence.

(10) P1 P2 P3 P4 P5
+ / Sensee-ga / gakusee-o / home-ta / rasii. /
teacher-NOM student-ACC praise-PST I.hear

P6 P7 P8 P9
{Kazi-de/ie-ga} / {ie-ga/kazi-de} / yak-e-ta / rasii.
{fire-due.to/house-NOM} {house-NOM/fire-due.to} be.burned.down-INCH-PST I.hear
'I hear that a teacher praised a student. I hear that a house burned down due to fire.'

The 24 sets of sentence pairs containing experimental items were divided into two lists, using a Latin Square design. Each list was combined with 48 distractor sentence pairs, yielding two lists of 72 sentence pairs (see the description of the distractor items below). Each list was assigned to 48 participants (96 participants in total).

For the distractor items, we prepared 48 sentence pairs. Half of these consisted of two acceptable sentences. In these acceptable pairs, the first sentences belonged to one of five categories, mirroring the structure of the first sentences in the experimental items: active transitives (N = 8), passives (N = 4), scrambled active transitives (N = 4), negative transitives containing the NPI (N = 4), and intransitives with an adjunct (N = 4). These constructions are illustrated by the examples in (9) above. The second sentences in these pairs were resultative constructions (e.g., (11)). They served as experimental items in an unrelated pilot study (not reported in this paper).

(11) Kenji-ga / sara-o / konagona-ni / wat-ta / rasii.
Kenji-NOM plate-ACC pieces-COP break-PST I.hear
'I heard that Kenji broke a plate into pieces.'

The remaining 24 distractor stimuli contained an unacceptable item as either the first or second sentence. These unacceptable sentences included semantically and morphosyntactically anomalous inchoatives with an adjunct (N = 8), semantically anomalous transitives with an adjunct (N = 8), and transitives containing the unlicensed NPI *sika* 'only' (N = 8). Examples of each are provided below.

(12) a. Semantically and morphosyntactically anomalous inchoative with an adjunct:
*Danbooru-bako-ga omosa-de nur-asi-ta rasii.
cardboard-box-NOM weight-due.to wet-CAUSE-PST I.hear
'Lit. I hear that its weight made a cardboard box wet.'

b. Semantically anomalous transitive with an adjunct:
*Notihodo daihyoo-ga kekka-o sim-er-u rasii.
later representative-NOM result-ACC close-INCH-PRES I.hear
'Lit. I hear that a representative will close a result later.'

c. Transitive with the unlicensed NPI *sika* 'only':
*Tentyoo-sika syoohin-o narabe-ta rasii.
owner-only product-ACC organize-PST I.hear
'Lit. I hear that only an owner organized products.'

The acceptable sentences consisted of four types: simple transitives (N = 7), transitives with the NPI (N = 8), transitives with an adjunct (N = 7), and inchoatives with a source adjunct (N = 2). The first three are exemplified by (9a), (9d), and (9e), respectively. An example of the fourth is provided below.

(13) Inchoative with a source adjunct:
Eda-ga ki-kara ot-i-ta rasii.
branch-NOM tree-from fall-INCH-PST I.hear
'I hear that a branch fell from a tree.'

3.1.3 Procedure

The experiment used a moving-window, self-paced reading task (Just et al., 1982). It was run on PCIbex (Zehr & Schwarz, 2018). Participants were instructed to read each item phrase by phrase at their own natural pace. In each trial, a series of dashes that masked the words was presented on the center of the screen. When the participant pressed the space bar, '+' appeared as the first phrase. The subsequent space bar press revealed the next phrase and masked the previous one. This procedure continued until the participant finished reading a sentence pair. After reading the pair, the participant was asked to make a forced-choice acceptability judgment. Specifically, they were asked to press 'J' if the sentence pair that they had just read included only acceptable sentences and 'F' if it contained at least one unacceptable sentence. They were instructed to make this judgment as accurately and as quickly as possible. Phrase-by-phrase reading times and accuracy on the forced-choice task were recorded.

Note that standard self-paced reading studies use a secondary memory task in the form of a comprehension question as a sanity check. Unlike them, we used the forced-choice task to make the experimental task short and simple, to prevent the participants' fatigue, which could negatively affect the data quality. The current experimental design was modeled after Koizumi and Imamura (2017), who used a forced-choice task in a self-paced reading paradigm. Citing an earlier report of the results in Koizumi and Imamura (2017), Miyamoto et al. (2014) replicated their results, using comprehension questions rather than forced-choice judgments. Therefore,

the use of the forced-choice task should not have affected the results of the current study in any critical way.

Each participant completed twelve practice trials before the actual experiment. The last four practice trials were inserted before the actual experiment without telling the participant. The whole experiment took less than 20 minutes.

3.1.4 Data analysis

We analyzed accuracy and phrase-by-phrase reading times in the following fashion.

For the statistical analysis of accuracy, we fitted logistic mixed-effects models (Jaeger, 2008) using the *lme4* package (Bates, Mächler, et al., 2015) in R (R Core Team, 2024). A fixed factor was word order (causer–theme and theme–causer). We used the treatment coding and set causer–theme as a reference level. Random factors were items and participants. Following Bates, Kliegl, et al. (2015), we selected the most parsimonious model. We initially fitted the maximum random effects model with by-participant and by-item intercepts and slopes. We then simplified the model by removing a random slope that did not improve the model. The final model included by-participant and by-item intercepts.

We pre-processed phrase-by-phrase reading times, following Hofmeister (2011) and Bader and Meng (2023).[4] First, extraordinary reading times (less than 100 ms and more than 2500 ms) were removed. Second, trials that generated incorrect responses were removed. These two steps affected 3.3% of the data. Third, reading times were log-transformed, to avoid skewing. Fourth, residual reading times were computed from the log-transformed raw reading times, taking both experimental and filler items into account. To obtain residual reading times, linear mixed-effects models were fitted to the log-transformed reading times with participants as a random factor and three fixed factors: word length (the number of morae), log-transformed trial order, and the position of the word within each sentence. For this purpose, we used the *lme4* package. The final fixed factor was coded as a categorical variable with three levels: the sentence-initial position (initial), the sentence-final position (final), and the sentence-medial position (i.e., every position except the initial one and the final one; medial). After computing the residual log reading times, we replaced data points outside of more than or less than 2.5 standard deviations from the individual means of participants at each phrase with their boundaries. This process affected 2.7% of the data points.

With the residual log reading times, we fitted linear mixed-effects models (Baayen et al., 2008) for each phrase in the experimental items. We followed the same model fitting and

[4] We did not include P1 in our data analysis, since it was always '+'.

selection procedures as in the statistical analysis of accuracy described above. We obtained *p* values with the *lmerTest* package (Kuznetsova et al., 2017).

3.2 Results

3.2.1 Accuracy

Mean accuracy was 99.0% (SD = 10.2) and 98.3% (SD = 13.1) for the theme–causer and causer–theme conditions, respectively. The difference was not statistically significant (*estimate* = –0.514, *se* = 0.371, z = –1.387, p = 0.165).[5]

3.2.2 Reading times

Phrase-by-phrase residual log-transformed reading times by condition are presented in **Figure 1**. This figure does not include the reading times for the first non-critical sentences (i.e., from P2 to P5). The results of linear mixed-effects models for the phrases of interest are summarized in **Table 1**.[6]

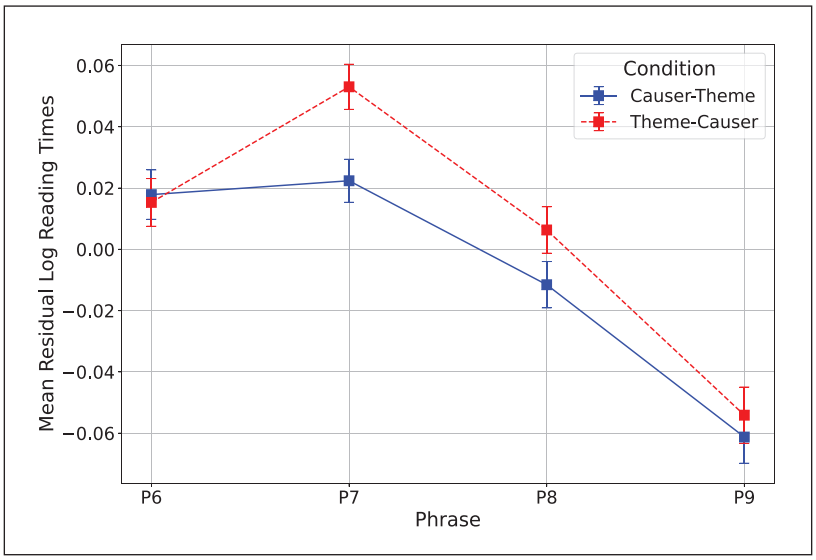

Figure 1: Mean residual log reading times by phrase and condition. Error bars indicate +/–1 standard error of the mean residual log reading times.

[5] For all distractors, accuracy was 96.8% (SD = 17.5). This high accuracy indicates that participants were attentive during the experiment.

[6] We found no significant effect of word order in any phrase within the first unrelated sentence (i.e., from P2 to P5). This was as expected, since we used the same item for the first sentences in each experimental sentence pair, irrespective of conditions.

Table 1: Summary of linear mixed-effects models for residual log reading times in Experiment 1.

		estimate	*SE*	*t*	*p*	
P6	Intercept	0.018	0.016	1.103	0.276	
	Word order	–0.002	0.015	–0.194	0.848	
P7	Intercept	0.022	0.014	1.493	0.141	
	Word order	0.031	0.009	3.308	<0.001	***
P8	Intercept	–0.01184	0.01553	–0.763	0.448	
	Word order	0.01876	0.00977	1.920	0.055	
P9	Intercept	–0.061	0.201	–3.029	0.003	**
	Word order	0.008	0.010	0.798	0.424	

In P6 (causer vs. theme in the causer–theme and theme–causer conditions, respectively), the effect of word order was not significant ($t = –0.194$, $p = 0.848$). In P7 (theme vs. causer in the causer–theme and theme–causer conditions, respectively), the effect of word order was significant such that the causer–theme condition was read more quickly than the theme–causer condition ($t = 3.308$, $p < 0.001$). We found no significant effect in P8 (verb) or P9 (*rasii* 'I hear') ($t = 1.920$, $p = 0.055$ and $t = 0.798$, $p = 0.424$, respectively).

3.3 Discussion

We found that the second phrase (P6) was read more quickly in causer–theme sentences than in theme–causer sentences. This result is consistent with the findings of Asami and Tomioka (2025), who reported shorter processing times for causer–theme sentences when the sentences were presented in full. Taken together with their results, the present reading-time pattern supports the view that the causer–theme order is canonical, whereas the theme–causer order is non-canonical, in inchoative constructions with a theme subject and a causer adjunct. Moreover, the observed significant difference indicates that our sentence-pair method enabled us to detect the processing asymmetry between canonical and non-canonical word orders with simple experimental stimuli.

The self-paced reading technique allowed us to examine the phrase-by-phrase processing of two word order variants of inchoative constructions. Based on the current results, we consider how non-canonical theme–causer sentences are processed under the filler–gap model (e.g., Clifton Jr & Frazier, 1989; Crain & Fodor, 1985; Frazier & Clifton Jr, 1989; Stowe, 1986); see also, for example, Miyamoto (2008) for its application to Japanese sentence processing). The previous research on non-canonical OSV sentences in Japanese (Aoshima et al., 2004; Miyamoto & Takahashi, 2002a, 2004; Nakano et al., 2002; Shibata et al., 2006) has suggested that a parser posits a gap associated with a fronted object (the filler) upon encountering the pre-verbal subject,

because this is the point at which the parser detects a non-canonical structure. We assume that a similar process occurs in the theme–causer sentences examined here. Upon encountering the causer phrase, the parser infers that the sentence-initial theme has been displaced, thereby triggering the insertion of a corresponding gap. It is this gap-filling operation that can account for the observed slowdown at the second phrase in the theme–causer condition (causer) relative to the canonical causer–theme condition (theme).

The current findings shed light on the processing costs associated with different Case markers. Miyamoto and Takahashi (2002b, pp. 176–177) hypothesized that noun phrases bearing nominative Case markers take longer to process than those with other Case markers. This hypothesis is based on two considerations: first, the nominative Case often signals a clause boundary (Miyamoto, 2002); and second, it is marked, in the sense that it may be associated with a specific interpretation – for instance, the exhaustive reading of nominative-marked phrases (Kuno, 1973). Thus, the inherent properties of the nominative Case marker were thought to contribute to increased processing difficulty. However, the current findings are not compatible with this hypothesis. We observed that the nominative-marked theme was read more quickly than the postpositional causer adjunct. This result suggests that the nominative Case does not inherently lead to longer reading times (see also Tamaoka et al., 2005 for relevant discussion).

It is worth noting that we did not control for word frequency in the critical sentences, despite the well-established effect of lexical frequency on processing speed (e.g., Ashby et al., 2005). However, lexical frequency alone cannot readily account for the observed slowdown at the second phrase (P6). Crucially, no significant reading-time difference was found at the first phrase (P5). If lexical frequency were a major contributing factor, we would expect to see effects in both P5 and P6, since the same lexical items (causer and theme) were compared in opposite orders across these two positions (i.e., causer vs. theme in P5 and theme vs. causer in P6). Thus, it is reasonable to conclude that lexical frequency did not meaningfully confound the observed reading-time pattern.

4 Experiment 2

Experiment 1 indicated that the formation of a filler–gap dependency slowed down the processing time in non-canonical theme–causer sentences compared to canonical causer–theme sentences. Experiment 2 investigated the interaction between syntax and information structure. Specifically, it tested whether the preferred information flow, that is, given information comes before new information in a clause (Aissen, 1992; Birner & Ward, 2009; Kuno, 1978, 1995), would affect the processing asymmetry observed in Experiment 1, and at which point in the sentence this would occur. Following Asami and Tomioka (2025) (see also Yano, 2019), Experiment 2 used the demonstrative *sono* ‘that’ to mark theme or causer phrases as discourse-given.

We made the following four predictions: (i & ii) An effect of givenness would emerge at the first and second phrases, corresponding to the positions where the discourse-given phrase appeared in the given-first and given-second conditions, respectively. (iii) An interaction between word order and information structure would be observed at the second phrase, where the parser is expected to detect whether the sentence has a non-canonical structure and whether it adheres to the given-before-new information flow. Specifically, we predicted that the processing asymmetry between the two word orders would be reduced when the first phrase was marked as discourse-given. (iv) A main effect of word order would be observed such that theme–causer sentences would take longer to read than causer–theme sentences at one or more phrases. This prediction follows from the previous findings that processing asymmetries between canonical and non-canonical word orders rarely disappear entirely, even when discourse conditions are satisfied.

4.1 Methods

4.1.1 Participants

Our target number of participants was 288. We recruited 317 native speakers of Japanese through Lancers (https://www.lancers.jp) and compensated them ¥350 (approximately 2.5 USD) for their participation. Twenty-nine participants were excluded from the analysis due to less than 80% accuracy on the experimental task. We applied the same participation requirements and data exclusion criteria as in Experiment 1.

4.1.2 Materials and design

The experiment employed a 2 × 2 within-subjects design, crossing word order (theme–causer vs. causer–theme) with information structure (given-first vs. given-second). Example items for each condition are shown in (14). To manipulate discourse-givenness, we used the demonstrative *sono* 'that', following Yano (2019) and Asami and Tomioka (2025). We reason that when readers encounter a phrase marked with *sono*, they interpret it as referring to old information, whereas a bare noun is interpreted as discourse-new by default. For example, *sono-ie* 'that house' refers to a specific, previously mentioned house, while its bare counterpart *ie* 'house' does not carry such a presupposition. All target items were adopted from the second experiment in Asami and Tomioka (2025), with one modification: the addition of the sentence-final phrase *rasii* 'I hear' to take into account an end-of-sentence wrap-up effect. Twenty-four sets of sentences (96 items in total) were used in the experiment.

(14) a. Causer$_{\text{given}}$–Theme:
Sono-kazi-de / ie-ga / yak-e-ta / rasii.
that-fire-due.to house-NOM be.burned.down-INCH-PST I.hear
'I hear that a house burned down due to that fire.'

b. Causer–Theme$_{given}$:
Kazi-de / sono-ie-ga / yak-e-ta / rasii.
fire-due.to that-house-NOM be.burned.down-INCH-PST I.hear
'I hear that that house burned down due to fire.'

c. Theme$_{given}$–Causer:
Sono-ie-ga / kazi-de / yak-e-ta / rasii.
that-house-NOM fire-due.to be.burned.down-INCH-PST I.hear
'I hear that that house burned down due to fire.'

d. Theme–Causer$_{given}$:
Ie-ga / sono-kazi-de / yak-e-ta / rasii.
house-NOM that-fire-due.to be.burned.down-INCH-PST I.hear
'I hear that a house burned down due to that fire.'

As in Experiment 1, our experimental items were sentence pairs in which the first sentence was a filler sentence while the second one was a critical sentence. The filler sentences were adopted from Experiment 1, and one-third of them had a phrase with *sono* 'that' to mask the critical sentences. Phrases in each experimental sentence pair were labeled in the same way as in Experiment 1: the sequence of P2, P3, P4, and P5 formed the filler; that of P6, P7, P8, and P9 constituted the target item (P1 was always '+').

In addition to the experimental sentence pairs, we included 48 distractor sentence pairs. These were adopted from the distractor items used in Experiment 1 with two modifications. First, in half of the distractor pairs, the demonstrative *sono* 'that' was inserted into either the first or second sentence to make the distractors similar to the experimental items. Second, 24 resultative constructions used in Experiment 1 were replaced with another set of resultative constructions for an unrelated pilot study (not reported in this paper).

The experimental items were counter-balanced across four lists, using a Latin Square design. Each list was combined with 48 distractor sentence pairs, giving rise to four lists of 72 sentence pairs each. Each list was assigned to 72 participants (a total of 288 participants).

4.1.3 Procedure

The procedure was the same as in Experiment 1.

4.1.4 Data analysis

For the statistical analysis of accuracy, we fitted logistic mixed-effects models (Jaeger, 2008), using the *lme4* package (Bates, Mächler, et al., 2015) in R (R Core Team, 2024). Fixed factors were sum-coded (.5/–.5) main effects of word order (causer–theme vs. theme–causer) and information

structure (given-first vs. given-second), and their interaction. Sum-coding allowed us to interpret fixed effects as main effects. Random effects were participants and items. We followed the same model selection procedures as in Experiment 1. The final model included by-participant and by-item intercepts.

To interpret the significant interactions, if any, we conducted a follow-up analysis using nested contrasts.[7] This analysis aimed to examine the effect of word order at the two levels of information structure. In particular, we re-ran the model as in the main analysis, but replaced the main effect of word order and interaction terms with two sum-coded (.5/–.5) nested contrasts: one compared the effects of causer–theme and theme–causer in the given-first condition ($\text{Causer}_{\text{given}}$–Theme vs. $\text{Theme}_{\text{given}}$–Causer), and the other compared the same contrast in the given-second condition (Theme–$\text{Causer}_{\text{given}}$ vs. Causer–$\text{Theme}_{\text{given}}$).

We pre-processed reading times for each phrase, following the same steps as in Experiment 1. The removal of extraordinary reading times (less than 200 ms and more than 2500 ms) and items with incorrect responses affected 6.19% of the data points. An additional 2.67% of the data was affected by the replacement of the data outside of more than or less than 2.5 standard deviations from the individual means of participants at each phrase with their boundaries. For the statistical analysis of reading times, we fitted linear mixed-effects models (Baayen et al., 2008) for each phrase, following the same model fitting and selection procedures as in the statistical analysis of accuracy.

4.2 Results

4.2.1 Accuracy

Mean accuracy by condition is summarized in **Table 2**. The summary of logistic mixed-effects models for accuracy is provided in **Table 3**. The statistical analysis revealed a significant main effect of word order such that the causer–theme condition was responded to more accurately than the theme–causer condition ($z = 2.480$, $p = 0.013$). The main effect of information structure was not significant ($z = 0.746$, $p = 0.455$). The interaction of the two factors was significant ($z = 3.250$, $p = 0.001$). The follow-up analysis with nested contrasts revealed that accuracy was higher in the causer–theme condition than in the theme–causer condition in the given-first condition, while their difference was not significant in the given-second condition ($z = 3.893$, $p < 0.001$ and $z = –0.571$, $p = 0.568$, respectively).[8]

[7] We used the data analysis method of Fujita and Yoshida (2024) as a reference to make our follow-up analysis plan.

[8] Accuracy for distractor items was 93.9% (SD = 24.0), which indicates that participants were attentive during the experiment.

Table 2: Mean accuracy by condition in Experiment 2. M and SD stand for mean and standard deviation, respectively.

Condition	M	SD
$\text{Causer}_{\text{Given}}$–Theme	98.1	13.5
Causer–$\text{Theme}_{\text{Given}}$	96.8	17.6
$\text{Theme}_{\text{Given}}$–Causer	95.9	19.7
Theme–$\text{Causer}_{\text{Given}}$	97.1	16.8

Table 3: Summary of logistic mixed-effects models for accuracy in Experiment 2.

	estimate	*SE*	*z*	*p*	
Intercept	4.247	0.186	22.782	<0.001	***
Word order	0.378	0.152	2.480	0.013	*
Information structure	0.113	0.152	0.746	0.455	
Word order × Information structure	0.991	0.305	3.250	0.001	**
Word order: given-first	0.873	0.224	3.893	<0.001	***
Word order: given-second	–0.117	0.206	–0.571	0.568	

4.2.2 Reading times

Phrase-by-phrase residual log reading times by condition are shown in **Figure 2**. This figure does not include the reading times for the first non-critical sentences (i.e., from P2 to P5).[9] The summary of linear mixed-effects models for critical phrases (i.e., from P6 to P9) is provided in **Table 4**.

[9] From P2 to P5, no reading time differences were expected because the same lexical items were used across different conditions, but we found an interaction of word order with information structure in P5 (*estimate* = –0.042, *se* = 0.013, t = –3.075, p = 0.002). A follow-up analysis with nested contrasts showed that the reading time was shorter in the causer–theme condition than in the theme–causer condition in the given-first condition (*estimate* = –0.025, *se* = 0.009, t = –2.654, p = 0.007), whereas the same contrast was not significant in the given-second condition (*estimate* = 0.016, *se* = 0.009, t = 1.694, p = 0.090). This sort of spurious reading time difference is occasionally detected in self-paced reading studies.

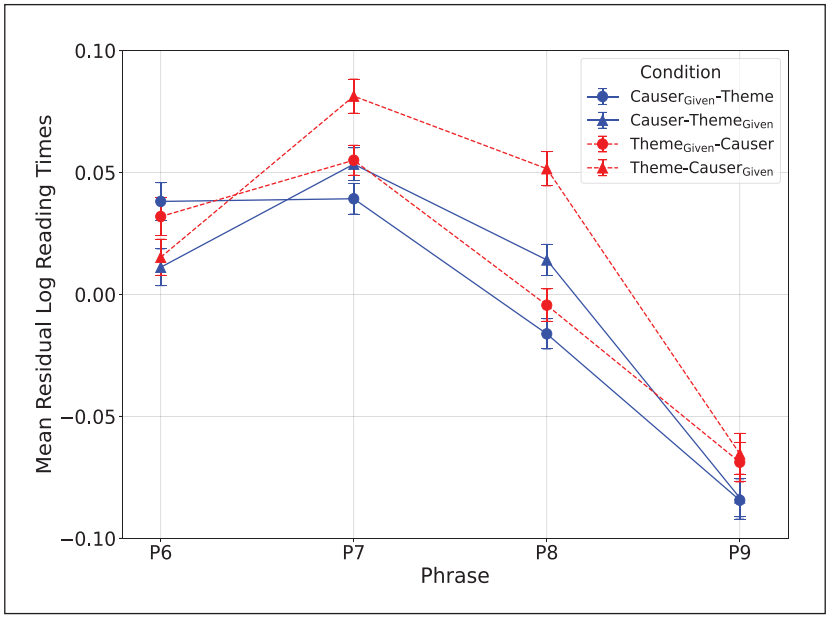

Figure 2: Mean residual log reading times by phrase and condition. Error bars indicate +/–1 standard error of the mean residual log reading times.

In P6, the main effect of information structure was significant such that the given-first condition was read more slowly than the given-second condition ($t = 3.081$, $p = 0.002$). No other main effect or interaction was significant.

In P7, the main effect of information structure was significant. This time, the given-second condition was read more slowly than the given-first condition ($t = –3.395$, $p < 0.001$). No other main effect or interaction was significant.

In P8 (i.e., verb), the main effects of word order and information structure were significant. The causer–theme condition was read more quickly than the theme–causer condition ($t = –3.116$, $p = 0.004$); the given-first condition was read more quickly than the given-second condition ($t = –7.207$, $p > 0.001$). Their interaction was also significant ($t = 2.037$, $p = 0.041$). The follow-up analysis revealed that the causer–theme condition was read significantly more quickly than the theme–causer condition in the given–second condition while their reading-time difference was not significant in the given-first condition ($t = –4.232$, $p < 0.001$ and $t = –1.476$, $p = 0.140$, respectively).

In P9 (i.e., *rasii* 'I hear'), the main effect of word order was significant such that the causer–theme condition was read more quickly than the theme–causer condition ($t = –2.480$, $p = 0.013$). No other main effect or interaction was significant.

Table 4: Summary of linear mixed-effects models for residual log reading times in Experiment 2.

		estimate	*SE*	*t*	*p*	
P6	Intercept	0.025	0.013	1.968	0.055	
	Word order	> 0.001	0.006	0.016	0.987	
	Information structure	0.021	0.006	3.081	0.002	**
	Word order × information structure	0.009	0.013	0.696	0.486	
P7	Intercept	0.057	0.012	4.667	> 0.001	***
	Word order	–0.021	0.014	–1.523	0.141	
	Information structure	–0.020	0.006	–3.395	> 0.001	***
	Word order × information structure	0.012	0.012	1.005	0.314	
P8	Intercept	0.013	0.011	1.101	0.278	
	Word order	–0.025	0.008	–3.116	0.004	**
	Information structure	–0.043	0.006	–7.207	> 0.001	***
	Word order × information structure	0.024	0.012	2.037	0.041	*
	Word order: given-first	–0.013	0.008	–1.476	0.140	
	Word order: given-second	–0.037	0.008	–4.232	> 0.001	***
P9	Intercept	–0.075	0.014	–5.276	> 0.001	***
	Word order	–0.016	0.006	–2.480	0.013	*
	Information structure	–0.001	0.006	–0.188	0.850	
	Word order × information structure	> –0.001	0.013	–0.063	0.949	

4.3 Discussion

Experiment 2 investigated how syntactic structure and information structure interact during the online processing of inchoative constructions in Japanese. We reiterate our four predictions: (i & ii) effects of discourse status (givenness) would be observed at the first and second phrases; (iii) an interaction between word order and information structure would emerge at the second phrase; (iv) theme–causer sentences would elicit longer reading times than causer–theme sentences at one or more phrases. In light of these predictions, we discuss the results below.

The first phrase was read more slowly when it was marked as discourse-given than when it was not. This finding aligns with our first prediction that the discourse effect would emerge at this phrase. We speculate that the observed slowdown reflects the pragmatic inference required when a noun phrase marked with the demonstrative *sono* 'that' is encountered. Specifically, such a phrase signals that its referent is discourse-given. Because no explicit discourse context

was provided in the experiment, this inference may have imposed an additional cognitive load, resulting in longer reading times.

A main effect of information structure was also observed at the second phrase, but in the opposite direction: reading times were longer in the given-second condition than in the given-first condition. This pattern confirms our second prediction that the discourse effect would also emerge at the second phrase, where the given-marked phrase appears in the given-second condition. We interpret the observed slowdown similarly to that detected at the first phrase: the demonstrative in the absence of explicit contextual support likely triggered a pragmatic inference about discourse givenness, which incurred additional cognitive cost.

Aside from this effect, no significant reading-time difference was observed at the second phrase. This result does not support our third prediction that this would be the point at which an interaction between word order and information structure would emerge. One possible explanation for this unexpected finding is that the processing time at this phrase was confounded or masked by the additional pragmatic inference triggered by the demonstrative *sono*, as discussed above.

Crucially, an interaction between word order and information structure was observed at the verb: reading times were significantly longer for the non-canonical theme–causer order than for the canonical causer–theme order when the second phrase was marked as discourse-given. When the first phrase was discourse-given, however, we found no evidence for such a reading-time difference. This finding is at least partially consistent with our third prediction. It also aligns with previous studies of object-initial non-canonical sentences using the self-paced reading paradigm. For example, Kaiser and Trueswell (2004) found that the reading-time difference between canonical SVO and non-canonical OVS sentences in Finnish was not significant at the second noun phrase when the sentence-initial phrase represented old information. Similarly, Koizumi and Imamura (2017) reported that the processing costs associated with non-canonical OSV sentences in Japanese were greatly reduced when the fronted object was mentioned in prior context.

It is important to note that the timing of the interaction observed in the current study differs from that reported by Koizumi and Imamura (2017). In our experiment, the interaction emerged at the verb, whereas in Koizumi and Imamura's study, it was detected at the second phrase immediately before the verb. We conjecture that in the present study, the interaction may have initially occurred in the second (preverbal) phrase but was obscured by the additional cognitive cost associated with the pragmatic inference triggered by the demonstrative; still, the interaction effect may have persisted and become visible at the verb as a spill-over effect. Unlike our experiment, Koizumi and Imamura included a context sentence to explicitly establish whether a particular phrase represented given information without additional elements like the demonstrative *sono* 'that'. We reason that, in contrast to our design, this contextual support

minimized the cognitive cost associated with the additional pragmatic inference discussed above. As a result, Koizumi and Imamura were able to detect the interaction at the preverbal phrase.

Finally, theme–causer sentences were read more slowly than causer–theme sentences at the sentence-final phrase (i.e., *rasii* 'I hear').[10] This slowdown is consistent with our fourth prediction that the non-canonical theme–causer order would take longer to process than the canonical causer–theme order at one or more points in the sentence. As in Experiment 1, we attribute this slowdown to the formation of a filler–gap dependency between the fronted theme and its corresponding gap. What distinguishes the current finding from that of Experiment 1 is the position at which the slowdown occurred: in Experiment 1, it appeared at the second phrase, whereas in Experiment 2, it emerged at the final phrase. We explain this difference as follows. In Experiment 2, the slowdown due to the filler–gap dependency formation likely originated at the second phrase but was masked by the additional discourse-related processing triggered by the demonstrative. Nonetheless, the associated processing cost persisted, extending into the following phrases. This spill-over effect was detected in Experiment 2 but not in Experiment 1, presumably because the extra discourse-related process depleted cognitive resources, thereby making the cost related to the non-canonical sentences more evident in a subsequent phrase. Although the precise mental mechanisms underlying this effect remain to be determined, our interpretation is supported by prior findings that reading-time slowdowns for non-canonical sentences tend to become more evident if complex sentences are used as experimental stimuli, as introduced in 2 (see also Miyamoto, 2008, pp. 232–234 for relevant discussion).

It is worth noting that Kaiser and Trueswell (2004) also found a processing difference between canonical SVO and non-canonical OVS sentences in Finnish, even when a felicitous discourse context was provided. In particular, they observed a slowdown at the verb in non-canonical OVS sentences relative to canonical SVO sentences, despite the presence of a supportive context. They attributed this effect to predictive processing: upon encountering the verb, the parser anticipates an upcoming phrase (which is assumed to represent new information), and it is this predictive process that incurs a processing cost at the verb in contextually supported OVS sentences. Evidence consistent with this hypothesis was reported in their second experiment, which used eye-tracking methodology. However, this line of reasoning does not readily account for the slowdown observed at the final phrase in the current experiment. Due to the verb-final structure of Japanese, the parser would have already processed the new-information phrase prior to reaching the final element (*rasii* 'I hear'). Thus, the observed slowdown cannot easily be attributed to predictive processing. Instead, we suggest that the spill-over effect of filler–gap

[10] A main effect of word order was also significant at the verb; however, this effect appears to be specific to the given-second condition because the difference was not significant in the given-first condition, as shown by the interaction discussed in the main text.

dependency formation better explains the result. Further research is required to determine to what extent syntactic factors are at work along with the predictive process in the processing of discourse-licensed non-canonical OVS sentences in Finnish.

Overall, the results of Experiment 2 suggest that discourse factors play a crucial role in the processing of subject-initial non-canonical sentences, as is the case with the processing of object-initial ones. The current results give further credence to the view that non-canonical word orders are associated with discourse requirements (Aissen, 1992; Birner & Ward, 2009; Kuno, 1978, 1995). However, it is important to emphasize that this does not mean that syntactic factors become irrelevant once the discourse requirement is satisfied. This is evidenced by the observed slowdown at the final phrase in the $\text{Theme}_{\text{given}}$–Causer condition relative to the $\text{Causer}_{\text{given}}$–Theme condition. The observed persistence of the processing advantage for canonical sentences is consistent with what previous sentence processing studies have found (e.g., Bader & Meng, 2023; Imamura et al., 2016; Jeong et al., 2025; Kaiser & Trueswell, 2004; Koizumi & Imamura, 2017; Miyamoto et al., 2014). We thus conclude that both syntax and information structure are relevant to the processing of non-canonical word orders.

Before moving on to the next section, we note that the current experiment employed pairs of simple sentences in each trial; hence, we expected high accuracy on the secondary forced-choice task, and consequently, no significant accuracy differences among conditions because of a ceiling effect. However, the causer–theme order yielded significantly higher accuracy than the theme–causer order in the given-first condition. Although it is unexpected, the observed significant difference is consistent with our conclusion we drew from the reading-time data: the canonical word order enjoys a processing advantage over its non-canonical counterpart, even when information structure is taken into account. In contrast, in the given-second condition, no significant difference was observed between the causer–theme and theme–causer orders. We must leave it open why we saw a significant difference between the two word orders only in the given-first condition.

5 General discussion

This paper has reported on two self-paced reading experiments investigating how syntax and information structure interact in the phrase-by-phrase processing of subject-initial non-canonical sentences. Our target construction was Japanese inchoatives involving a theme subject and a causer adjunct. To enhance sensitivity to subtle processing effects, we employed a sentence-pair method, in which participants read two unrelated sentences in succession on each trial. This design enabled us to detect processing-time differences using structurally simple sentences within a self-paced reading paradigm. Experiment 1 revealed that the pre-verbal phrase was read more quickly in causer–theme sentences than in theme–causer sentences. This result is consistent with Asami and Tomioka's (2025) conclusion that the causer–theme order is canonical and that

the theme–causer order is derived by an additional movement. Experiment 2 demonstrated an interaction between syntax and information structure at the verb: the reading-time difference between the two word orders was significant when the second phrase was marked as discourse-given but not significant when the sentence-initial phrase was marked as discourse-given. This indicates that information structure is closely associated with the processing of non-canonical sentences. We also found that theme–causer sentences elicited a reading-time slowdown compared to causer–theme sentences at the sentence-final phrase. This asymmetry indicates that syntactic factors are still at work, even when discourse-related factors are taken into account.

In light of the current findings, we (i) revisit the contrasting results reported by Yasunaga et al. (2015) and Yano et al. (2019), (ii) discuss the nature of the processing costs associated with non-canonical sentences, and (iii) highlight our methodological contribution to future research on the online processing of mono-clausal, simple sentences.

5.1 Interaction of syntax with information structure in subject-initial non-canonical sentences

The results of Experiments 1 and 2 showed that both syntactic structure and information structure have an impact on the processing of subject-initial non-canonical sentences. Crucially, processing costs associated with syntactic structure were detected even when discourse-related factors were controlled. This finding aligns with prior research on the processing of object-initial non-canonical constructions (e.g., Bader & Meng, 2023; Kahraman & Hirose, 2018; Kaiser & Trueswell, 2004; Koizumi & Imamura, 2017; Miyamoto et al., 2014; Slioussar, 2011). In light of these results, we now turn to reconciling the contrasting findings of two ERP studies, Yasunaga et al. (2015) and Yano et al. (2019), which investigated the processing of canonical VOS and non-canonical SVO sentences in Kaqchikel and Seediq, respectively.

As introduced in 1.2, using the P600 component as an index of processing cost, Yasunaga et al. (2015) reported a clear processing advantage for canonical VOS sentences over non-canonical SVO sentences in Kaqchikel even when a non-verbal context was provided. In contrast, Yano et al. (2019) found that a similar contextual manipulation significantly reduced the processing cost for non-canonical SVO sentences relative to canonical VOS sentences in Seediq. There are two different possible ways to reconcile the seemingly contradicting ERP studies so that their results are still compatible with our findings.

Yano et al. (2019) proposed that the P600 reflects processing costs arising from a conflict between syntactic structure and information structure (see also Yano, 2019; Yano & Koizumi, 2018). If their interpretation of the P600 is to be adopted, the processing cost associated with non-canonical SVO sentences may still be present in Seediq even when a supportive non-verbal context is present, as the P600 may not be sensitive to this type of cost. Therefore, the findings of Yano et al. (2019) are not incompatible with our conclusion that syntactic processing costs exist even when discourse requirements are satisfied.

The question remains, however, why Kaqchikel and Seediq showed a different P600 pattern. There are at least three potential causes: (i) the non-verbal context used to facilitate pragmatic support, (ii) the syntactic structure of the SVO word order, and (iii) information structure that supports or encourages subject movement. As for the non-verbal contexts in the two studies, the difference is minimal. Both studies employed line drawings depicting events involving two individuals, the subject referent and the object referent, in different colors. It is important to note that the kind of drawing used in the experiments makes both the subject and the object referents discourse-given, which will be a crucial part of the explanation later.

Let us now turn to the syntactic structures of VOS and SVO sentences in Kaqchikel and Seediq. The following are two sample stimuli tested in Yasunaga et al. (2015) and Yano et al. (2019). In these examples, the subjects are marked in boldface. One notable difference between the two languages concerns the morphological marking of the subject in SVO sentences. In Kaqchikel, the fronted subject in SVO order appears morphologically identical to its in-situ counterpart in VOS order. In contrast, in Seediq, the moved subject is marked with the particle *o* on its right edge, while the in-situ subject bears the nominative Case marker *ka* on its left.

(15) Kaqchikel (Yasunaga et al., 2015, 402, (8a, c)):

a. VOS:
Xkoyoj ri xar **ri taq käq**.
CP-ABS3sg-ERG3pl-call DET blue **DET PM red**

b. SVO:
Ri taq käq xkoyoj ri xar.
DET PM red CP-ABS3sg-ERG3pl-call DET blue
'The reds called the blue.'

(16) Seediq (Yano et al., 2019, 402, (7a, b)):

a. VOS:
qmqah emqliyang niyi **ka embanah niyi**.
kick.AV blue DET nom red DET

b. SVO:
embanah niyi o qmqah emqliyang niyi.
red DET CNJ kick.AV blue DET
'The red kicks the blue.'

This morphological difference raises the possibility that subject movement in SVO sentences may differ qualitatively between the two languages. Particularly relevant is the analysis of Seediq by Tang (2011), who treats the particle *o* as the topic marker. The availability of an overt topic-marking strategy can affect the kind of information structure that is suitable for the subject initial word order. Our speculation is as follows. In Kaqchikel, the SVO order is supported by a context where the subject referent is discourse-given and the object referent is discourse-new.

In Seediq, on the other hand, the context that supports the SVO order makes reference only to fronted subjects: being topical, the referent of a fronted subject with *o* should be discourse-given whereas the object referent can be either discourse-new or -given. This asymmetry between the two languages can account for the reported contrast with respect to the P600. Recall that the drawings used in the experiments portrayed both the subject and the object referents as discourse-given. Such a context is only partially congruent with SVO in Kaqchikel. The subject satisfies the condition, but the object does not, and consequently, a P600 effect is expected, as detected in Yasunaga et al. (2015). There is no such incongruity in Seediq, which should lead to significant attenuation of the P600, as observed in Yano et al. (2019).

We also see another possibility that is coupled with the more traditional view of the P600 that this ERP component indexes cognitive load associated with filler–gap dependency formation (e.g., Kaan et al., 2000; Phillips et al., 2005; Ueno & Kluender, 2003). Under this view, the contrast between Kaqchikel and Seediq may come down to the presence vs. absence of a filler–gap dependency in SVO sentences. If a fronted subject with *o* in Seediq is a topic phrase, it is conceivable that a topical subject is base-generated at the sentence-initial position without undergoing any movement, as has been argued for *wa*-marked thematic topic phrases in Japanese (Saito, 1985). This means that the subject-initial stimuli in Yano et al. (2019) may not necessarily involve a filler–gap dependency, which would account for the significant reduction of the P600 in their studies. It can be maintained, on the other hand, that the subject-initial order in Kaqchikel is a result of movement, and the presence of the P600 effect observed in Yasunaga et al. (2015) is straightforwardly interpreted as the effect of a filler–gap dependency that cannot be completely eliminated by their contextual manipulation. The findings in our studies are compatible with this possibility.

To sum up, we reviewed the connection between our studies and the two previous ERP studies of subject-initial non-canonical sentences. Since our knowledge of the grammar of Kaqchikel and Seediq is very limited, our interpretation of their findings remains speculative. However, there is more than one way to accommodate the seemingly contradictory results of the previous studies in such a way that they are compatible with our conclusion that the processing cost associated with a non-canonical structure exists even with matching information structure.

5.2 Nature of processing costs associated with non-canonical sentences

We now turn to the nature of processing costs associated with non-canonical sentences. In Experiment 2, the given–new information structure did not fully eliminate the processing difference between canonical causer–theme and non-canonical theme–causer sentences. The distinction between canonical and non-canonical orders remained evident in the reading times at the sentence-final phrase (*rasii* ‘I hear’) (and in accuracy in the secondary forced-choice task). These findings suggest that satisfying discourse-related constraints does not necessarily eliminate processing asymmetries tied to syntactic configuration.

One potential concern about our experiment is that it did not include a context sentence to explicitly manipulate information structure, which could explain why the processing asymmetry between canonical and non-canonical sentences did not disappear. However, we emphasize that in most reading-time studies, a felicitous context rarely eliminates the processing advantage for canonical word order altogether (e.g., Bader & Meng, 2023; Imamura et al., 2016; Kaiser & Trueswell, 2004; Koizumi & Imamura, 2017; Miyamoto et al., 2014). Moreover, these studies consistently showed that non-canonical sentences seldom become significantly easier to process than their canonical counterparts, even when discourse conditions were carefully controlled. Taken together, these findings suggest that the persistence of the processing asymmetry in our study is not solely attributable to the absence of a context sentence.

In relation to this point, and setting aside the reading-time literature, it is worth highlighting the recent work by Funasaki and Yano (2025) using pupil size or pupillometry as an index of cognitive load. Using auditory stimuli, Funasaki and Yano found that non-canonical OSV sentences in Japanese were, at least temporarily, easier to process than canonical SOV sentences when used as a response to subject-wh questions, which required the subject to be a focus. Based on these findings, they argued that contextually marking the displaced phrase as discourse-given is not sufficient to eliminate the processing asymmetry between canonical SOV and non-canonical OSV sentences. They further suggested that the felicitous use of the OSV order requires not only that the fronted object be discourse-given or topicalized, but also that the pre-verbal subject be interpreted as a focus. We find this interpretation compelling and expand on it as follows: the persistent difficulty in eliminating or overriding the processing asymmetry between canonical and non-canonical word orders suggests that the processing cost associated with non-canonical structures is substantial. This cost may only be canceled out or overridden when multiple discourse conditions are properly satisfied, such as givenness and focus alignment. In other words, the primary source of the processing difficulty may be syntactic in nature, as argued by Koizumi (2023) and others.

Needless to say, the present study has not explored in detail other potential sources of processing cost, including but not limited to anticipatory processes, frequency of certain word orders, and (implicit) prosody (e.g., Kaiser & Trueswell, 2004; Koizumi, 2023; Miyamoto & Nakamura, 2005; Miyamoto & Takahashi, 2002b; Tamaoka et al., 2005). These factors are not mutually exclusive and may jointly contribute to processing difficulty during comprehension. Further research is needed to clarify the respective roles of these sources in shaping real-time processing. In addition, while the current investigation has focused on Japanese, it is important to consider how the present claims generalize to other languages with flexible word order, such as German, Finnish, and Russian (see Kaiser, 2014, 527–533 for a short overview of early studies on these languages and relevant cross-linguistic discussion).

5.3 Sentence-pair method for future sentence-processing studies

Finally, we highlight our methodological contribution to the examination of phrase-by-phrase processing of mono-clausal, simple sentences. As discussed in 2, earlier self-paced reading research often failed to detect processing asymmetries between canonical and non-canonical sentences (Mazuka, 2002; Miyamoto & Takahashi, 2002a; Nakayama, 1995; Tamaoka et al., 2003; Yamashita, 1997). Consequently, several researchers have questioned the suitability of the self-paced reading technique for investigating the online processing of non-canonical structures, particularly when sentences are syntactically simple (Mazuka, 2002; Miyamoto & Nakamura, 2005; Tamaoka & Koizumi, 2006; Witzel & Witzel, 2016). One plausible explanation for the earlier null results is that participants developed a fixed rhythm for pressing the button, which led to minimal variance in recorded reading times (Tamaoka & Koizumi, 2006; Tamaoka et al., 2003). Another possibility is that the experimental sentences themselves were too simple to reveal subtle processing-time differences between canonical and non-canonical structures (Miyamoto, 2008). The present study addressed these concerns by introducing the sentence-pair method, in which each trial consisted of an unrelated filler sentence followed by a target sentence. This method allowed us to detect reliable reading-time differences even with mono-clausal, simple sentences. We interpret this as evidence that the inclusion of an unrelated filler sentence helps to disrupt rhythmic button-pressing and add sufficient complexity to the task, enabling the self-paced reading task to reveal processing costs that might otherwise go undetected.

We acknowledge that the sentence-pair method is not without limitations.[11] One potential concern is that presenting two unrelated sentences in succession is somewhat unnatural, as readers do not typically encounter such a sequence in everyday language use. We were aware of this issue during the experimental design phase and addressed it by having participants complete twelve practice trials, which familiarized them with the atypical format prior to the main experiment (see 3.1.3). Notably, none of the participants reported difficulty with the sentence-pair method itself. A related concern is that the presentation of two unrelated sentences might impede parsing and comprehension. However, this issue does not appear to apply to our experiments because participants' performance on the secondary forced-choice task was consistently high, as evidenced by higher than 90% accuracy.

In light of these potential concerns, we do not claim that the sentence-pair method is *the* best approach for all sentence-processing studies. Like any experimental technique, it has its strengths and limitations and should be employed selectively, depending on the research goals and the nature of the target constructions. As discussed later, there are cases in which this method is particularly useful. On the other hand, when the target constructions are sufficiently complex, such as relative clauses, there is no need to adopt our method. The same holds for

[11] The discussion in this paragraph and the next greatly benefited from comments by an anonymous reviewer.

designs in which a context sentence is followed by a target sentence, as in Miyamoto et al. (2014) and Koizumi and Imamura (2017). In such cases, concerns about failing to detect reading-time differences generally do not arise.

One might suggest that alternative experimental methods (e.g., eye-tracking, maze, and ERP techniques) should be used instead of the self-paced reading paradigm (see Kaiser, 2013, for a review of key experimental paradigms). The use of such methods is indeed valuable and often provides richer data. However, we maintain that the self-paced reading paradigm remains a useful and productive tool, particularly due to its relatively low financial and technical demands; thus, the availability of more advanced paradigms does not diminish the value of our sentence-pair method within the context of self-paced reading studies. Rather, we see our method as a practical enhancement to this widely accessible approach.

Before concluding, let us illustrate how the sentence-pair method can offer new insights into the online processing of structurally simple sentences. As an example, we consider ditransitive constructions in Japanese. These constructions involve a dative-marked indirect object (DAT) and an accusative-marked direct object (ACC), and allow at least two grammatical word orders: DAT–ACC and ACC–DAT. We provide relevant examples below:

(17) a. DAT–ACC:
Junko-ga Ziroo-ni syasin-o mise-ta.
Junko-NOM Ziro-DAT picture-ACC show-PST

b. ACC–DAT:
Junko-ga syasin-o Ziroo-ni mise-ta.
Junko-NOM picture-ACC Ziro-DAT show-PST
'Junko showed Ziro a picture.'

Using a speeded forced-choice task (referred to as a plausibility judgment task in their terminology), Koizumi and Tamaoka (2004) found that DAT–ACC sentences were processed more quickly than ACC–DAT sentences. Based on this result, they concluded that the correct theoretical analysis of Japanese ditransitives aligns with the proposal of Hoji (1985), in which the dative-marked object originates hierarchically above and linearly precedes the accusative-marked object (cf. Matsuoka, 2003; Miyagawa, 1997).

However, Miyamoto and Nakamura (2005) responded critically to Koizumi and Tamaoka (2004), arguing that their theoretical conclusion was premature. They noted that the experimental task in Koizumi and Tamaoka's study only measured the total time to read the entire sentence, offering coarse temporal resolution and leaving unclear when the processing cost was incurred. Miyamoto and Nakamura proposed that the results could be compatible with syntactic theories other than that of Hoji (1985), depending on how sentence processing unfolds incrementally

(see also Miyagawa, 2012, pp. 113–116 for a response to Koizumi & Tamaoka, 2004). Their critique was rich in proposals for future research aimed at probing the nature of the processing differences observed by Koizumi and Tamaoka. However, those proposals have yet to be fully implemented, presumably due to the widespread belief that the self-paced reading paradigm lacks the sensitivity to detect cognitive costs in the processing of structurally simple sentences (see especially Koizumi & Tamaoka, 2006 for a direct response to Miyamoto & Nakamura, 2005). Crucially, our sentence-pair method refutes this belief by demonstrating that the self-paced reading technique, when suitably modified, can detect such subtle processing costs. It is therefore timely to adopt and adapt Miyamoto and Nakamura's ideas to revisit the conclusion drawn by Koizumi and Tamaoka. Needless to say, theoretical analyses of Japanese ditransitives have continued to evolve since the debate between Koizumi and Tamaoka, on the one hand, and Miyamoto and Nakamura, on the other (see, for instance, Asami & Bruening, 2025). Future research should take these theoretical developments into account to formulate a detailed mapping between theories of competence and language processing.

The potential of our sentence-pair method extends beyond the specific case discussed above. We hope that this approach will prove valuable for future research, particularly when processing costs in structurally simple sentences are otherwise difficult to detect with standard methods.

6 Conclusion

This paper reported on two self-paced reading experiments investigating how syntax and information structure interact in the online processing of subject-initial non-canonical sentences. Focusing on Japanese inchoative constructions with a theme subject and a causer adjunct, we found that discourse-related factors substantially but not entirely reduced the processing asymmetry between canonical causer–theme and non-canonical theme–causer sentences. These findings are consistent with the previous research on the processing of object-initial non-canonical sentences. Building on these results, we revisited two seemingly conflicting ERP findings concerning the processing of canonical OVS and non-canonical SVO sentences in Kaqchikel and Seediq (Yano et al., 2019; Yasunaga et al., 2015). We hypothesized that the discrepancy stemmed either from differences in the discourse requirements associated with subject fronting or from a syntactic difference in topic-marking in the two languages. Additionally, we discussed the sources of processing costs involved in comprehending alternative word orders and argued that syntactic factors play the most prominent role. Finally, this study introduced a novel sentence-pair method designed to detect subtle processing costs in mono-clausal, structurally simple sentences in a self-paced reading paradigm. We hope that this methodological innovation will serve as a valuable addition to the toolkit of sentence processing researchers.

Abbreviations

AV = Actor voice; ABS = Absolutive; ACC = Accusative; CL = Classifier; COMP = Complementizer; CONJ = Conjunction; COP = Copula; CP = Completive; DAT = Dative; DET = Determiner; ERG = Ergative; INCH = Inchoative; NEG = Negative; NOM = Nominative; PART = Partitive; PL = Plural; PST = Past; PRES = Present; PROG = Progressive.

Data accessibility statement

All stimuli, data, and analysis code are available at https://osf.io/u9gw2/.

Ethics and consent

Approval for the experiments reported in this paper was obtained from the IRB of the University of Delaware (ID: 2243836-1). All participants gave informed consent prior to the experiments.

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Competing interests

The authors have no competing interests to declare.

Author contributions

DA: Conceptualization, Data curation, Formal (theoretical) analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Validation, Visualization, Writing – original draft, review & editing. **ST**: Conceptualization, Formal (theoretical) analysis, Methodology, Project administration, Supervision, Writing – review & editing.

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