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Chapter 5
The time course of SOV and OSV sentence processing in Japanese

1 Introduction

As native speakers acquire their language, the mental lexicon is developed and stored in their brains. The process of retrieving the meaning of a certain item from the mental lexicon is called lexical access. Psycholinguists often refer to the syntactic operation system believed to exist in the brain as the *parser*. The time course of sentence formation depends on syntactic complexity and semantic context. Any transitive verb indicates what kind of subject phrase and object phrases are required for constructing a sentence. For example, the verb "eat" in the sentence "Tom ate an orange" provides information on the subject "Tom" as an actor and the object "an orange" as a thing to be eaten. This type of information provided by the verb is called *argument information.* A transitive sentence in the verb-final Japanese language has two basic orders: SOV or OSV (S is subject phrase, O object phrase and V verb). These arguments of noun phrases (NPs) are marked by one of three markers: two case markers of nominative *-ga* (NP_{NOM}) and accusative *-o* (NP_{ACC}) and one topic marker *-wa* (NP_{TOP}). These three markers construct four variations of SOV and OSV orders, as in sample sentences (1) to (4). All these sentences carry the same meaning of "(My) mother ate (an) apple." In this sentence, "mother" is understood as "my" mother unless otherwise specified. Moreover, there is no distinction between plural and singular or definite and indefinite articles for "apple." These four formats seem to be processed differently even though they carry the same or at least similar meanings. Thus, an examination of how these sentences are differently processed and the underlying factors is warranted.

(1) SOV canonical order

Haha	*ga*	*ringo*	*o*	*tabe*	*ta*
mother	NOM	apple	ACC	eat	PST

"(My) mother ate (an) apple."

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(2) OSV scrambled order

Ringo	*o*	*haha*	*ga*	*tabe*	*ta*
apple	ACC	mother	NOM	eat	PST

(3) Subject topicalized: the same order as SOV canonical

Haha	*wa*	*ringo*	*o*	*tabe*	*ta*
mother	TOP	apple	ACC	eat	PST

(4) Object topicalized: the same order as OSV scrambled

Ringo	*wa*	*haha*	*ga*	*tabe*	*ta*
apple	TOP	mother	NOM	eat	PST

Sentence (1) "(My) mother ate (an) apple" is in the order of "(my) mother," with nominative case marker -*ga* (NP_{NOM}), "(an) apple," with an accusative case marker -*o* (NP_{ACC}), and finally a past tense verb (V-PST) "ate." This sentence order is canonical in a transitive sentence. In sentence (2) the positions of NP_{NOM} and NP_{ACC} are scrambled, as is characteristic of the OSV order. Again, the final verb "ate" appears at the end of the sentence. A slowing in the speed of sentence processing for the scrambled OSV order relative to the canonical SOV order is frequently observed (e.g., Tamaoka et al. 2005; Tamaoka et al. 2014; Tamaoka and Mansbridge 2019). Thus, the first question (Question 1) arises as to why an OSV scrambled sentence requires additional processing time over a canonical SOV sentence. On this matter, it is also true that the scrambled distance becomes even longer in a ditransitive sentence (O_1SOt_1V; t is trace and O_1 is the originally placed t_1 position) relative to a transitive sentence ($O_1S\ t_1\ V$). A second question (Question 2) is then posed as to whether the scrambled distance affects the processing speed. If so, what is the factor responsible for it?

The verb appears at the end of all sentences from (1) to (4) and contains the argument information necessary to create a sentence structure. In Japanese, this information is only available at the end of the sentence. Thus, a native Japanese speaker cannot identify the cases of NPs required to construct a sentence until the final verb is seen. The third question (Question 3) of whether a verb-final language is disadvantageous for sentence processing subsequently emerges. Furthermore, if native Japanese speakers can process a sentence without the argument information provided by a verb, the question of the function of the final verb for Japanese sentence processing (Question 4) is warranted. This question can be further rephrased to ascertain whether there is any use for argument information in a verb-final language.

Noun phrases in Japanese are topicalized by the topic marker -*wa* (NP_{TOP}). The subject and object can be topicalized by the same topic marker. Sentence (3) is an example of a subject-topicalized ($NP_{SUB\text{-}TOP}$) sentence. This sentence is in the same order as the SOV canonical order. Subject topicalized sentence (3) starts with "Speaking of (my) mother." The subject topicalization also implies an exclusionary meaning, "mother," not other family members. Sentence (4) is an object topicalized ($NP_{OBJ\text{-}TOP}$) sentence. The object topicalization is in the same order as the OSV scrambled order. This sentence starts with "Speaking of (the) apple." This object topicalization also implies an exclusionary meaning, "(the) apple," not other fruits. Finally, the fifth question (Question 5) asks how topicalization affects sentence processing. It can be restated to be measurable as follows: Does a topicalized sentence require longer or shorter processing time than the equivalent non-topicalized sentence? This chapter discusses these five questions in-depth.

2 (Question 1): Why does an OSV scrambled sentence require more processing time than a canonical SOV sentence?

The processing speed and accuracy of Japanese sentences are often measured by a sentence correctness decision task using experimental software (e.g., E-prime, DMDX, PsychoPy). In this task, asterisks ******** indicating an eye-fixation point are presented at the center of a computer screen. Soon after (a 600 ms interval is often used), a stimulus sentence with semantically coherent and anomalous responses is presented to participants in random order. Participants are asked to decide whether the sentences are semantically acceptable by pressing a "Yes" or "No" button. They are also asked to answer as quickly as possible while maintaining accuracy. The task measures the elapsed time between the presentation of a sentence and the participant's subsequent response. This interval is called reaction (or processing) time. Thus, reaction time includes accessing lexical items, constructing a syntactic structure, understanding the meaning of the whole sentence, and finally making the decision.

The canonical order of SOV was found to be processed faster than the scrambled order of OSV in various psycholinguistic studies (e.g., Imamura, Sato and Koizumi 2016; Koizumi and Tamaoka 2004; Mazuka, Itoh, and Kondo 2002; Miyamoto 2006; Miyamoto and Takahashi 2004; Tamaoka et al. 2005; Tamaoka et al. 2014; Tamaoka and Mansbridge 2019; Ueno and Kluender 2003; Witzel and Witzel 2016). Tamaoka et al. (2005) used a sentence correctness decision task to measure the processing time for SOV and OSV sentences such as those presented in (1) and (2). The processing time of an SOV sentence is shorter than that of a scrambled OSV sentence (without any context). Japanese SOV sentences required 1,209 ms on average, while Japanese OSV scrambled sentences required 1,432 ms on average to process. The processing time difference between SOV and OSV sentences was 223 ms. The same trend occurred in processing accuracy for SOV sentences (M = 96.98%, M is the mean) over scrambled OSV sentences (M = 90.93%).

The scrambling effect describes the delay in processing time and more frequent inaccuracy for scrambled OSV-ordered sentences over their SOV canonical counterparts. The sentence processing model of *gap-filling parsing* (Frazier 1987; Frazier and Clifton 1989; Frazier and Flores D'Arcais 1989; Frazier and Rayner 1982; Stowe 1986) provides one possible explanation for the delay with the scrambled OSV order. This scrambling can be explained as a syntactic operation of phrasal movement from the original locus (t_1) of the object (NP_{ACC}-o_1) in the canonical position to the sentence-initial position as in [$_{CP}$ NP_{ACC}-o_1 [$_{IP}$ NP_{NOM}-*ga* [$_{VP}$ t_1 V]]], where IP is the inflectional phrase, and CP, complementizer phrase (or simply O_1S t_1 V). The t_1 (gap_1) indicates the original position in the canonical order from which the NP-o_1 was moved to the sentence-initial position.

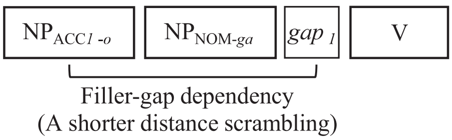

Figure 1: The filler-gap dependency in a transitive sentence (O_1S t_1 V).

From Figure 1, to accomplish the processing of a scrambled sentence, native Japanese speakers must recognize the initial NP_{ACC}-o_1 as the filler and find its original position in VP (gap_1) to establish the filler-gap dependency. Here, given the degree of syntactic complexity, a canonical SOV-ordered sentence is expected to be processed more quickly than its OSV-ordered scrambled counterpart (O_1S t_1 V).

3 (Question 2): Does longer-distance scrambling require longer processing time than shorter-distance scrambling?

From Figure 1, the scrambled distance in a transitive sentence (O_1S t_1 V) comprises only the subject NP_{NOM} (S) between the filler (O_1) and the gap (t_1). It is called shorter-distance scrambling. For longer-distance scrambling (Tamaoka et al. 2005), a ditransitive sentence is used to measure the effect of scrambled distance. When the original locus of the object (NP-*o*, *hon-o* “(a) book”) in the canonical position of sentence (5) is moved to the sentence-initial position, as in sentence (6), the scrambled distance comprises the two NPs of NP_{NOM} (S) and NP_{DAT} (O) between the filler (O_1) and the gap (t_1). This scrambling is denoted as O_1 S O t_1 V.

(5) SOOV canonical order

Hanako	*ga*	*Taro*	*ni*	*hon*	*o*	*kaesi*	*ta*
Hanako	NOM	Taro	DAT	book	ACC	return	PST

“Hanako returned to Taro (a) book.”

(6) O_1 S O t_1 V scrambled order

Hon	*o*	*Hanako*	*ga*	*Taro*	*ni*	*kaesi*	*ta*
book	ACC	Hanako	NOM	Taro	DAT	return	PST

From Figure 2, the gap_1 in O_1 S O t_1 V (t_1 is equal to gap_1) shows the original position in the canonical SOOV order from which the NP_{ACC}-o_1 was moved to the sentence-initial position. Native Japanese speakers must recognize the initial NP_{ACC}-o_1 as the filler and find its original position in gap_1 to establish the filler-gap dependency and process the scrambled sentence. Relative to the transitive sentence in Figure 1, the scrambling in a ditransitive sentence in Figure 2 can be considered a longer-distance scrambling. The effect of the scrambled distance on processing can be probed by comparing the difference in the scrambling effect between transitive and ditransitive sentences.

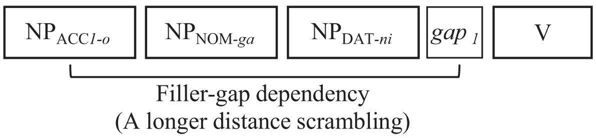

Figure 2: The filler-gap dependency in a ditransitive sentence (O_1S O t_1 V).

Figure 3 shows the processing speed results for shorter- and longer-distance scrambling in (di)transitive sentences. As noted, Tamaoka et al. (2005) report that the difference in the processing time of a transitive sentence between SOV and O_1 S t_1 V (i.e., the shorter-distance scrambling effect) orders was 223 ms. They show that canonical SOOV ditransitive sentences required 1,359 ms on average, while the corresponding O_1S O t_1 V scrambled sentences required 1,963 ms on average. The difference in processing time (i.e., the longer-distance scrambling effect) was 604 ms. Thus, the difference in the scrambling effect between shorter- and longer-distance scrambling was 381 ms (604 ms – 223 ms). The magnitude of the scrambling effect was large even though the scrambled distance differed by only a single NP between transitive and ditransitive sentences.

Further, the percentage difference in processing accuracy between an SOV and an O_1 S t_1 V transitive sentence was 6.05%, while the difference in the accuracy between an SOOV and an O_1 S O t_1 V ditransitive sentence was 10.00%. The difference in the accuracy of the scrambled effect between transitive and ditransitive sentences was 3.95% (10.00% − 6.05%). Relative to shorter-distance scrambling, longer-distance scrambling was more challenging to accurately process. Thus, the scrambled distance caused a larger delay in reaction times and a higher rate of errors, even with a single NP difference.

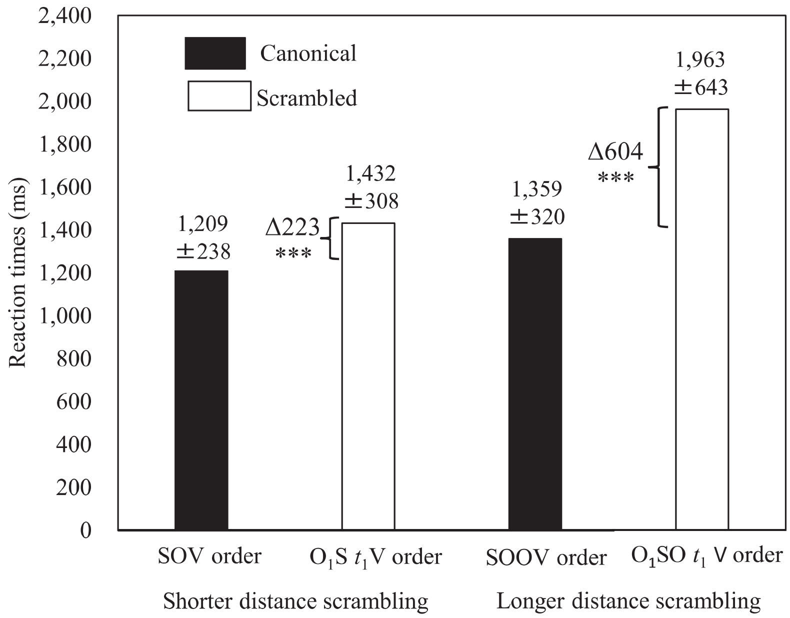

Figure 3: The scrambling effect of shorter- and longer-distance scrambling.
Note: *** p<.001. Δ is the scrambling effect and ± is a standard division.

In Tamaoka et al. (2005), canonical SOV or SOOV sentences were re-arranged into scrambled OSV or OSOV orders, respectively, such that each pair of canonical and scrambled sentences carried the same meaning. Moreover, SOV-OSV and SOOV-OSOV conditions were presented under the same experimental condition, where no previous contextual information was given to native Japanese speakers for the sentence correctness decision task. One weakness may have been that the comparison in differences in the scrambling effect between the shorter SOV-OSV and longer SOOV-OSOV scrambling distances emerged from sentences not being semantically identical. The difference between the shorter and longer scrambling distance was, however, large at 381 ms in speed and 3.95% in accuracy. As Tamaoka et al. (2005) used the simplest syntactic structures of sentences to probe the scrambling effect, the distance effect in scrambling seems to exist as an inhibitory effect in sentence processing. This effect may stem from the distance difference in the filler-gap dependency for performing the gap-filling parsing, as in Figures 1 and 2 for shorter and longer-distance scrambling, respectively.

4 (Question 3): Is a head (verb) final language disadvantageous for sentence formation?

Head-driven parsing (Pritchett 1988, 1991, 1992) suggests that syntactic phrasal structures are established by the head verb that provides necessary argument information for the construction of a sentence (Ikuta et al. 2009; Wolff et al. 2008). According to this processing model, understanding the information provided by the verb is the key to sentence formation. The head-driven parsing model applies best to English and other European languages. However, when the model is extended to other languages, it raises an additional question: are head- (verb)-final languages, such as Japanese and Korean, disadvantageous for sentence formation, unlike head- (verb)-initial languages, such as Kaqchikel and Tongan?

Regarding the head-final language of Japanese, the transitive verb "eat" provides information for the two arguments of the agent "(my) mother" with a nominative case marker ($NP_{NOM\text{-}ga}$) and the theme "(an) apple" with an accusative case marker ($NP_{ACC\text{-}o}$) in sentence (1). The two NPs are linked by the verb "eat." However, as the verb is at the end of the sentence, argument information cannot be utilized by native Japanese speakers. One can follow the two NPs with other verbs, such as "buy," "wash," and "cook." According to the head-driven parsing model, the verb-final position required for a head-final language causes confusion among native speakers, which may explain the delay in sentence processing. However, in such a situation, native Japanese speakers can combine the two NPs to get a head start on processing the whole sentence until the final verb "eat" becomes available.

By contrast, when the head-driven parsing model is applied to verb-initial languages, such as many Austronesian (e.g., Tagalog, Hawaiian, and Tongan) and Mayan (e.g., Kaqchikel, Tz'utujil, and Achi) languages, a great advantage is expected in processing sentences. Native speakers of these languages obtain the argument information from the verb at the beginning of a sentence and can easily process a whole sentence based on argument information. Thus, a distinct difference in reaction time is observed between a verb-initial language and a verb-final language: a sentence of a verb-initial language is processed much faster than an equivalent sentence of a verb-final language.

Koizumi et al. (2014) document reaction times for transitive sentences in canonical VOS and scrambled VSO orders in the verb-initial Kaqchikel language. Sentences with two NPs and a single verb in Kaqchikel transitive sentences may be considered equivalent in constituent elements to a Japanese transitive sentence. The mean reaction times for canonical and scrambled orders in both languages are comparable in cognitive load for sentence processing. As in Figure 4, processing of canonical VOS sentences in Kaqchikel took 3,403 ms on average (89.39% of accuracy) while scrambled VSO sentences took 3,601 ms on average (77.10% of accuracy). The scrambling effect measured 198 ms (3,601 ms in VOS – 3,403 ms SOV). The magnitude of the scrambling effect in Kaqchikel was similar to that of Japanese at 223 ms.

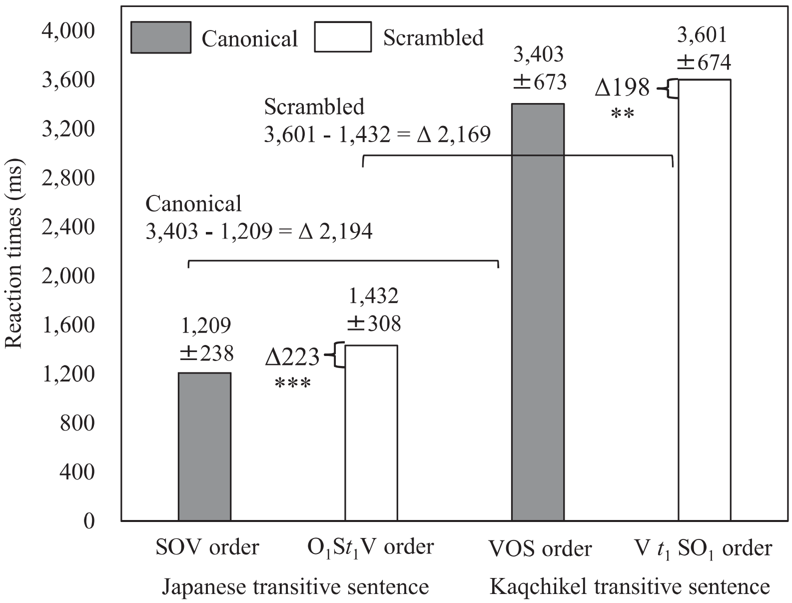

Figure 4: The scrambling effect in transitive sentences in Japanese (visual presentation) and Kaqchikel (auditory presentation).
Note: ** *p*<.01. *** *p*<.001. ± is the standard division.
Δ is the difference in the scrambling effect.

Since Kaqchikel sentences were auditorily presented, reaction times include the length of time for pronouncing a whole sentence. Thus, longer decision times for sentences were expected. The difference in the average reaction times for processing whole transitive sentences in the canonical (or basic word order) was large at 2,194 ms (3,403 ms in Kaqchikel VOS – 1,209 ms Japanese SOV). Moreover, the difference for transitive sentences in scrambled order was also large at 2,169 ms (3,601 ms in Kaqchikel VSO – 1,432 ms Japanese OSV). This difference in reaction times between Japanese and Kaqchikel stemmed from the different presentation methods used for the experiments: visual (auditory) presentation in Japanese (Kaqchikel). Considering that the overall average duration of an auditory presented Kaqchikel sentence is approximately 2,100 ms, native Japanese and Kaqchikel speakers are likely to process sentences at near equivalent times. Likewise, as in Figure 4, the magnitude of the scrambling effect was similar at 223 (198) ms for Japanese (Kaqchikel). Thus, the result does not support the existence of an advantage in sentence processing time in the verb-initial (-final) language of Kaqchikel (Japanese). Japanese and Kaqchikel seem to have similar processing times for canonical and scrambled sentences.

Given that Kaqchikel is a unique language in that the object precedes the subject in its VOS basic word order, examining another head-final Austronesian language, such as Tongan, may add more data useful for analyzing the scrambling effect. In Tongan, VSO is the canonical order of transitive sentences, while VOS is also grammatically possible as a scrambled order sentence (Churchward 1953; Custis 2004; Dixon 1979, 1994; Otsuka 2000, 2005a, 2005b). During a sentence correctness decision task, native speakers of the verb-initial Tongan language were observed to process simple transitive sentences, such as “The woman ate the fish.” The result showed an average speed of 1,643 ms for the VSO canonical order and 1,753 ms for VOS scrambled order (data yet to be published). The difference in speed was 110 ms (significant at 0.001 level). Although the magnitude of the scrambling effect was much smaller than that for Japanese and Kaqchikel, the scrambling effect was still apparent in Tongan.

Regarding Kaqchikel and Tongan, there is no advantage evidence in the processing of head- versus verb-initial language sentences. Therefore, the verb-initial order cannot be considered advantageous in sentence processing. The head-driven parsing model may be a good fit for English and other European languages. However, the head-final language of Japanese seems to rely on features other than verb information for advantageous sentence processing. Notably, Tamaoka and Mansbridge (2019) show that the argument information provided by the verb is an important factor for processing a sentence in Japanese. This factor will be introduced in the following section.

5 (Question 4): What function does a finally positioned verb have for sentence processing?

If the verb-initial position is not advantageous for sentence processing, how is a sentence in the verb-final language of Japanese processed? Kamide and Mitchell (1999) and Kamide, Altmann, and Haywood (2003) provided evidence for pre-head processing using the "visual-world" eye-tracking paradigm. In this paradigm, multiple pictorial items are presented on a single screen, some of which regard a sentence that is auditorily presented. Participants look at this screen for approximately one second. A sentence is then auditorily presented and the sequential duration of eye-fixation times is recorded by the eye-tracker. Kamide and Mitchell (1999) and Kamide, Altmann and Haywoodet (2003) find that participants were likely to focus on pictorial items on the screen, which had not yet been auditorily presented. Accordingly, Kamide and Mitchell (1999) suggested that advance planning for comprehending sentences occurs incrementally before the final verb is seen. Native Japanese speakers can anticipate the formation of a sentence based on the argument information provided by the NPs' case markers.

Figure 5 shows the processing sequence of the Japanese SOV sentence (1). Native Japanese speakers see or hear the agent *haha-ga* "(my) mother" first. They can identify the subject phrase by referring to the nominative case marker *-ga* ($NP_{NOM\text{-}ga}$). At this stage, native Japanese speakers already know that "(my) mother" is the actor. Next, the theme *ringo-o* "(an) apple" with the accusative case marker ($NP_{ACC\text{-}o}$) follows. By relying on these case markers, native Japanese speakers can begin to form a sentence containing two NPs, as in [$_{IP}$ NP(mother)$_{NOM\text{-}ga}$ [$_{VP}$ NP(apple)$_{ACC\text{-}o}$. . .]]. Then, they simply wait for the ending verb *tabe-ta* "ate" to complete the sentence. Thus, for pre-head anticipatory processing (Kamide and Mitchell 1999; Kamide, Altmann and Haywoodet 2003; also see Kamide 2008; Altmann and Kamide 1999 for general discussion), the first part of a Japanese sentence is formed before seeing the ending verb.

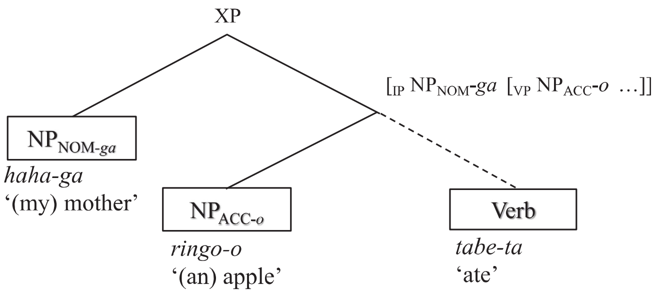

Figure 5: Pre-head anticipatory sentence processing based on case markers.

If anticipatory processing takes place as Kamide et al. (1999, 2003) describe, one may wonder whether a Japanese verb has any role in sentence processing. An eye-tracking study by Tamaoka and Mansbridge (2019) shows that even a simple transitive sentence with a shorter-distance scrambling, as in Figure 1, involves pre-head anticipatory processing (Kamide 2008; Kamide and Mitchell 1999; Kamide, Altmann, and Haywood 2003) and head-driven processing (Pritchett 1988, 1991, 1992). Tamaoka and Mansbridge (2019) employ a set of sentences (7) and (8) to investigate the mechanism of processing. Note that sentence (8) is not the exact equivalent of the scrambled ordered sentence (7). Ideally, for measuring eye-fixation times in each region, the words of paired canonical and scrambled sentences should be as similar as possible. For instance, the only difference in the NP in Region 1 was the single case marked *Taro, -ga* in sentence (7) and *-o* in sentence (8). Similarly, Region 2 was controlled such that the only difference was the case marked *Hanako, -o* in sentence (7) and *-ga* in sentence (8). The ending verb *syootaisi-ta* "invited" was retained. Eye-fixation durations and regression-in and -out frequencies in each region were recorded using the EyeLink 1000 Core System (SR Research Ltd., Ontario, Canada) for whole sentence reading by native Japanese speakers.

(7) SOV canonical order

Region 1		Region 2		Region 3	
Taro	*ga*	*Hanako*	*o*	*syootaisi*	*ta*
Taro	NOM	Hanako	ACC	invite	PST

"Taro invited Hanako."

(8) O_1 S t_1 V scrambled order

Region 1		Region 2		Region 3	
Taro	*o*	*Hanako*	*ga*	*syootaisi*	*ta*
Taro	ACC	Hanako	NOM	Invite	PST

The results of processing transitive sentences in Figure 6 are recorded in milliseconds, with Δ indicating differences in fixation times between O_1 S t_1 V and SOV transitive sentences. Processing times for canonical ordered sentences were subtracted from those for scrambled ordered sentences. The involvement of pre-head anticipatory processing (e.g., Aoshima, Phillips, and Weinberg 2004; Aoshima, Yoshida, and Phillips 2009; Kamide 2008; Kamide and Mitchell 1999; Kamide, Altmann and Haywoodet 2003; Miyamoto 2006; Mazuka, Itoh and Kondo 2002; Witzel and Witzel 2016) indicated a significantly longer "go-past time" of Δ 129 ms in Region 2 before the verb appears (see details of eye-tracking measurements in Tamaoka and Mansbridge 2019). The ending verb in Region 3 also received a significantly longer go-past time of Δ 140ms.

Additionally, evidence of heavy head-driven processing (Ikuta et al. 2009; Wolff et al. 2008) was seen in the re-reading time of Δ147 ms in Region 2. Given that the gap_1 (or t_1) in O_1 S t_1 V scrambled sentences is found between $NP_{NOM\text{-}ga}$ (S) in Region 2 and the head verb (V) in Region 3, the significantly longer re-reading time suggested that native Japanese speakers read back to the crucial $NP_{NOM\text{-}ga}$ in Region 2 to check the argument structure of $NP_{NOM\text{-}ga}$ and $NP_{ACC\text{-}o}$ after seeing the head verb. This trend was further supported by the occurrence of significantly higher regression-in frequency of Δ 13% for O_1 S t_1 V scrambled sentences in Region 2 from the ending verb.

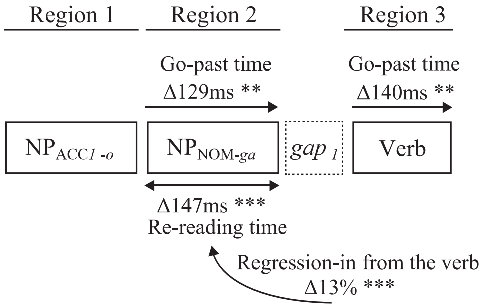

Figure 6: Processing of scrambled transitive sentences observed by eye-tracking.
Note: ** p<.01. *** p<.001. Δ (ms) is a difference in fixation time (O_1 S t_1 V – SOV).

In summary, a scrambled $NP_{ACC\text{-}o}$ and $NP_{NOM\text{-}ga}$ order trigger pre-head anticipatory processing to form a partial sentence structure. However, commonly-used individuals' first names as two NPs do not provide sufficient information to establish the filler-gap dependency. The O_1 S t_1 V sentence was most often read up to the head verb and then read back to the crucial $NP_{NOM\text{-}ga.}$ Evidence of reading backward from the ending verb to Region 2 and re-reading times in Region 2, as observed by Tamaoka and Mansbridge (2019), suggests that native Japanese speakers require the argument information provided by the verb to resolve the filler-gap dependency of scrambling even in simple transitive sentences.

Processing scrambled sentences was further probed in complex sentences comprising three NPs and two verbs in the [S [SOV] V] format. Tamaoka and Mansbridge (2019) embedded the stimulus sets in sentences such as (7) and (8) into complex sentences, as in sentences such as (9) and (10). Again, sentence (10) is not based exactly on sentence (9). However, a direct comparison of eye fixations and regression-in and -out in an eye-tracking study requires only that the same noun is used in each Region. In sentence (10), the filler O_1 or $NP_{ACC\text{-}o1}$ was moved from the original locus of the embedded sentence (t_1) to the sentence-initial position of Region 1 as ([O_1 S [S t_1 V] V]). Notably, Tamaoka and Mansbridge (2019) used short-distance scrambling in complex sentences. However, an analysis of that condition is omitted here to simplify the discussion.

(9) [S [SOV] V] canonical order

Region 1		Region 2		Region 3		Region 4	
Kenji	*ga*	*Taro*	*ga*	*Hanako*	*o*	*syootaisi*	*ta*
Kenji	NOM	Taro	NOM	Hanako	ACC	invite	PST

Region 5		
to	*kii*	*ta*
COMP	hear	PST

"Kenji heard that Masato helped Keiko."

(10) [O_1 S [S t_1 V] V] scrambled order

Region 1		Region 2		Region 3		Region 4	
Kenji	*o*	*Taro*	*ga*	*Hanako*	*ga*	*syootaisi*	*ta*
Kenji	ACC	Taro	NOM	Hanako	ACC	invite	PST

Region 5		
to	*kii*	*ta*
COMP	hear	PST

The results of complex sentence processing, measured by eye tracking, as in Figure 7, are recorded in milliseconds, with Δ indicating differences in fixation times between canonical sentences [S [S O V] V] and scrambled sentences [O_1 S [S t_1 V] V]. Processing times for canonical ordered sentences were subtracted from those for scrambled ordered sentences. The initial NP_{ACC1} in Region 1 had no significant go-past time. The second NP_{NOM} had a significant go-past time (Δ49 ms). As for Kamide et al. (1999, 2003), the OS order or the *o*-and-*ga* order in Regions 1 and 2 can provide the initial basis for a partially constructed phrasal structure [$_{IP}$ $NP_{NOM\text{-}ga}$ [$_{VP}$ $NP_{ACC\text{-}o}$ . . .]]. At the early processing stage (i.e., go-past time), there was no extra processing in Region 3 for a scrambled sentence. Commonly-used individuals' first names as the three NPs do not provide sufficient information to establish the filler-gap dependency. Thus, native Japanese speakers read ahead until they reach the subsequent two verbs: the verb in the subordinate clause in Region 4 (Δ739 ms) and that in the main clause in Region 5 (Δ1,147 ms). Eye fixation on these two verbs lasted much longer than on their corresponding complex sentences, as in Figure 7. At the later stage of processing, re-reading time and regression-in were highly significant in multiple Regions of complex sentences. These significant re-reading times were seen in all three NPs; $NP_{ACC\text{-}o}$ in Region 1 (Δ292 ms), $NP_{NOM\text{-}ga}$ in Region 2 (Δ256 ms), and $NP_{NOM\text{-}ga}$ in Region 3 (Δ369 ms). After obtaining argument information from the verbs in the subordinate and main clauses, native Japanese speakers read back to all three NPs to properly form the noun phrase structure. Given that significant re-reading times were observed in Region 4 (Δ171 ms), this pattern is especially salient in cases where the verb is seen in the subordinate clause. This trend was also seen in the significant frequencies of regression-in into $NP_{ACC\text{-}o}$ in Region 1 (Δ24%) and $NP_{NOM\text{-}ga}$ in Region 3 (Δ19%).

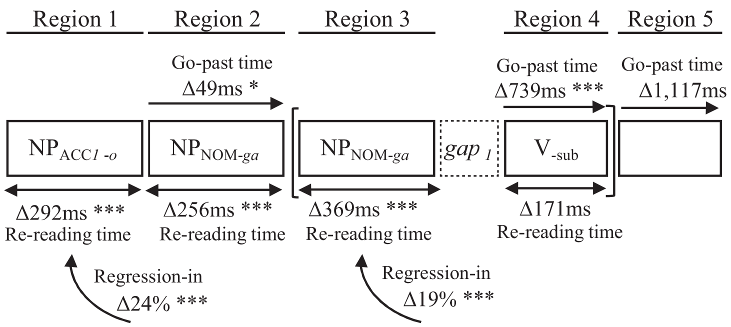

Figure 7: Processing of a scrambled complex sentence measured by eye-tracking.
Note: * p<.05. *** p<.001. Δ (ms) is the difference in fixation times while Δ (%) is the difference in frequencies of regression-in. The differences were calculated by subtracting the processing time for the canonical order [S [SOV] V] from that of the scrambled order [O_1 S [S t_1 V] V] in each region.

As Kamide et al. (1999, 2003) have proposed, pre-head anticipatory processing is observed in head-final languages, such as Japanese. Furthermore, an eye-tracking study by Tamaoka and Mansbridge (2019) showed longer go-past times for verbs and re-reading times in all three NPs. Regression-in to $NP_{NOM\text{-}ga}$ was found in simple transitive and complex sentences. Native Japanese speakers must establish a relationship between the filler $NP_{ACC\text{-}o1}$ and the *gap*$_1$ after obtaining argument information given by the verb to perform gap-filling parsing. Thus, depending on the availability of processing cues, native Japanese speakers must perform pre-head and head-driven (post-head) processing for scrambled sentences.

6 (Question 5): How does the nature of topicalization affect sentence processing?

Topicalization in Japanese is produced by the topic marker -*wa*. The subject and the object can be topicalized, as shown by the subject topicalization ($NP_{SUB\text{-}TOP}$) in sentence (3) and the object topicalization ($NP_{OBJ\text{-}TOP}$) in sentence (4). A topicalized phrase is usually positioned at the beginning of a sentence. When a topicalized NP is placed in the second or even later position, the sentence becomes less acceptable. This phenomenon warrants further investigation via a simple questionnaire survey of naturalness judgments.

Shibatani (1990) proposed that $NP_{SUB\text{-}TOP}$ of transitive sentences ($S_{TOP}O_{ACC}V$) are external to the IP in $[_{CP}\ NP_{SUB\text{-}TOP1}\ [_{IP}\ t_1\ [_{VP}\ NP_{ACC}\ V]]]$. In this structure, $NP_{SUB\text{-}TOP}$ belongs to a CP, placed structurally higher than the IP. If true, $S_{TOP}O_{ACC}V$ will be more complex in syntactic structure than $S_{NOM}O_{ACC}V$. The difference in structural complexity predicts that $S_{TOP}O_{ACC}V$ sentence processing will take longer than S_{NOM} $O_{ACC}V$ sentence processing. Moreover, since $S_{TOP}O_{ACC}V$ involves only a topicalized movement, which does not move beyond any NP, the scrambled $O_{ACC}S_{NOM}V$ order is anticipated to take longer to process than the $S_{TOP}O_{ACC}V$ order. Moreover, the order of an object topicalized ($NP_{OBJ\text{-}TOP}$) transitive sentence is $O_{TOP}S_{NOM}V$, which is the same order as the scrambled order of $O_{ACC}S_{NOM}V$. Kuroda (1987) further proposed that $NP_{OBJ\text{-}TOP}$ involves a topicalization movement and a scrambling movement. Because $NP_{OBJ\text{-}TOP}$ involves movements of both topicalization and scrambling, sentence structure becomes even more complex than the scrambled $O_{ACC}S_{NOM}V$. This difference in structural complexity yields a prediction that $O_{TOP}S_{NOM}V$ will require longer processing time than will $O_{ACC}S_{NOM}V$. As for the discussion of syntactic structure (Kuroda 1987; Shibatani 1990), Imamura, Sato and Koizumi (2016) hypothesized the following order in sentence processing speed.

$S_{NOM}O_{ACC}V$	=	$S_{TOP}O_{ACC}V$	<	$O_{ACC}S_{NOM}V$	<	$O_{TOP}S_{NOM}V$
Canonical		Topicalizatio		Scrambled		Topicalization and Scrambled

Figure 8: Assumed order of sentence processing speed based on syntactic complexity.
Note: Reproduced from Imamura, Sato and Koizumi 2016, p. 5.

Imamura, Sato and Koizumi (2016, Experiment 1) created four types of sentences exemplified in sentences (11) to (14) to confirm the hypothesized order of sentence processing in Figure 8. These stimulus sentences used commonly-used family names such as Sato, Suzuki, Iida, and Hirota. The family names were used interchangeably between the subject (e.g., *Suzuki-ga*) and object (e.g., *Suzuki-o*). In this situation, native Japanese speakers could not utilize semantic cues of animacy contrast, such as "(my) mother" and "(an) apple" to construct a partial sentence structure before seeing the ending verb.

(11) S_{NOM} O_{ACC} V: Canonical order

Satoo	*ga*	*Suzuki*	*o*	*home*	*ta*
Sato	NOM	Suzuki	ACC	praise	PST

"Sato praised Suzuki."

(12) S_{TOP} O_{ACC} V: Subject topicalized order
Satoo wa Suzuki o home ta
Sato TOP Suzuki ACC praise PST

(13) O_{ACC} S_{NOM} V: Scrambled order
Suzuki o Satoo ga home ta
Suzuki ACC Sato ACC praise PST

(14) O_{TOP} S_{NOM} V: Object topicalized order
Suzuki wa Satoo ga home ta
Suzuki TOP Sato ACC praise PST

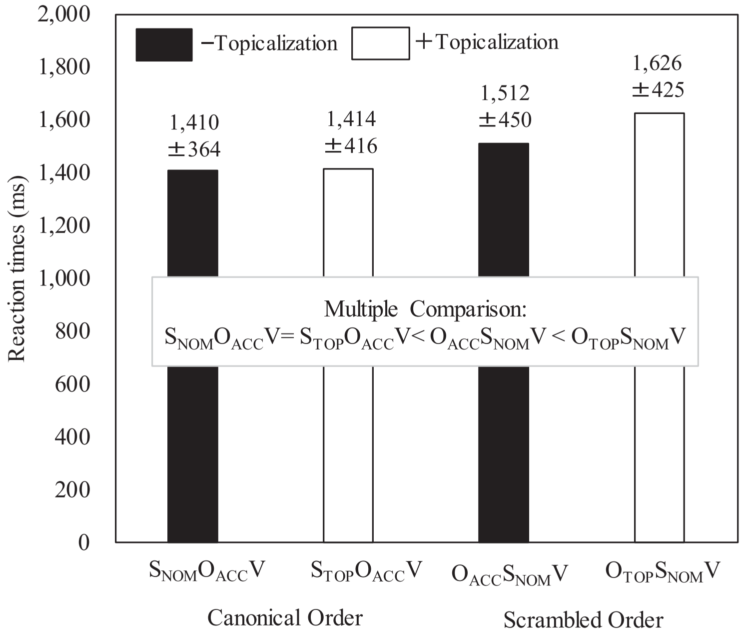

Figure 9: Processing topicalized sentences with canonical and scrambled orders.
Note: ± is the standard division. Taken from Imamura, Sato and Koizumi 2016, p. 6.

Using a sentence correctness decision task, Imamura, Sato and Koizumi (2016) presented whole sentences to participants who were asked to decide whether the sentences were syntactically and semantically correct. Given that the four types of sentences presented in this part of the study contained the same constituent elements of nouns and verbs, reaction times were directly comparable. Figure 9 shows the means of sentence processing speeds in Imamura, Sato and Koizumi (2016). There was a difference of only 4 ms in processing speed between the canonical $S_{NOM}O_{ACC}V$ (M = 1,410 ms, M refers to the mean reaction time) and the subject topicalized $S_{TOP}O_{ACC}V$ (M = 1,414 ms) sentences. Given no difference in processing time between the canonical $S_{NOM}O_{ACC}V$ and the subject topicalized $S_{TOP}O_{ACC}V$ sentences, the syntactic structure with movement, as proposed by Shibatani (1990) and Kuroda (1987), may not represent the "psychological reality" of sentence processing. This result implies that subject topicalization may occur without any movement. Imamura, Sato and Koizumi (2016) explain that $S_{NOM}O_{ACC}V$ and $S_{TOP}O_{ACC}V$ would be processed as the SOV canonical order.

The overall scrambling effect between $S_{NOM}O_{ACC}V$ plus $S_{TOP}O_{ACC}V$ (the mean of both conditions was M = 1,412 ms) and $O_{ACC}S_{NOM}V$ plus $O_{TOP}S_{NOM}V$ (the mean of both conditions was M = 1,569 ms) was significantly greater at 157 ms. Thus, the scrambling effect accords with previous studies (e.g., Koizumi and Tamaoka 2004, 2010; Mazuka, Itoh and Kondo 2002; Miyamoto and Takahashi 2004; Tamaoka et al. 2005; Tamaoka, et al. 2014; Ueno and Kluender 2003).

The topicalized object sentences $O_{TOP}S_{NOM}V$ (M = 1,626 ms) took significantly longer to process than did the scrambled sentences $O_{ACC}S_{NOM}V$ (M = 1,512 ms). The increasing order of processing speed of $S_{NOM}O_{ACC}V < O_{ACC}S_{NOM}V < O_{TOP}S_{NOM}V$ may be accounted for by syntactic complexity. In any case, Imamura, Sato and Koizumi (2016) discount Shibatani's (1990) topicalization movement proposal for $S_{TOP}O_{ACC}V$. If topicalization does not involve any movement, $O_{TOP}S_{NOM}V$ may involve only a single movement of scrambling: $O_{TOP}S_{NOM}V$ takes on the same structure as $O_{ACC}S_{NOM}V$. Thus, no difference in processing speed between $O_{ACC}S_{NOM}V$ and $O_{TOP}S_{NOM}V$ should have been found in their experiment. Nevertheless, the results indicated that $O_{TOP}S_{NOM}V$ took longer to process than $O_{ACC}S_{NOM}V$. Hence, this result supports the idea of double movements of scrambling and topicalization proposed by Kuroda (1987).

Recapping the processing result of Imamura, Sato and Koizumi (2016), the subject topicalized word order of $S_{TOP}O_{ACC}V$ is the same as that of the canonical $S_{NOM}O_{ACC}V$. Thus, as Imamura, Sato and Koizumi (2016) suggest, this order seems to be commonly used such that the structures of $S_{NOM}O_{ACC}V$ and $S_{TOP}O_{ACC}V$ are easily understood within a short processing time. A simple explanation could be that the use of the topic marker *-wa* in the SOV order by native Japanese speakers is interpreted as forming the subject with the topicalized NP-*wa*. Stimulus sentences by Imamura, Sato and Koizumi (2016) using two family names included an example of subject topicalization (S_{TOP}) in the sentence *Sato-wa Suzuki-o hometa*. On reading the name Sato, it is understood that no other actor praised Suzuki. This exclusionary meaning may not function well for S_{TOP} and may also explain the lack of processing time difference between $S_{NOM}O_{ACC}V$ and $S_{TOP}O_{ACC}V$. The lesser degree of interpretability for the exclusionary meaning makes it easier to understand S_{NOM} and S_{TOP} as simply the subjects of a sentence.

Conversely, with the object topicalization (O_{TOP}) of *Sato-wa Suzuki-ga hometa*, Sato is the recipient of praise from the actor Suzuki. In this sentence, the recipient object Sato is placed at the beginning of the sentence by topicalization. However, this placement also stems from scrambling movement. By topicalizing the object Sato, it is probably easier to understand the exclusionary meaning. Among the group who could be praised, only Sato was praised by Suzuki. This semantic processing may require longer processing time than does the scrambled $O_{ACC}S_{NOM}V$. Consequently, the degree of ease for exclusionary interpretation by the topic marker *-wa* could be an additional factor in the resultant extra processing load for the object topicalized $O_{TOP}S_{NOM}V$.

The Japanese topic marker *-wa* appears to have dual functions of sentence-initial topicalization and exclusionary focus. As for Imamura, Sato and Koizumi (2016), future studies should clarify the exclusionary function of the Japanese topic marker *-wa*. Proof of a clear exclusionary meaning could be established by using sentences with animacy contrast. For example, sentence (3) *haha-wa ringo-o tabe-ta* has clear animacy contrast in that "my mother," not any other family member, ate an apple. In object topicalization, the focus is on "an apple," not any other fruits, which my mother ate. The function of the topic marker *-wa* could be clarified by setting a clear exclusionary meaning in a sentence.

Further, to avoid interference from canonical and scrambled word orders in identifying topicalization in the Japanese language, it would be advisable to use other VSO-ordered languages, such as Tagalog, Hawaiian, and Tongan for comparison. For example, the canonical order of the Tongan language is VSO (Churchward 1953; Custis 2004; Dixon 1979, 1994; Otsuka 2000, 2005a, 2005b). As with the Japanese language, the subject and object may be topicalized. When the subject is topicalized, S_{TOP} is placed before the verb as SVO. Native Tongan speakers also perceive the topic of the sentence "mother" signifies that it was not any other family member who ate an apple. When the object is topicalized, O_{TOP} is placed before the verb as OVS, signifying that it was "an apple," not any other fruit, the mother ate. The topicalized NP is placed before the verb as SVO or OVS. Thus, the word order of topicalization in the Tongan language does not overlap with either canonical or scrambled orders in Japanese. Hence, a verb-initial language such as Tongan is ideal for probing the processing function of topicalization.

7 Closing remarks

The question of how SOV and OSV transitive sentences in Japanese are processed can be summarized as follows: The SOV order is the basic structure for sentence processing in Japanese. An OSV scrambled sentence is processed using gap-filling parsing (establishing the filler-and-gap dependency). Even though pre-head anticipatory processing will function before the final verb appears, head-driven processing (verb argument information) is also required, especially for processing an OSV scrambled ordered sentence. Topicalization of a Japanese subject marked by *-wa* has a dual function of stating the topic at the beginning of the sentence and adding an exclusionary meaning. Nevertheless, as subject topicalization uses the same word order as the canonical SOV, a topicalized noun phrase may be interpreted as being the subject, as is an NP marked by the nominative case marker *-ga*. It applies all the more so when there is no clear semantic distinction between the subject and the object. By contrast, object topicalization is understood as sentence-context topicalization and exclusionary-semantic focus. The processing of the dual functions of topic marker *-wa* may explain the longer processing time required over the OSV scrambled order. Future studies can probe Japanese sentence processing by comparing Japanese to languages with different canonical orders, especially verb-initial languages, such as Tongan in which subject-object topicalized order does not overlap with canonical or scrambled order.

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