

PROCESSING RELATIVE CLAUSES IN FIRST AND SECOND LANGUAGE:
A CASE STUDY

DISSERTATION

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By

Akiko Kashiwagi, B.A., M.A.

Graduate Program in
East Asian Languages and Literatures

The Ohio State University

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Dissertation Committee:
Professor Mineharu Nakayama, Advisor
Professor Etsuyo Yuasa
Professor Shari Speer

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ABSTRACT

This dissertation investigates processing of English and Japanese relative clause (RC) sentences by native speakers and second/foreign language (L2) learners.

Particularly, the relationship between the sentence processing and individual differences in working memory (WM) capacity was examined. The main question addressed in this study is whether the performances of L2 learners in processing RCs are similar to those of native speakers depending on one's WM capacity.

Two major approaches regarding the processing of RCs have been proposed to account for the differences between the difficulty of the subject-gap and the object-gap sentences: the cost of resources taken up by temporary storage and integration when processing (Dependency Locality Theory; Gibson, 1998, 2000) and the depth of embedding of the extracted element (Structural Distance Hypothesis; O'Grady, 1987; O'Grady, Yamashita, Lee, Choo and Cho, 2000). This study also evaluated these two hypotheses and answers the question: To which hypothesis do the performances of L2 learners best correspond?

Fourteen English native speakers who were Japanese language learners and 14 Japanese native speakers who were English language learners participated in the experiment, which consisted of three parts: First language (L1) and L2 reading span tests, L1 and L2 self-paced moving window reading tasks, and a L2 proficiency test. The comprehension accuracy rates of the experimental sentences and individuals' residual

reading times in each region of the RC sentence types were used for comparisons. Additionally, the individual participants' sentence reading patterns were examined, so what may have been invisible on the group level analyses were revealed.

The results of the experiments showed that (1) English object-gap sentences are more difficult to comprehend than English subject-gap sentences for both L1 native speakers and L2 learners, (2) Japanese subject-gap sentences are more difficult to comprehend than Japanese object-gap sentences for both L1 native speakers and L2 learners, which supported Dependency Locality Theory and (3) the differences in comprehension accuracy rates, if any, were seen between the lower WM L2 learners and the group of the higher WM L2 learners and the native speakers. The results of the individual reading pattern comparisons showed that (4) there seems to be a commonly-preferred reading pattern among the native speakers in processing the subject-gap and object-gap sentences, and (5) L2 learners who demonstrated reading patterns dissimilar to the L1 native speakers' commonly-preferred reading pattern showed a tendency of having a lower WM capacity, and both of these tended to have an effect on L2 comprehension accuracy.

It was concluded that the performances of L2 learners in processing RCs can be similar or dissimilar to those of native speakers depending on one's WM capacity. It was also concluded that having a lower WM capacity seems to hinder processing a sentence in a way similar to the native speakers. Moreover, for L2 learners, being unable to process L2 sentences in the manner that is commonly preferred by the native speakers seems to lead to lower comprehension accuracy in the RC sentences, especially in the more-difficult-to-comprehend English object-gap and Japanese subject-gap sentences.

Dedicated to my family

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VITA

January 1976Born – Kanagawa, Japan

1999.....B.A. Japanese Language and Studies,
Tokyo University of Foreign Studies,
Tokyo, Japan

2001.....M.A. TESOL/Bilingual Education,
The University of Findlay, Findlay, Ohio

1999-2001Graduate Teaching Associate,
The University of Findlay, Findlay, Ohio

2003M.A. East Asian Languages and Literatures,
The Ohio State University, Columbus, Ohio

2001-2006Graduate Teaching Associate,
The Ohio State University, Columbus, Ohio

2007-2008Lecturer of Japanese,
Oakland University, Rochester, Michigan

PUBLICATION

Research Publication

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LIST OF ABBREVIATIONS

Acc	Accusative
Comp	Complementizer
Dat	Dative
Gen	Genitive
N	Noun
Nom	Nominative
NP	Noun Phrase
RC	Relative Clause
S	Sentence
Top	Topic marker
V	Verb
VP	Verb Phrase

CHAPTER 1

INTRODUCTION

First language (L1) processing research has shown that various linguistic aspects such as syntactic, semantic, pragmatic, and prosodic, as well as individual differences in working memory (WM) capacity play important roles in parsing sentences (see Clifton and Duffy, 2001; Gibson and Pearlmutter, 1998, for a review). A great deal of understanding has been achieved on L1 processing in the past several decades, yet sufficient research has not been carried out on online second/foreign language (L2) processing despite the fact that there are increasing numbers of people who are proficient in more than one language. If the ultimate goal of language processing research is to understand the nature of the human cognitive mechanisms, then understanding how L2 learners comprehend and process L2 sentences should help better understand the mechanisms as well as how L2 learners acquire and construct L2 system.

The relationship between individual differences in WM and L2 parsing behavior has not been fully investigated. From L1 processing research, we know that the L1 parser takes different parsing strategies depending on the size of one's WM capacity (e.g. Just and Carpenter, 1992). The question naturally arises as to whether the L2 parser also takes different parsing strategies depending on the size of one's WM capacity. If the L2 parsing

mechanism was similar to that of L1 parsing, then L2 learners of different WM capacity would take different parsing strategies in reading L2 sentences. If WM capacity does not affect L2 sentence processing, then it may indicate a substantial difference in processing L1 and L2, possibly indicating that in a foreign language, one will never process the language the same way as a native speaker. If this were shown to be the case, it would contribute a step forward in the understanding of the human cognitive mechanisms.

Another question that may arise is whether L2 learners behave similarly to L1 native speakers in reading L2 sentences. Assuming processing L2 adds more burdens on the processing mechanism because the retrieval of lexical and grammatical knowledge may be more difficult in L2 than in L1, L2 learners with a large WM capacity may be able to process sentences in a similar manner as the native speakers. In other words, between the large and the small WM capacity L2 learners, only the ones with the large WM capacity—those who have sufficient processing resources—may be able to behave similarly to native speakers while the ones with the small WM capacity would suffer from the limitation of memory resources and fail to process L2 input efficiently and in a native-like manner.

This dissertation presents the results of self-paced moving window reading experiments investigating how individual differences in WM would influence L1 and L2 sentence processing. In particular, we will examine the performances of English native speakers who are Japanese language learners and Japanese native speakers who are English language learners in their respective L1 and L2. The sentence structures examined in all of the sentence reading experiments are English subject-gap and object-

gap relative clause (RC) sentences and Japanese subject-gap and object-gap RC sentences, as exemplified in (1) and (2), respectively.

(1a) English subject-gap RC

The reporter_{*i*} [who *e_i* attacked the senator] admitted the error.

(1b) English object-gap RC

The reporter_{*i*} [who the senator attacked *e_i*] admitted the error.

(2a) Japanese subject-gap RC

[*e_i* Giin-o hinanshita] repootaa_{*r*}-ga machigai-o mitometa.

e_i senator-acc criticized reporter-nom error-acc admitted

‘The reporter who criticized the senator admitted the mistake.’

(2b) Japanese object-gap RC

[Giin-ga *e_i* hinanshita] repootaa_{*r*}-ga machigai-o mitometa.

senator-nom *e_i* criticized reporter-nom error-acc admitted

‘The reporter who the senator criticized admitted the error.’

Examining the online sentence reading performances of subject-gap and object-gap sentences in English and in Japanese is interesting because they are different in many ways (Kuno, 1973; Tsujimura, 1996). Many of the differences are due to the differences between the two languages’ canonical word order, i.e. Subject-Verb-Object (SVO) for English and Subject-Object-Verb (SOV) for Japanese. First, Japanese RCs are prenominal, in which the RC precedes its head noun. On the other hand, English RCs are

postnominal, in which the RC follows its head noun. Second, Japanese has no relative pronouns whereas English has relative pronouns such as *who* and *that*. Third, the gap precedes the filler RC head noun in Japanese, which means that the opening of the RC in Japanese is not clear. On the contrary, the opening of the RC is clearly indicated with the use of relative pronoun filler in English. Moreover, in English, the location of the gap comes after the filler (see Nakayama (1999) for an overview). Thus, in (1a), the relative pronoun *who* is extracted from the subject position of the RC, leaving a gap in its extraction site indicated as *e*, whereas the same pronoun is extracted from the object position in (1b). In (2a), the relative head noun *repootaa* is extracted from the subject position of the RC. On the other hand, the relative head noun *repootaa* is extracted from the object position in (2b).

Another interesting difference between English and Japanese subject-gap and object-gap sentences is that one of the widely accepted processing-based explanations makes opposite predictions in the ease of comprehending English and Japanese gap sentences (Gibson, 1998, 2000; O'Grady, 1987; O'Grady, Yamashita, Lee, Choo and Cho, 2000). It is predicted that object-gap RCs are more difficult to process than subject-gap RCs in English because the distance between the filler and the gap is further in the former than in the latter. On the contrary, in Japanese, it is predicted that subject-gap RCs are more difficult to comprehend than object-gap RCs because the distance between the filler and the gap in subject-gap RCs are further away. These differences between English and Japanese subject-gap and object-gap RC sentences provide a good arena for comparing the performances of Japanese-speaking L2 learners of English and English-

speaking L2 learners of Japanese because the L2 learners have to learn new processing strategies, which are quite different from those of one's L1.

Based on the above discussions, the following research questions are specifically addressed in this study for L1 and L2.

- (3a) Is there a difference in the comprehension accuracy rates of subject-gap and object-gap sentences in English and in Japanese respectively?
- (3b) Is there a difference in the comprehension accuracy rates of subject-gap and object-gap sentences by different WM capacity groups in English and in Japanese respectively?
- (4a) Is there a difference between reading times of subject-gap and object-gap sentences per region in English and in Japanese respectively?
- (4b) Is there a difference between reading times of subject-gap and object-gap sentences per region by different WM capacity groups in English and in Japanese respectively?
- (5a) Do the performances of the L1 native speakers and L2 learners differ in subject-gap/object-gap sentence comprehension accuracy rates in English and in Japanese?
- (5b) Do the performances of the L1 native speakers and L2 learners differ in subject-gap/object-gap sentence processing in English and in Japanese?
- (6a) Is the tendency in individual sentence reading patterns of the L2 learners similar to that of L1 native speakers?
- (6b) Is the tendency in the individual sentence reading patterns of L1 native speakers and L2 learners influenced by their WM capacity?

(6c) Do the individual sentence reading patterns of L1 native speakers and L2 learners affect comprehension accuracy?

The organization of this dissertation is as follows. Chapter 2 presents a number of relevant previous studies on WM and individual differences in sentence processing, L1 and L2 English RC sentence processing, and L1 and L2 Japanese RC sentence processing. Chapter 3 reports on self-paced moving window reading experiments by English native speakers and Japanese native speakers and presents the effect of WM capacity on their respective L1 and L2 RC gap sentence reading. The results of the experiments will show that (1) English object-gap sentences are more difficult to comprehend than English subject-gap sentences for both L1 native speakers and L2 learners, (2) Japanese subject-gap sentences are more difficult to comprehend than Japanese object-gap sentences for both L1 native speakers and L2 learners, (3) L2 WM capacity has an effect on L2 sentence comprehension, and (4) L2 sentence processing by the learner groups are somewhat different from those of the native speaker groups. Chapter 4 presents the comparisons of L1 and L2 sentence processing in English and in Japanese with the focus on the L2 learners' reading patterns. After the comparisons between L1 and L2 English and L1 and L2 Japanese, the participants' data will be discussed on an individual level. The analyses imply that in L2, having a higher L2 WM capacity seems to help to process a sentence in a manner similar to that of the native speakers. By being able to process L2 sentences in a similar manner to the native speakers, higher comprehension accuracy in the gap type sentences is likely to be achieved, especially in the "more-difficult-to-comprehend" gap sentences. Finally, Chapter 5 will summarize the major findings from

the previous chapters and discuss the role of WM in L2 sentence processing. Additionally, the limitation of this study and implication for future research will be addressed.

CHAPTER 2

PREVIOUS STUDIES

Most of the previous studies of L2 have focused on the investigation of linguistic knowledge. By contrast, relatively little is known about the online sentence processing strategies that L2 learners employ in L2 reading. Needless to say, the relationship of WM and L2 sentence processing other than in English has not been fully investigated. In this chapter, we will review the previous literature relevant to the current dissertation study: WM and sentence processing. Specifically, we will review the studies on WM and its role in L1 and L2 sentence processing focusing on, but not limited to, RC processing in both English and Japanese languages.

2.1. Working Memory and Reading Span Test

Working memory is a theoretical concept that refers to the ability to maintain information while manipulating and integrating other information (Baddeley, 2003). It is theorized to take an important role in complex cognitive tasks such as reasoning and overall processing of a language. In sentence processing, the utilization of WM is essential for comprehending a sentence. The reason is because sentence comprehension requires one to process the incoming elements on top of storing, maintaining, and

integrating other pieces of information, such as lexical and discourse information, to accomplish the understanding of a sentence (Daneman and Carpenter, 1980). For example, one needs to recognize a string of letters such as *a, p, p, l, e*, as the word *apple*. If the word *apple* appeared in a sentence like, *an apple a day keeps the doctor away*, one will need to process the word as a meaningful and functional component of the sentence. If one remembered that *an apple a day keeps a doctor away* is a popular quotation, then it means that another process of tapping into the long-term memory and retrieval of the meaning of quotation was necessary in addition to whatever process one may be tackling at that time. These processes are done rapidly and the outcome of the processes is held actively in our WM. Despite the activity of reading being a quite complex cognitive task that involves the active use of our WM, we do it everyday without consciously thinking and we even do it in languages that are other than our native language.

Working memory is generally assumed to have limited capacity. WM capacity is often described as a pool of limited resources that perform the processing and storing functions. The previous studies that investigated the effects of WM on sentence comprehension utilized two basic approaches. The first approach is based on the logic that performance in sentence comprehension will be reduced with the addition of a secondary task, assuming that both tasks rely on the same WM resources. In this approach, the secondary task is often manipulated in the number of items (load) to be held in memory while doing a sentence comprehension task. The second approach is to divide participants into high and low WM capacity groups often using a variant of the Daneman and Carpenter's Listening Span Test (LST) and Reading Span Test (RST) to compare group differences in syntactic complexity. Both approaches assume that

sentence comprehension is constrained by the amount of resources available and the efficiency of using those resources, which are also assumed in this study. Comprehension difficulty is thought to be either the result of decreased resource capacity or inefficient resource use. Of the two approaches, the researchers who are interested in investigating the performance of sentence reading comprehension among groups with different WM capacity have used Daneman and Carpenter's RST task to measure the capacity of WM.

The original Daneman and Carpenter's RST (Daneman and Carpenter, 1980) was designed so that it taxes both the storage and processing resources of WM. Two assumptions underlie their design: (1) individuals have limited capacity of WM, and (2) some individuals have more WM resources than others to perform a cognitive task. These differences in capacity and the availability of WM are assumed to reflect the efficiency of an individual's available resources (Just and Carpenter, 1992), and these differences manifest themselves when the RST task is administered.

The method of carrying out the Daneman and Carpenter's RST is fairly simple. The researchers show participants a set of sentences written on an index card, which the participants have to read aloud (process). While reading, the participants are supposed to remember a target word, which is the final word of the sentence (store). After reading the sentences in each set, they are asked to recall the target word of each sentence in the set. The number of sentences in each set steadily increases (usually from a two-sentence to a five-sentence condition), and there are five trials in each sentence condition. The reading span size is then determined as the maximum number of sentences the participants is able to read aloud while recalling all the target words in the majority of the trials (minimally three out of five trials). Daneman and Carpenter's RST was found to correlate with a

number of measures of individuals' reading skills and other cognitive tasks, and quite a few studies suggested that RST may be an effective measurement to reveal WM constraints on language comprehension (Baddley, Logie, Nimmo-Smith, and Brereton, 1985; Daneman and Carpenter, 1980; Daneman and Merikle, 1996; Just and Carpenter, 1992; Just, Carpenter, and Keller, 1996; King and Just, 1991; Miyake, Carpenter, and Just, 1994).

Despite the frequent use of RST in the research of WM constraints on language comprehension, the test faces several criticisms. First, there is no way of ensuring that the reading span test is taxing both storage and processing resources. In the procedure, the processing component was supposed to be burdened as a result of the read-aloud portion of the task. However, that reading aloud may not necessarily mean that the participants are processing the sentences for comprehension. The participants may be attending to the sound of each lexical item to ensure correct pronunciations and/or they may not be processing syntactic and semantic information of the sentences for the purpose of language comprehension. Second, the fact that the test does not have a measure of processing performance allows participants to focus only on memorizing the target word rather than reading the sentences (Roberts and Gibson, 2002; Waters and Caplan, 1996).¹ This would indeed defeat the purpose of the task, as performance on this test may only reflect how many target words participants can store in short-term memory. Furthermore, the participants may be selectively attentive to one of the two parts of the task, the read-aloud part or the recall part. In fact, Waters and Caplan (1996) noted that a high score on

¹ Waters and Caplan (1996) also argues that Daneman and Carpenter's RST is not the best measurement for the verbal working memory capacity because sentence processing efficiency and storage capacity are not equally considered in the task. In addition, they question test-retest reliability of the task.

the Daneman and Carpenter RST may only reflect how skillfully participants shift their attention away from the read-aloud part to the recall part, rather than reflect the capacity of the WM system itself.² Third, Omaki (2005) questions whether Daneman and Carpenter's RST makes participants tax both the processing and storage component simultaneously within each trial, since participants have to memorize only the final word of the sentence. The primary role of WM in language comprehension is to store information temporarily while processing new information. Thus, using only the final word as the target word to be memorized seems completely different from normal language comprehension process. In addition, a head-final language with SOV word order, like Japanese, generally has a predicate at the end of the sentence, which limits the types of lexical items that can become target words.³ Fourth, the length and the complexity of the sentences in the RST are not controlled and it may affect the participants' performance. For example, the 4-sentence condition may be easier than the 3-sentence condition if the 3-sentence condition happened to contain many complex sentences with center-embeddings such as subject-modifying object RCs, while the 4-

² Waters and Caplan (1996) used an acceptability/grammaticality judgment task instead of a read-aloud RST to measure WM capacity. The acceptability/grammaticality judgment RST is said to be designed as a 'processes for meaning' task and not merely the memorization of the final word of the sentences. Some studies such as Harrington and Sawyer (1992) and Omaki (2005) used the acceptability/grammaticality judgment RST for L2. However, there are concerns about the use of this type of task for L2 learners. Because the acceptability/grammaticality judgment task only requires the participants to judge right or wrong, it may overestimate or underestimate the L2 ability (Juffs, 2004).

³ Osaka and Osaka (1992) considered this issue seriously and resolved by having target words in different positions in the sentences in their L1 Japanese RST. However, this raises the issue of having the target word appearing in a different position of a sentence and the effect of memorizing the target word earlier in the reading process has not been fully examined yet. Generally speaking, it is more difficult to locate and memorize the target word that changes the location of appearance depending on a sentence. Thus for L2 Japanese, Itomitsu and Nakayama (2005) created the RST by controlling the vocabulary and sentence structures so that different category of words could be the target words located at the end portion of the sentence.

sentence condition happened to contain relatively long but non-complex sentences with a conjunction (King and Just, 1991).

These criticisms are fair but one must remember that WM is a theoretical concept. It is not something one can see or directly measure, but something we need to infer from behavior (McBurney and White, 2009). Daneman and Carpenter's RST has been used in a large number of previous studies extensively as a WM measurement for language processing and its predictive power of sentence comprehension have been investigated (see Daneman and Merikle (1996) for a review of 77 previous studies, and Conway, Kane, Bunting, Hambrick, Wilhelm and Engle (2005) for reliability and validity of the task). Additionally, the ease of its administration, such as testing duration, material used, and simple scoring method, as well as the use of an actual reading task, makes the RST, the 'competitively practical' measurement for research in verbal WM (Itomitsu, 2005).

The studies of L1 and L2 WM capacity show that the relationships between L1 and L2 WM are not language-specific (Juffs, 2005; Osaka and Osaka, 1992; Osaka, Osaka and Groner, 1993). For example, Osaka and Osaka (1992) compared Japanese RST and English RST scores among Japanese university students. They found that there was a correlation between the two RST scores. The similar result was found in Osaka, Osaka and Groner (1993) in which L1 German and L2 French participants were tested. They concluded that if an individual has larger WM capacity in L1 language, then the individual has larger capacity in L2 language as well. Ikeno (2006), who tested Japanese-speaking learners of English, found that there is a reliable correlation between L2 RST (English) and L1 RST (Japanese) scores as well as between L2 RST (English) and TOEFL reading comprehension scores. However, he did not find correlations between L1

RST (Japanese) and TOEFL reading comprehension scores. Another study by Van den Noort, Bosch and Hugdahl (2006) investigated the L1 Dutch, L2 German (fluent) and L3 Norwegian (beginner) reading span tasks and has found high correlations between WM capacities in the L1, L2 and L3.

Some research has found only a moderate relationship between L1 and L2 WM capacities (Harrington and Sawyer, 1992; Juffs, 2004, 2005; Miyake and Friedman, 1998). For example, Juffs (2004) tested Spanish, Chinese, and Japanese native speakers learning English to examine how individual differences in WM capacity might explain individual variation in online L2 performance. Among five different tests administered, which included English (L2) RST and L1 RST tests, the correlation was found between the L1 RST and L2 RST scores ($r=.61$), but it was not as high as, for instance, over .70 found in Osaka (2000). Miyake and Friedman (1998) examined language aptitude of Japanese-speaking learners of English. Using the framework of the competition model (MacWhinney and Bates, 1989), they tested the preference of cues (word order, animacy and agreement) that L2 learners use in L2 English comprehension and found the correlation between L1 RST and L2 RST scores ($r=.58$). They concluded that L1 and L2 WM share the same pool of resources.

These previous studies on the relationship of L1 and L2 WM showed moderate to strong correlation between the two. From this, it is natural to assume that if L1 and L2 WM have moderate to strong correlations, then both L1 and L2 WM capacities are expected to be associated with L2 reading performance. Some previous studies, however, provide contradictory results to this prediction, showing the effects of L1 WM on L2 comprehension are indirect at best, whereas those of L2 WM are direct (Alptekin and

Erçetin, 2010; Chun and Payne, 2004; Miyake and Friedman, 1998; Walter, 2004). For example, Walter (2004), who examined the relationship between reading span and L2 reading comprehension for upper- and lower-intermediate French learners of English, found a low correlation between the L1 reading span and L2 summary completion scores ($r=.33$). However, she found a strong correlation between the L2 reading span and L2 summary completion scores ($r=.73$). These results suggest that L2 reading comprehension is more strongly associated with L2 WM capacity than L1 WM capacity. These previous studies suggest that L1 and L2 WM may, in general, share same WM resources, but L2 WM capacity may be associated more directly to L2 comprehension.

2.2. Working Memory, Individual Differences and Sentence Processing

Researchers have long asked whether individual differences in sentence processing performance are an outcome of individual differences in WM capacity and/or efficiency in using WM. Having said this, illuminating the structure of WM itself has not been easy and various models have been proposed for WM.

The original Baddeley and Hitch (1974)'s WM construct suggests that WM consists of a limited capacity 'work-place' and that it is divided between storage and control of processing demands. Daneman and Carpenter (1980) suggested that what accounts for the individual difference in a WM task, i.e. RST, is the efficiency with which an individual is able to read the sentences and remember the target words and recall them. This "resource-sharing" account indicates that individuals who processed information relatively efficiently would have more of their limited WM capacity available for storage purpose and that this processing efficiency is primarily what

determines WM capacity. Accepting a single cognitive workspace for all the WM performance assumes a domain-general nature of WM. This account is supported by several studies, including studies that examined different age groups and that employed different complex WM tasks (Case, Kurland, and Goldberg, 1982; Fry and Hale, 2000; Hartley, Speer, Jonides, Reuter-Lorenz, and Smith, 2001).⁴ A capacity-constrained theory by Just and Carpenter (1992), based on Daneman and Carpenter (1980)'s theory, proposes that memory (capacity) and computational operations (efficiency) necessary for sentence processing are shared by a single WM system. In their model, there are trade-offs between storage and processing, and the model predicts (working memory group \times sentence complexity) and (working memory load \times sentence complexity) interactions. Their model suggests that an individual has a different amount of resources for processing and storing and that the individual differences in performances are caused by the amount of resources, i.e. capacity.

Another model by Caplan and Waters (1996, 1999, 2002) proposes that sentence processing is mediated by two separate WM systems. The first one is used for online interpretive processing, while the second processes offline, post-interpretive information. The syntactic processing is part of interpretive processes and their theory predicts that WM and sentence complexity interactions do not occur. According to their theory, the individual differences occur due to domain-specific WM capacity. Based on the studies of normal participants and patients with poor WM and with aphasia, they argued that the lack of significant interactions between WM and syntactic complexity in published data supports their theory (Caplan and Waters, 1999). However, several studies have found

⁴ There are alternative explanations such as a “task-switching” account (Towse, Hitch and Hutton, 1998; see Saito and Miyake, 2004, for a review) for individual differences in WM.

that increasing sentence complexity does indeed interact with WM capacity (Eastwick and Phillips, 1999; Fedorenko, Gibson and Rohde, 2004, 2006; Gordon, Hendrick and Levine, 2002). These contradictory findings challenge Caplan and Waters's theory and imply a shared pool of resources in WM.

A model by MacDonald and Christiansen (2002), based on connectionist models, proposes that there are no distinctions between language-processing tasks and linguistic WM tasks, but rather only one language processing skill. The individual differences found in processing abilities emerge from an individual's experience with language and from biological differences such as phonological representations developed for language. Despite the differences in these models discussed above, they all seem to agree that WM has an effect on sentence processing.

King and Just (1991) examined the relationships between high and low WM capacity groups and the processing of different complexity sentences. Specifically, they examined the processing of subject RCs and object RCs using a self-paced moving window task. In their experimental task, the participants had to read each word of a sentence by button-pressing, and additionally remember the final word of the sentence in each sentence set where the set size ranged from one to three sentences. Using Daneman and Carpenter's RST, they also measured the participants' reading span size and compared the performance of participants who had a high span to those who had a low span. They found that the low span group experienced more difficulties than the high span group when processing syntactically complex sentences because the former showed longer reading times than the latter group in the complex object RC region. Another example by MacDonald, Just, and Carpenter (1992) further supports the finding that

individual differences exist in parsing performance. In their study, MacDonald, Just, and Carpenter examined the processing of sentences like (1), which also contained main verb/reduced relative ambiguity.

(1a) The experienced soldiers warned about the dangers before the midnight raid.

(1b) The experienced soldiers warned about the dangers conducted the midnight raid.

In both (1a) and (1b), *warned about the dangers* is ambiguous between (a) a main verb plus a prepositional phrase and (b) a past participle in a reduced relative clause. The result of their experiment showed that the high span group had longer reading times than the low span group in the final region of both sentences like (1a) and (1b). From this result, they inferred that the high span group held two analyses throughout the ambiguous region (i.e., *warned about the dangers*), whereas the low span group only held one (i.e., main verb analysis, as in (1a)). The results of King and Just (1991) and MacDonald, Just, and Carpenter (1992) suggest that different span groups behave differently in L1 sentence processing depending on the complexity of sentence structures.

Some previous studies have shown that L2 learners with a high WM capacity can utilize L2 linguistic information more efficiently than the learners with a low span (Osaka, 2002; Walter, 2004). Despite that, there have not been many studies that investigated whether WM capacity influences L2 learners' sentence processing and how it affects the reading time of sentences. Among the few studies, Juffs (2004) presented the re-analysis of data from Juffs (2000, 2002) with four different L1 groups of participants to look at the English sentence processing. The intention of the study was to examine whether the

individual differences in WM capacity would explain the individual variation in L2 parsing performance. Thirty Chinese-speaking, twenty-eight Japanese-speaking, and forty-six Spanish-speaking learners of L2 English who lived in the U.S. participated in the study in addition to the control group of twenty-one native speakers of English. Three types of sentences were used as the experimental stimuli.

(2a) After the children cleaned the house looked very neat and tidy.

(2b) When the student arrived the professor asked her about her trip.

(2c) The doctor knew the nurses liked the man from England.

(Juffs, 2004: 209-210)

Sentence (2a) involves ambiguity at the phrase *the house* as the object of the verb *cleaned* or as the matrix subject due to the possibility for the verb in question to have an ‘unstated’ object. Sentence (2b) does not have any ambiguity due to the transitivity properties of the verb *arrived*. Sentence (2c) requires reanalysis at the object position *the nurses*.

Participants were given several tests that included a WM task based on Harrington and Sawyer (1992), RST in their L1, and a reading and judgment task where sentences were presented using the moving window paradigm. The results showed a correlation between the L1 and L2 reading span scores. However, there was no relationship between all of the memory scores and reading time of the verb in garden-path sentences as shown in (2a).

Juffs additionally analyzed the data by grouping participants into three groups (High, Middle, Low) according to their scores based on their L2 English reading span and the L1 reading span. No reliable results were found, although when Middle span group was

eliminated from the analyses, the probability for WM to have an effect, of course, increased. He also showed that the Low span group demonstrated significantly slower reading times in the experiment than the High span group, but the effect of WM capacity did not interact with sentence complexity, since this difference was obtained in both the garden-path and the non-garden-path conditions. From this result, Juffs concluded that there is only a weak relationship between reading span and L2 sentence processing. Juffs (2005) also tested whether there is a correlation between the reading time in a critical region of a long-distance subject-gap sentence and WM capacity groups, but again, he found no correlations.

Omaki (2005) investigated the resolution of Japanese and English RC attachment ambiguity in L1 and L2 sentence processing. In his study, Omaki tested English native speakers and advanced Japanese-speaking learners of English on RC attachment using offline and online experiments. The results showed that the WM capacity influenced the preference of RC attachment in English native speakers' offline experiments, but not in online experiments. However, Japanese-speaking learners of English did not show any association with the WM capacity in Japanese nor English RC attachment preferences, though some learners showed similar RC attachment preferences as the English native speakers. He also notes that there was no interaction between sentence complexity and WM capacity. Though these L2 studies seem to indicate that there is no interaction between WM capacity and L2 sentence processing, more empirical studies are necessary to confirm the findings because available evidence is still sparse.

2.3. Relative Clause Processing in English and Japanese

In sentence comprehension, a parser has to process the incoming lexical items while considering other linguistic and discourse information. In dealing with such a cognitively demanding task, it is natural to assume that the parser is constrained by the capacity of WM. For example, in SVO languages with postnominal RCs such as English, parsing of object-gap RCs is known to be more complex than that of subject-gap RCs (Gibson 1998, 2000; Gibson and Pearlmutter, 1998; King and Just, 1991). Consider the following two gap type sentences, repeated from (1a) and (1b).

(3a) English subject-gap RC

The reporter_{*i*} [who *e_i* attacked the senator] admitted the error.

(3b) English object-gap RC

The reporter_{*i*} [who the senator attacked *e_i*] admitted the error.

(Gibson and Pearlmutter, 1998: 265)

In example (3b), the relative pronoun *who* is extracted from the object position of the RC, leaving a gap in its extraction site (*e*). In example (3a), the relative pronoun *who* is extracted from the subject position of the RC. Two approaches have been proposed to account for the processing of this type of RCs: one concerning the cost of resources taken up by temporary storage and integration while processing and the other concerning the depth of embedding of the extract element. For example, Gibson (2000) proposes the Dependency Locality Theory (DLT), in which he assumes two types of resources required for language comprehension: (a) storage of the structure built thus far and (b)

integration of the current word into the structure built thus far (Gibson, 2000: 101-102).

Gibson further notes that many resource complexity effects can be accounted for by using the integration cost alone (p.102). Therefore, we will only consider the integration cost in the following sentences. The complexity of integration is determined by whether the two elements being integrated are local or in distance. The integration cost is quantified as follows:

DLT discourse processing cost: (the cost associated with accessing or constructing the discourse structure for the maximal projection of the input word head $h2$) 1 energy unit (EU) is consumed if $h2$ is the head of a new discourse referent; 0EUs otherwise.

DLT structural integration cost: The structural integration cost associated with connecting the syntactic structure for a newly input head $h2$ to a projection of a head $h1$ that is part of the current structure for the input is dependent on the complexity of the computations that took place between $h1$ and $h2$. For simplicity, it is assumed that 1EU is consumed for each new discourse referent in the intervening region.

(Gibson, 2000: 104-105)

(4a) English subject-gap RC

The	reporter	who	attacked	the	senator	admitted	the	error.
0	1	0	1	0	1	3	0	1

(4b) English object-gap RC

The	reporter	who	the	senator	attacked	admitted	the	error.
0	1	0	0	1	3	3	0	1

(Gibson, 1998: 20-21)

Sentence (4) above shows the integration cost of the DLT in English gap sentences. According to the DLT, the subject-gap RC (4a)'s maximal integration cost occurs at only one point, *admitted*: 3EUs. At the point of *attacked*, the cost is only 1EU: for the construction of the new discourse referent, the verb *attacked*. Because the integration of the subject-position empty category to the preceding RC pronoun *who* is local, no structural integration cost is consumed; there is no new discourse referent. The object-gap RC (4b)'s maximal integration cost occurs at the point of processing *attacked* and *admitted*. At the point of *attacked*, the cost is 3EUs: 1EU for the construction of the new discourse referent, the verb *attacked*, 0EUs for integrating the object-empty category to the verb *attacked* and 2EUs for the structural integration of the object-position empty category to the preceding RC pronoun *who* because two discourse referents —the NP *the senator* and the event referent *attacked* —were introduced beforehand. At the point of *admitted*, the cost is also 3EUs: 1EU for the construction of the new discourse referent *admitted*, and 2EUs for the structural integration of the verb *admitted* to the subject NP *the reporter* with two new intervening discourse referents — *the senator* and *attacked*. The word, *attacked*, is the embedded verb in each gap type sentences and integration cost is longer at this embedded verb for the object-gap RC than in the subject-gap RC. Therefore, the DLT predicts that object-gap RCs are more difficult to process than subject-gap RCs in English.⁵

O'Grady and his colleagues (O'Grady, 1987; O'Grady, Yamashita, Lee, Choo and Cho, 2000) proposed a depth-of-embedding-based theory called Structural Distance

⁵ Subsequently, Gibson and his colleagues (Chen, Gibson and Wolf, 2005; Gibson, Desmet, Grodner, Watson, and Ko, 2005) further provided evidence for the prediction storage cost from online reading experiments in English and separated the integration component of the DLT and storage component of the DLT to explain where the locus of the relative slowdown occurs in RC sentence processing.

Hypothesis (SDH). The SDH calculates the number of nodes crossed to determine a syntactic structure's relative complexity.

The Structural Distance Hypothesis

The distance traversed by a syntactic operation, calculated in terms of the number of nodes crossed, determines a structure's relative complexity.

(O'Grady, Yamashita, Lee, Choo and Cho, 2000)

According to the SDH, the number of nodes between the gap and the head is fewer in the English subject-gap RC than in the object-gap RC. Thus, this theory also predicts the object-gap RC will be more difficult than the subject-gap RC.

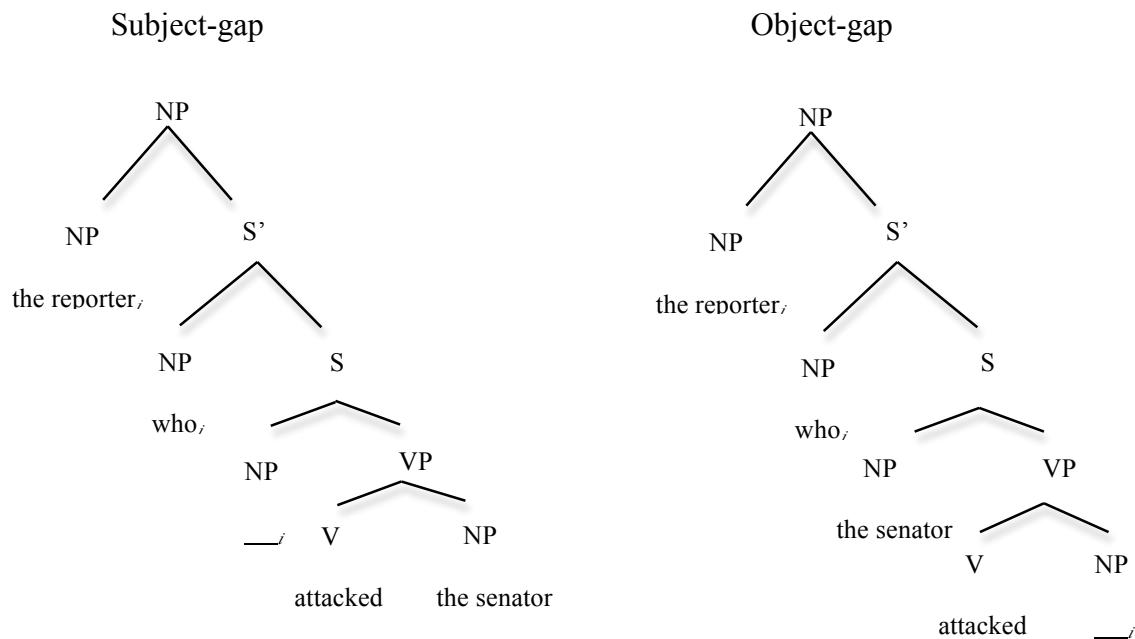


Figure 2.1: Syntactic structures for subject-gap and object-gap RCs in English

(Ueno and Garnsey, 2008: 648)

Both theories, either DLT or SDH, predict that object-gap RCs will be more difficult than subject-gap RCs in English. In Japanese, however, the DLT predicts that object-gap RCs are easier to process because there are fewer intervening words between the gap and the head noun. The SDH predicts that subject-gap RCs are easier to process. This prediction comes from the fact that Japanese is an SOV language with a prenominal RC. Consider the subject-gap RC and object-gap RC in Japanese below.

(5a) Japanese subject-gap RC

[e_i Giin-o hinanshita] repootaa_{*i*}-ga machigai-o mitometa.
 e_i senator-acc criticized reporter-nom error-acc admitted
 ‘The reporter who criticized the senator admitted the error.’

(5b) Japanese object-gap RC

[Giin-ga e_i hinanshita] repootaa_{*i*}-ga machigai-o mitometa.
 senator-nom e_i criticized reporter-nom error-acc admitted
 ‘The reporter who the senator criticized admitted the error.’

Sentence (5), repeated as (6) below, shows the integration cost of the DLT in Japanese gap sentences. The differences between the subject-gap and object-gap RCs in Japanese occur at the verb *hinanshita* and the head noun *repootaa*. At the point of the verb *hinanshita* in the Japanese subject-gap RC, the cost is 2EUs: 1EU for the construction of the new discourse referent, the verb *hinanshita*, and 1EU for integrating the subject-empty category to the verb. At the verb *hinanshita* in the object-gap RC, the cost is 1EU for the cost of constructing the new referent. No structural integration cost is required

because the integration of the object-position empty category is local. At the point of the head noun *repootaa* in the subject-gap RC, the cost is 3EUs: 1EU for the construction of the new discourse referent, the noun *repootaa*, and 2EUs for the structural integration of the subject-position empty category because two discourse referents are in the interim. At the head noun *repootaa* in the object-gap RC, the cost is 2EUs: 1EU for the construction of the new discourse referent and 1EU for the structural integration of the object-position empty category because only one discourse referent intervenes. Because the differences between the EUs consumed in the Japanese subject-gap and object-gap RCs, the DLT predicts the subject-gap RC to be more difficult than the object-gap RC. On the other hand, due to the object-gap being placed lower in the syntactic representation, the SDH predicts the Japanese object-gap RC to be more difficult than the subject-gap RC (Figure 2.2).

(6a) Japanese subject-gap RC

Giin-o	hinanshita	repootaa _i -ga	machigai-o	mitometa.
1	2	3	1	1

(6b) Japanese object-gap RC

Giin-ga	hinanshita	repootaai-ga	machigai-o	mitometa.
1	1	2	1	1

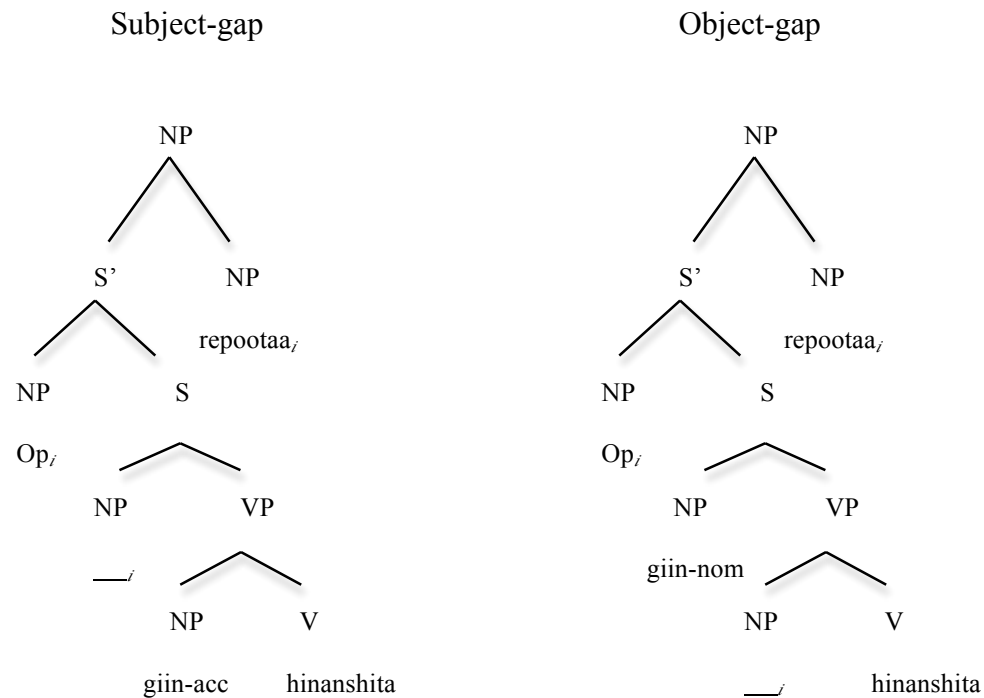


Figure 2.2: Syntactic structures for subject-gap and object-gap in Japanese

(Ueno and Garnsey, 2008: 652)

Miyamoto and Nakamura (2003) examined Japanese subject-gap and object-gap sentence processing using a self-paced moving window method. Their Experiment 2, which included test sentences such as (7), showed that the Japanese subject-gap sentences were generally read faster than the Japanese object-gap sentences at the head noun and the following regions (in bold). They concluded that the Japanese object-gap sentences are more difficult to process than the Japanese subject-gap sentences, which supports the SDH.

(7a) Japanese subject-gap RC

[*e_i* Tosiyorino obaasan-o basutei-made miokutta] **onnanoko_i-ga nuigurumi-o** daiteita.

elderly woman-acc bus stop-to accompanied girl-nom stuffed-toy-acc hugging

‘The girl that accompanied the elderly woman to the bus stop was hugging a stuffed toy.’

(7b) Japanese object-gap RC

[Tosiyorino obaasan-ga *e_i* basutei-made miokutta] **onnanoko_i-ga nuigurumi-o** daiteita.

elderly woman-nom bus stop-to accompanied girl-nom stuffed-toy-acc hugging

‘The girl that the elderly woman accompanied to the bus stop was hugging a stuffed toy.’

(Miyamoto and Nakamura, 2003: 348)

Ishizuka (2005) investigated the sentence processing of Japanese subject-gap RC and object-gap RC. Using a self-paced moving window task, she tested singly embedded and doubly embedded subject-gap and object-gap RCs.⁶ Despite the comprehension accuracy rates of the tested sentences being low (average 71.8%), probably due to the complexity of the test sentences, the results showed that the object-gap RCs are more difficult to process than the subject-gap RCs, which supports the SDH over the DLT.

Ishizuka explains that the temporal ambiguity in Japanese object-gap RCs, in which the first NP-nom can be taken as either the subject of the matrix sentence or the subject of the

⁶It is known that the effects of perspective shift and case-matching affect the processing (MacWhinney and Pleh, 1988; Sauerland and Gibson, 1999). MacWhinney and Pleh (1988) claim that processing resources are required to shift the perspective of a clause, where the perspective of a clause is taken from the subject of the clause. A subject-modifying object-gap RC requires two perspective shifts: (1) from the perspective of the matrix subject to the subject of the RC and (2) from the perspective of the subject of the RC back to the matrix subject, after the RC is processed. Processing the subject-gap RC requires no perspective shifts, because the matrix subject is also the subject of the RC. That is, both clauses come from the same perspective. From this, the object-gap RC is more complex to process than the subject-gap RC. A case matching principle predicts an increase in processing complexity when the case of a relative pronoun and its associated head noun do not have the same case (‘case clash’ conditions).

RC, is the cause of this outcome because the parser needs to reanalyze upon encountering the relative head noun. To resolve the problem of temporal ambiguity seen in Japanese object-gap RC sentences, Ishizuka, Nakatani, and Gibson (2006) re-examined the Japanese gap sentences by providing the context for the gap sentences to minimize the reanalysis effect caused by the ambiguity. Their study showed that the subject-gap RCs are more difficult to process than the object-gap RCs. From these findings, it seems that the subject-gap sentence seems to be more difficult to process in Japanese, which is in line with the DLT.⁷ In addition to these online studies, a study from a neurolinguistics perspective, however, adds evidence for Japanese object-gap sentences being more difficult to process than Japanese subject-gap sentences (Ueno and Garnsey, 2008). From the results from these previous studies, we assume that the results of investigating Japanese object-gap RC and subject-gap RC sentences are mixed.

2.4. L2 Sentence Processing in English and Japanese

Processing a sentence is a cognitively challenging and demanding task. One can assume that the parsing of L2 would put more of a burden on the processing mechanism than that of L1 because, for instance, the retrieval of the lexical and grammatical knowledge of L2 would be more challenging. The previous studies on L2 sentence processing suggest that there are several differences between the sentence processing of native speakers and L2 learners. First of all, adult L2 learners seem to have difficulty with the online integration of different information sources. For example, Felser, Roberts,

⁷ Chinese has a prenominal RC and it seems object-gap sentences are easier to process than subject-gap sentences (Hsiao and Gibson, 2003), thus, making distance matter (c.f. DLT) in Chinese RC processing. On the other hand, subject-gap RCs were found to be easier to process in Turkish, which is a pro-drop language with SOV canonical word order and prenominal RCs (Kahraman, 2011).

Gross, and Marinis (2003) showed that in parsing ambiguous sentences, L2 learners relied more on nonstructural information. Second, L2 learners might be receiving influence from their L1 in processing L2 input. Although this issue is far from conclusive, several studies showed L1 influence on L2 parsing (e.g. Frenck-Mestre, and Pynte, 1997; Juffs, 2005), though others did not (Felser, Roberts, Gross and Marinis, 2003; Williams, Möbius, and Kims, 2001). Third, the studies in neurolinguistics have shown that L2 learners process the target language less rapidly which may be caused by a lack of automaticity (Hahne, 2001; Hahne and Friederici, 2001; Weber-Fox and Neville, 1996) and by L2 requiring more computation and activity from the brain network (Hasegawa, Carpenter and Just, 2002; Yokoyama, Okamoto, Miyamoto, Yoshimoto, Kim, Iwata, Jeong, Uchida, Ikuta, Sassa, Nakamura, Horie, Sato, and Kawashima, 2006). Fourth, language processing mechanisms that are available to matured adults may be only partially accessible, thereby restricting L2 learners to using only one part of brain memory systems (Ullman, 2001).

Few L2 online sentence processing studies indicated that WM may influence L2 sentence reading patterns. Sawasaki (2007) examined the processing strategies used by L2 learners of Japanese with different L1. Based on the previous findings that Japanese native speakers use case information effectively in online parsing (Kamide, Altmann, and Haywood, 2003; Kamide and Mitchell, 1999; Miyamoto, 2002; Nagata, 1993; Sakamoto, 1995, 2002; Yamashita, 1994; 1995; 1997), Sawasaki tested whether L2 learners of Japanese would use preverbal case information in a way similar to that of

Japanese native speakers. In order to test whether the parser utilizes the case information, he used the following five types of sentences.⁸

(8a) Tanaka-san-ga / bikkuri-simasita.

Mr./Ms.Tanaka-nom / was surprised

‘Mr./Ms. Tanaka was surprised.’

(8b) Tanaka-san-ga / kinoo / bikkuri-simasita.

Mr./Ms.Tanaka-nom / yesterday / was surprised

‘Mr./Ms. Tanaka was surprised yesterday.’

(8c) Tanaka-san-ga / kinoo / totemo / bikkuri-simasita.

Mr./Ms.Tanaka-nom/ yesterday / very / was surprised

‘Mr./Ms. Tanaka was very surprised yesterday.’

(8d) Tanaka-san-ga / sensei-o / tetudaimasita.

Mr./Ms.Tanaka-nom / teacher-acc / helped

‘Mr./Ms. Tanaka helped the teacher.’

(8e) Tanaka-san-ga / kinoo / sensei-o / tetudaimasita.

Mr./Ms.Tanaka-nom / yesterday / teacher-acc / helped

‘Mr./Ms. Tanaka helped the teacher yesterday.’

(Sawasaki, 2007: 43)

⁸ The slash (/) in the example sentences indicates the segment boundary that participants read at one time.

The above sentences used both transitive and intransitive verbs and the number of arguments and adjuncts were varied. The previous studies in English have shown that arguments and adjuncts are processed differently (Clifton, Speer and Abney, 1996; Frazier and Clifton, 1996). If L2 learners of Japanese process preverbal arguments and adjuncts differently, then they would process arguments faster than adjuncts. Using a self-paced moving window task, Sawasaki compared residual reading times (RRTs) of each preverbal region among English, Chinese, and Korean L1 groups with different L2 proficiency: 53 native Japanese speakers, 27 Japanese as second language (JSL) learners and 24 Japanese as foreign language (JFL) learners, who were undergraduate and graduate students at the time of the study, participated in the study.⁹ Twenty sets of the five types of experimental sentences were created. The results showed that different L1 language groups demonstrated different sensitivity to arguments and adjuncts. He found that English-speaking higher proficiency JSL learners of Japanese showed some sensitivity to argument/adjunct differentiation but not the lower proficiency JFL learners. Chinese-speaking JSL learners showed no sensitivity but Korean-speaking JSL learners did. Interestingly, although all of the different L1 groups demonstrated different types of reading patterns compared to those of Japanese native speakers, the reading patterns of the different L1 groups were somewhat similar to each other. This is interesting because Korean takes a SOV word order similar to Japanese, and English and Chinese take a SVO word order; the fact that their reading pattern is different from those of the Japanese native speakers, but somewhat alike among the different L1 groups suggests that there are

⁹ Japanese as a second language (JSL) learners and Japanese as a foreign language (JFL) learners are different in that the former learns Japanese in Japan (a target language speaking country) whereas the latter learns Japanese outside of Japan.

reading strategies universal among all learners and not merely L1 transfer. Furthermore, Sawasaki discusses that the differences between L1 native speakers and L2 learners in general reading patterns come from the limited linguistic experiences that L2 learners have and it is affecting the efficiency of their knowledge use. The RRT peaks at the nominative NP and the verbs may be the indication of L2 learners being attentive to the special informative cues to compensate the lack of efficiency in reading L2.

Based on Sawasaki's finding, Kashiwagi and Nakayama (2005) conducted a study investigating how low and advanced English-speaking learners of Japanese (JFL learners; approx. 580 hours and more than 700 hours of classroom instruction respectively) and Japanese native speakers process NPs with three different complexity levels. The complexity was manipulated by making test sentences with (9a) 3-morae NP, (9b) 6-morae NP, and (9c) 6-morae NP with the NP-genitive-NP (Genitive NP) structure.

(9a) Teraki-san-wa / kyooju-ga / dorama-o / mita / to / itta /. (3 morae)

Mr./Ms. Teraki-top / professor-nom/ drama-acc/ saw/ that/ said/.

‘Mr./Ms. Teraki said that the professor saw the drama.’

(9b) Teraki-san-wa / kyooju-ga / hoomudorama-o / mita / to / itta /. (6 morae)

Mr./Ms. Teraki-top / professor-nom/ serial drama-acc/ saw/ that/ said/.

‘Mr./Ms. Teraki said that the professor saw the serial drama.’

(9c) Teraki-san-wa / kyooju-ga / kuji-no-dorama-o/ mita / to / itta /. (6 morae)

Mr./Ms. Teraki-top / professor-nom/ drama-acc/ saw/ that/ said/.

‘Mr./Ms. Teraki said that the professor saw the 9 o'clock drama.’

(Kashiwagi and Nakayama, 2008)

Using the self-paced moving window task, Kashiwagi and Nakayama found that the native speakers spent a longer time reading structurally more complex 6 morae phrases NP-*no*-NP (9c) than structurally simpler NP phrases regardless of length. The advanced JFL learners showed some evidence of native-like processing. The JFL learners with a lower proficiency level, however, failed to make such differentiation. Based on these findings, Kashiwagi and Nakayama suggested that the learners of Japanese, especially less proficient L2 learners seemed to have spent much of their WM resources on phonological decoding and thus concluded that the use of WM resources between the L2 learners and the native speakers are different.

As for the studies on L2 subject-gap and object-gap RC sentences, a number of L2 researchers have examined the difficulty in the acquisition and learning of RC in English. Mostly these studies have adopted Keenan and Comrie's (1977) Noun Phrase Accessibility Hypothesis as the framework of analysis and have shown that object-gap RC sentences are indeed more difficult to acquire or learn than subject-gap RC sentences in English (For review, see Comrie, 2007; Eckman, 2007; Hawkins, 2007). Hashimoto (2007) examined processing of English subject-gap and object-gap sentences of Japanese-speaking learners of English. Specifically, Hashimoto investigated where the learners have the most difficulty in comprehension of sentences like (10) using Gibson's Syntactic Prediction Locality Theory (SPLT; 1998, 2000).

(10a) English subject-gap RC

The nurse / who / kisses / the doctor / treats / the patient.

first NP / relative pronoun / first V / second NP / second V / third NP

(10b) English object-gap RC

The nurse / whom / the doctor / kisses / treats / the patient.

First NP / relative pronoun / second NP / first V / second V / third NP

(Hashimoto, 2007)

Comparing general reading time patterns of these two types of gap sentences with the SPLT predictions, he found that the L2 English learners not only demonstrate longer reading times in verb regions, which the theory predicts to be most demanding in terms of computational resources, but also in the second NP region in the relative clause.

Although no statistical comparisons were made between the two gap type sentences, Hashimoto speculated the longer reading time of the object NP of relative clauses might have been due to the reactivation process of the subject NP. In other words, he reasoned that the L2 learners might be performing other processes like trying to remember the subject NP of the main clause. He concluded that the L2 English learners may be using a different strategy to read the RC sentences from the native speakers.

In contrast to L2 English RC processing studies, there have not been many studies on L2 Japanese subject-gap and object-gap RC sentences. Sakamoto and Kubota (2000) examined RCs in a written essay and a sentence combination task of L2 Japanese learners whose L1 is English, Chinese, and Indonesian. They found that subject-gap RCs were more frequently used than object-gap RCs in their essays and in the sentence combination task; that is, the L2 learners were able to relativize NPs in the subject position of an action verb more correctly than NPs in the direct object position. Another study by Ozeki (2005) examined Oral Proficiency Interview data of L2 Japanese learners whose L1 were

Korean, English, and Chinese. She found that most learners of Japanese, other than intermediate level of English and Chinese speaking learners, used subject-gap RC more frequently.¹⁰ When it comes to the sentence processing studies of L2 Japanese subject-gap and object-gap, Kanno (2007) showed that the subject-gap sentences were easier to process than the object-gap sentences in a listening comprehension task. She also suggested a possibility that when RCs are too difficult to process, L2 learners may use L1 language strategies such as head-direction, word-order and filler-gap order to process RCs. Sawasaki (2008, 2009) tested the processing of Japanese subject-gap, object-gap and postpositional phrase-gap RCs by L2 learners of Japanese using a self-paced moving window reading task. In Sawasaki (2008), 50 L2 learners of Japanese with different L2 proficiency levels (High, Intermediate and Low groups) and 40 Japanese native speakers participated in the study. The test sentences were as follows:

(11a) Japanese subject-gap RC

Tabako-o /	yameta /	otona-wa /	yasashii.
Cigarettes-acc	quit	adult	nice

‘The adult who quit cigarettes is nice.’

(11b) Japanese object-gap RC

Yoko-ga /	totta/	shashin-wa /	maamaa desu.
Yoko-nom	took	picture-top	so-so

‘The picture that Yoko took is so-so.’

¹⁰ Ozeki (2005) noted that the number of total RCs produced by L2 learners were few. On average, there were 2.6 uses per interview by English L1 intermediate learners and 3.4 uses per interview by Chinese L1 intermediate learners.

(11c) Japanese postpositional phrase-gap RC

Keiko-ga / shinbun-o / katta / baiten-wa / sugusoko desu.

Keiko-nom newspaper-accbought kiosk-top just right there

‘The kiosk where Keiko bought the newspaper is just right there.’

(Sawasaki, 2008: 8)

Comparing the RRTs of the regions in the test sentences between the four participant groups, he found a significant difference in all regions. Further analyses showed differences between all groups in all regions except between the High and Intermediate learner groups. That is, no difference was found between the High and Intermediate learner groups in all regions. From this result, he treated the High and Intermediate learner groups as one group in the further analyses. Sawasaki then compared the regional RRTs of the three gap type sentences within a participant group. He found that the High/Intermediate and Low groups read the RC verb region of the subject-gap sentences the fastest, followed by the postpositional phrase-gap sentences, and then the object-gap sentences (subject-gap>postpositional phrase-gap>object-gap). He also found that the High/Intermediate and Low groups read the region after the RC of the object-gap sentences the fastest, followed by the postpositional phrase-gap sentences, and then the subject-gap sentences (object-gap>postpositional phrase-gap>subject-gap). The interesting finding from Sawasaki’s study is that the difficulty of processing, reflected in

the reading times, seems to change in the RC verb region and the region after the RC verb between the three gap type sentences.¹¹

2.5. Conclusion

This chapter reviewed major findings and issues relevant to the effects of WM on L1 and L2 sentence processing in English and in Japanese. There is abundant evidence to support the effect of WM in L1 sentence processing, but the evidence for the effect of WM in L2 sentence processing is far from enough. We know that L2 learners with a high WM capacity can utilize L2 linguistic information more efficiently than the learners with a low WM capacity (Osaka, 2002; Walter, 2004). However, whether the individual difference in WM capacity can explain the individual variation in L2 processing performance is not fully investigated.

Empirical findings indicate that sentences are processed incrementally. That is, the information that becomes available as each word is heard or read in an utterance is processed in that order (for example, see Kamide and Mitchell (1999)) and that native speakers somehow utilize WM in the most effective way possible to comprehend sentences based on their L1 linguistic knowledge. Naturally, the question of L2 sentence processing and its relation to WM arises from these previous findings and deserves investigation. Additionally, the typological difference between English and Japanese makes it interesting to investigate and compare the performances of L1 native speakers

¹¹ The comprehension accuracy rates were not compared in Sawasaki (2008, 2009), and all participant groups had higher than 90% comprehension accuracy rates for the test sentences. However, based on the error rates on the comprehension questions of the subject-gap and object-gap RCs from Sawasaki (2009), it seems that the subject-gap RCs showed a slightly higher error rate (5%) than the object-gap RCs (2%) by the English-speaking learners of Japanese (K. Sawasaki, personal communication, February 16, 2011).

and L2 learners because they are likely to need to use different strategies to comprehend their respective L2.

The next two chapters will report the findings from the experiments conducted to answer the two principal questions: (1) whether the L2 learners of English and the L2 learners of Japanese process respective L2 sentences similarly to the native speakers, and (2) whether the difference seen in sentence processing reading patterns in L2 is due to one's WM capacity.

CHAPTER 3

EXPERIMENTS

This chapter reports on self-paced reading experiments by English native speakers and Japanese native speakers in their respective L1 and L2. The experiments were designed to investigate the relationship between L1 and L2 sentence processing and differences in WM capacity. There were in total three types of tests: L1 and L2 Reading Span Tests (RSTs), L1 and L2 sentence reading tests, and a L2 language proficiency test.

The chapter is organized as follows. First, the restatement of experimental questions and the experimental design for this study will be provided. Second, the results of L1 and L2 English sentence reading tests in relation to the participants' WM capacity will be reported. Third, the results of L1 and L2 Japanese sentence reading tests in relation to the participants' WM capacity will be reported, followed by a summary of this chapter.

3.1. Experimental Design

Our interest in this study is to investigate how English and Japanese L2 learners are processing respective L2 sentences and whether the learners' L2 sentence processing is similar to that of the L1 native speakers. Another interest in mind is to investigate

whether there is a relationship between individual differences in L2 sentence reading and one's WM capacity. The following research questions are addressed in this chapter.

(1a) Is there a difference in the comprehension accuracy rates of subject-gap and object-gap sentences in English and in Japanese respectively?

(1b) Is there a difference in the comprehension accuracy rates of subject-gap and object-gap sentences by different WM capacity groups in English and in Japanese respectively?

(2a) Is there a difference between reading times of subject-gap and object-gap sentences per region in English and in Japanese respectively?

(2b) Is there a difference between reading times of subject-gap and object-gap sentences per region by different WM capacity groups in English and in Japanese respectively?

The previous research showed a strong or moderate correlation between L1 and L2 WM (L1 German and L2 French: Osaka, Osaka and Groner, 1993; L1 Japanese and L2 English: Miyake and Friedman, 1998; Osaka and Osaka, 1992; L1 Portuguese and L2 English: Fortkamp, 1999; L1 Spanish and L2 English: Leiser, 2007; L1 Turkish and L1 English: Alptekin and Erçetin, 2010; among others). Thus, it is predicted that there would be correlations between the two in this study as well. That is, if a participant has a high span score on the L1 RST, then we expect to find a high span score on the L2 RST.

In the experiments of L1 and L2 English subject-gap and object-gap sentences, we expect to see a difference between the comprehension accuracy rates of the two gap type sentences, as shown by the previous studies in L1 (Gibson, 1998, 2000; Gibson and

Pearlmutter, 1998; King and Just, 1991) and L2 (Comrie, 2007; Eckman, 2007; Hawkins, 2007; Hashimoto, 2007). More specifically, for the English native speakers, the English object-gap sentences are predicted to be more difficult to comprehend than the English subject-gap sentences as both Structural Distance Hypothesis (SDH) and Dependency Locality Theory (DLT) and the previous L1 studies indicated.

In this study, the difficulty in comprehension will be discussed from the viewpoint of comprehension accuracy rate and the difficulty of processing is discussed from the viewpoint of reading time. In other words, a lower comprehension accuracy rate means more difficult to comprehend and a slower reading time in a region means more time was required to process due to some kind of difficulty encountered when processing. Generally in L1 sentence processing studies, the difficulty in comprehension is assumed to link with the difficulty of processing. However, because there have not been enough studies on L2 sentence processing discussing the links between the difficulties in comprehension and processing and what is taken for granted in L1 sentence processing may not apply directly to L2 sentence processing, in this study, we will treat the difficulty of comprehension and the difficulty of sentence processing separately. Hence for the L2 learners of English, two predictions can be made based on the assumption that the L2 learners have already acquired the two English gap type sentence structures.

First, if acquiring the sentence structures means acquiring the native-like processing, then we would expect to see a similar performance by the L2 learners to that of the English native speakers. That is, the English object-gap sentences would be more difficult to comprehend and process than the English subject-gap sentences. Second, if acquiring the sentence structures does not necessarily mean acquiring the native-like

processing, then we would see a dissimilar performance by the L2 learners compared to the native speakers. More clearly, it is likely that we observe one of the following: (1) the English object-gap sentences would be more difficult to comprehend, but not necessarily more difficult to process than the English subject-gap sentences, (2) the English subject-gap sentences would be more difficult to comprehend and process than the English object-gap sentences, (3) the English subject-gap sentences would be more difficult to comprehend, but not necessarily more difficult to process, and (4) both the English subject-gap and object-gap sentences would show the same level of difficulties in comprehension and processing.

As discussed in Chapter 2, Gibson's integration cost part of the DLT has predicted where the slow down in reading times may occur in the processing of the English gap type sentences. In English object-gap sentences, the slower reading times should occur at embedded verb and main verb regions (cost=3EU each) whereas in the English subject-gap sentences, the slowest reading time should occur at the main verb region (cost=3EU). The cost of the embedded verb region in the English subject-gap sentence is 1EU. We will compare the reading times with the prediction of the theory.

The previous studies on L1 Japanese showed mixed results for the difficulty in comprehending Japanese subject-gap and object-gap sentences. Therefore, if structural distance (O'Grady's SDH) is an important factor for the online processing, we expect to see the Japanese object-gap sentences to have more processing load than the Japanese subject-gap sentences. The comprehension accuracy rate in the Japanese object-gap sentences, then, would be lower than that of the Japanese subject-gap sentences. If linear distance is an important factor (Gibson's DLT), then the Japanese subject-gap sentences

are predicted to show a lower comprehension accuracy rate than the Japanese object-gap sentences.

For the L2 learners of Japanese, two predictions can be made based on the assumption that the L2 learners have already acquired the two Japanese gap type sentence structures. Similarly to the prediction for the L2 learners of English, first, if acquiring the sentence structures means acquiring the native-like processing, then we would expect to see a similar performance by the L2 learners to that of the Japanese native speakers. Second, if acquiring the sentence structures does not necessarily mean acquiring the native-like processing, then we would see a dissimilar performance by the L2 learners to the native speakers.

According to the integration cost of the DLT, it is predicted that we see a difference between the reading times of the Japanese subject-gap and object-gap sentences. Specifically, it is expected to see the slowest reading time in the head noun region in both the Japanese subject-gap and object-gap RC sentences. Comparing the two gap sentence structures, the resources used for the head noun region of the Japanese subject-gap sentences are more than that of the Japanese object-gap sentences (3EU vs. 2EU, respectively). Therefore, we expect to see a slower reading time in the head noun region of the Japanese subject-gap sentences than in that region of the Japanese object-gap sentences.

In this study, we assume that WM capacity constrains online processing in L1 as well as in L2. As for the L1 and L2 RST span size groups and their effect on respective L1 and L2 sentence comprehension, it is predicted that the participants in the high RST span size group of L1/L2 RST would have a better comprehension accuracy rate than the

participants in the low RST span size group. In L1 and L2 online sentence processing experiments in both English and Japanese, we predict that the high RST span participants, who are assumed to have sufficient WM capacity and are efficient in using it, would behave differently from the low RST span participants, who would presumably suffer from the limitation of their WM.

3.1.1. Participants

Fourteen English native speakers and 18 Japanese native speakers participated in the study on a voluntary basis. These English and Japanese native speaker participants were either English-speaking learners of Japanese or Japanese-speaking learners of English. They were all recruited from The Ohio State University Japanese program, the Shizuoka Summer English Program at The Ohio State University, and the greater Detroit area community. They were paid \$14 for their participation. The participants were either taking classes or had taken classes in their respective L2 language at the time of the data collection. The average age of English native speakers is 25.78 (range=21-35, SD=4.19). The average age of Japanese native speakers is 26.55 (range=18-37, SD=6.06).

Fourteen English native speakers, i.e. English-speaking learners of Japanese, averaged 4.6 years of Japanese classroom instruction (range=1-10, SD=2.85). On average, they spent 1.4 years in Japan (range=0-5, SD=1.6). Eighteen Japanese native speakers, i.e. Japanese-speaking learners of English, averaged 9.61 years of English classroom instruction (range=6-14, SD=2.1). On average, they spent 3.47 years in English-speaking countries (range=0.1-12, SD=3.89).

Due to the expected great range in years of L2 classroom instruction and the length of stay in L2 speaking country, a L2 proficiency test was administered. The L2 proficiency test was used to determine whether the participants had a sufficient proficiency to carry out the tasks in the experiments. For the English native participants (L2 Japanese), a modified practice test of Japanese Language Proficiency Test, which was constructed with sample tests of Levels 2 and 3 of Japanese Language Proficiency Test (JLPT, Itomitsu and Nakayama, 2005a) was administered. The average of 88.03% (range=70-100, SD=8.72) was obtained. For the Japanese native participants (L2 English), a modified practice test of paper-based TOEFL sample tests was administered. The average score was 80.85% (range=47.06-100, SD=12.55). Participants who did not score at least 60% on the proficiency tests were not included in the study. One Japanese native participant was eliminated from further analysis. The remaining 17 Japanese participants had the average 82.83% (range=68.82-100, SD=9.58) in the modified practice test of the paper-based TOEFL sample tests.

3.1.2. Procedure

This study employed three types of tests. One was to measure the participants' L2 proficiency level, the second was to measure the participants' L1 and L2 WM capacity and the third was to measure L1 and L2 sentence reading times. The L2 proficiency test was given prior to the online experiments and the score was used to screen the level of L2 proficiency. There were two parts to the online experiments: tasks in L1 and tasks in L2. The participants started the experiment with their respective L1 tasks and then, moved on to their L2 tasks—that is, if the participant was a native speaker of English, then L1

English RST and L1 English sentence reading experiments were administered first. After a short break, L2 Japanese RST and L2 Japanese sentence reading experiments were administered. If the participant was a native speaker of Japanese, then L1 Japanese RST and L1 Japanese sentence reading experiments were administered first before moving on to L2 English RST and L2 English sentence reading experiments. There was either a break between L1 tests and L2 tests or they were administered over two different meeting sessions over two consecutive days because of time constraints.

Next, we will discuss the details on administration of RSTs and the sentence reading tasks. The experiments took the form of an individual (one-on-one) format in a quiet room. The first task was the L1 RST test, which has the same procedure as the original RST by Daneman and Carpenter (1980). In the RST experiment, the researcher showed participants a set of sentences written on 5'' by 7'' index cards, one sentence per card. The task was to read the sentences aloud and memorize the target word underlined in red. After reading the sentences in each set, a white index card was presented for the participant to recall the target words of each sentence in the set. The number of sentences in each set steadily increased (from a two-sentence to a five-sentence condition), and there were five trials in each sentence condition. For the L1 and L2 English RST tests, the target words were at the end of the sentence. However, because of SOV canonical word order in Japanese, whereby most sentences end in a predicate, the L1 Japanese RST used in this experiment (Osaka, 2002) placed the target words in a different position of the sentence. The L2 Japanese RST (Itomitsu and Nakayama, 2005b), on the other hand, had the target words at the end of the sentence, but still allowed for different categories of words to be the target words by controlling the sentence structures. The task was

recorded for the purpose of later coding the participants' responses by the researcher. This task took no longer than 15 minutes per language.

For the scoring of RSTs, the total number of words recalled across all trials was used for the analyses. For example, if a participant recalled three out of five words in a trial, he or she received three points for that trial. This total scoring method is different from the one used in the original Daneman and Carpenter (1980), but it is said that this method picks up the differences between individuals who could recall four out of five words at Level 5 (5 sentences per set) and individuals who could recall only one out of five words at Level 5 (see Friedman and Miyake, 2005, for the comparison of different RST scoring methods). The maximum possible score was 70. After the scoring, the participants were divided into a low span group and a high span group based on the cut-off point, which was determined based on the average score of each language group.

The sentence reading experiment was carried out using Psyscope based on Cohen, MacWhinney, Flatt, and Provost (1993) on an iMac laptop computer. The participants' task was to read each sentence appearing on the screen as quickly and accurately as possible while pressing the space bar. In the beginning, the dots (.....) appeared for the length the sentence they were to read. When they pressed the space bar, the first region of the sentence became visible and when they pressed the space bar again, the second region of the sentence became visible, and the previous region turned back to dots. Participants were instructed to read the sentence in this manner until the end (i.e., period). After the period at the end of the sentence, they pressed the space bar once more and a yes/no content question appeared for them to answer. The questions were presented as a whole

sentence on a computer screen and the participants were asked to press either a YES “/” or NO “z” button in order to answer the question.

The instructions were given in the participant’s native language and the task started with a practice part, which familiarized participants to the experiment and allowed time to ask any questions or concerns before proceeding on to the experiment part. There were eight practice sentences followed by 60 test sentences (20 experimental sentences + 40 fillers) with a yes/no content question for each sentence. This sentence reading experiment took 15-25 minutes per language.

The reading times for each segment were measured and stored in the computer file automatically. Before comparing the reading times of each region, the raw reading time data were modified. First, the data of the participants who did not reach the comprehension accuracy rate of 75% for L1 sentence reading task and 65% for L2 reading task were eliminated from further analyses of both languages. In total, three of the Japanese native speakers were disqualified, which left the data of 14 Japanese native speakers and 14 English native speakers for further analyses. Second, the reading times of the test sentences whose comprehension questions were answered incorrectly were also deleted from the data and replaced with the mean reading time of the region from the same sentence type by the same participant. Third, each participant’s mean reading time per syllable (English) or mora (Japanese) was calculated for each phrase. Each participant’s mean reading time per syllable/mora for all the sentences was then calculated. When the former exceeded two standard deviations (SDs) of the latter, it was replaced by the mean reading times ($SD \times 2$). Then, residual reading times (RRTs) per sentence segment were calculated and used for the analyses (Trueswell, Tanenhaus, and

Garnsey, 1994).¹² Residual reading times are used to adjust for differences in participants' reading rates or for differences in word length within conditions. In order to examine the overall RRT pattern, the reading time data were first examined without taking the RST span size into consideration. Then, the participants were divided into two span groups according to their L1 and L2 RST scores to see whether the span size affected the sentence processing RRTs.

3.1.3. Test Material

This study used four different L1 and L2 RSTs, which are L1 English RST (Daneman and Carpenter, 1980), L1 Japanese RST (Osaka, 2002), L2 English RST (a modified version of Harrington and Sawyer, 1992), and L2 Japanese RST (Itomitsu and Nakayama, 2005b), to measure the participants' WM capacity. The original L2 RST by Harrington and Sawyer (1992) was created to test the WM capacity of Japanese-speaking learners of English, which made it suitable to use in this study. However, the Harrington and Sawyer's RST task was different from that of Daneman and Carpenter. The RST of Harrington and Sawyer adopted the method used in Turner and Engle (1989) and used a grammaticality judgment task.¹³ Because of the nature of grammaticality judgment task, there were only 43 grammatically correct sentences in Harrington and Sawyer.¹⁴ To maintain the uniformity among the three RSTs, 27 sentences were newly created and added to the original 43 sentences of Harrington and Sawyer's L2 RST. The added

¹² For the calculation of RRTs and the difference in RRTs based on morae and syllables in Japanese language, see Sawasaki (2007) for a detailed explanation and comparison.

¹³ Their claim for using the grammaticality judgment task in RST is that it insures the participants' reading and processing the sentence for meaning.

¹⁴ The test sentences in Harrington and Sawyers L2 English RST were simple, active and 11-13 words in length.

sentences were 10-13 words in length with various syntactic structures taken from English handbooks for Japanese high school students.

For the sentence processing experiment, there were two sets of 20 experimental sentences, which were subject-gap and object-gap sentences in both English and Japanese. The English and Japanese sentences were independent of each other and they were not translations of one another. In English test sentences, there were in total seven regions and in Japanese test sentences, there were in total six regions. The sample experimental sentences are shown below.

(3a) English subject-gap RC

The client / who / irritated / the businessman / paid / the monthly bill / . /

(3b) English object-gap RC

The client / who / the businessman / irritated / paid / the monthly bill / . /

(4a) Japanese subject-gap RC

Uenosan-o / miokutta / ojisan-ga / omocha-o / hirotta / . /

Mr. Ueno-acc saw off uncle-nom toy-acc picked up

‘The uncle who saw Ueno off picked up a toy.’

(4b) Japanese object-gap RC

Uenosan-ga / miokutta / ojisan-ga / omocha-o / hirotta / . /

Mr. Ueno-nom saw off uncle-nom toy-acc picked up

‘The uncle who Ueno saw off picked up a toy.’

Each participant read 20 test sentences and 40 fillers, which were sequenced in a fixed order so that no item of the same structure was presented successively (see Appendix for a complete set of the test sentences in both languages). Two lists were created with each list containing exactly 10 subject-gap and 10 object-gap sentences and the 40 filler sentences per language. For English sentences, the vocabulary was chosen from Japanese high school English study aid books.¹⁵ For Japanese sentences, the vocabulary was chosen from the textbooks that are being used in Japanese courses offered at The Ohio State University and JLPT vocabulary list for Level 3 and Level 4. There was no control of the frequency and familiarity of vocabulary because of the limited available vocabulary in the participants' respective L2. Although familiarity of the words was not controlled, it is assumed that the words are used with high frequency because those words were chosen from the materials for foreign language learners, which usually introduce basic vocabulary in the target language.

English sentences used common nouns indicating human for the first and second overt NPs and the sentences were presented in the normal manner.¹⁶ The first NP in Japanese sentences, which was either the nominative phrase (i.e., NP-*ga*) or the accusative phrase (i.e., NP-*o*), was always family or personal names and the RC head nouns were always common nouns. Japanese sentences were presented in Japanese

¹⁵ Approximately 3000 words and 400-500 idiomatic phrases and sentence structures are introduced during junior high and high school's English education in Japan (Ministry of Education, Culture, Sports, Science and Technology, Japan. Retrieved from www.mext.go.jp/b_menu/shingi/chukyo/chukyo3/015/siryo/05120501/007/008.htm)

¹⁶ Nouns denoting human were used so that animacy cues would not affect the reading (Inoue and Den, 1997; Harrington, 1987).

orthography using *kanji*, *hiragana*, and *katakana* although their presentation was not necessarily authentic.¹⁷

The following tables show the average number of syllables and morae per region in the English and Japanese experimental sentences.

	Regions	1	2	3	4	5	6	7
English subject-gap	# of Syllable	3	1	2	3.9	1.2	4.75	0
	Range	3	1	1-4	1-4	1-2	1-2	
	SD	0	0	1.03	0.31	0.41	0.41	
English object-gap	# of Syllable	3	1	3.9	2	1.2	4.75	0
	Range	3	1	1-4	1-4	1-2	1-2	
	SD	0	0	0.31	1.03	0.41	0.41	

Table 3.1: Number of syllables in two gap type sentences in English

	Regions	1	2	3	4	5	6
Japanese subject-gap	# of Morae	6.35	4.15	4.8	4	3.65	0
	Range	5-7	3-5	3-5	3-4	3-6	
	SD	0.58	0.74	0.53	0.33	0.82	
Japanese object-gap	# of Morae	6.35	4.15	4.8	4	3.65	0
	Range	5-7	3-5	3-5	3-4	3-6	
	SD	0.58	0.74	0.53	0.33	0.82	

Table 3.2: Number of morae in two gap type sentences in Japanese

¹⁷ The vocabulary in Japanese sentences were chosen based on the textbook that the lowest proficiency level participants were supposed to have completed in their classroom instruction. The number of *kanji* that they learned in class was limited. Therefore, some words were presented in unauthentic form, with a mixture of *kanji* and *hiragana*. The vocabulary in English sentences was chosen from Japanese high school textbook and study aid workbooks.

3.2. Results of English Relative Clause Sentences

This section reports the results of the English sentence processing experiments by English native speakers (L1) and Japanese native speakers (L2). First, the results of L1 English speakers will be discussed in terms of sentence comprehension accuracy, RRTs, and how the different L1 English RST span groups varied. Second, the results of Japanese-speaking learners of English will be discussed in terms of sentence comprehension accuracy, RRTs, and the different L2 English RST span groups. Lastly, the findings of this section will be discussed.

3.2.1. L1 English

As discussed in the previous section, the reading time data of the participants were modified and used for further analyses. The average comprehension accuracy rate for all English sentences (including the fillers) for the 14 English native participants in the sentence reading task was 91.19% (range=80-98.33, SD=5.9). The cut-off score used for determining the L1 English RST High and Low groups was 53.5, which divided the 14 English native speakers into exact numbers of participants in each span size group (7 participants in L1 English RST High and 7 participants in L1 English RST Low). Table 3.3 shows the details of the participants' scores.

Participant #	L1 Eng RST Score ¹⁸	L1 Eng RST Group	Eng subject-gap accuracy (%)	Eng object-gap accuracy (%)
E01	56	G1	90	100
E02	64	G1	100	90
E03	44	G2	100	100
E04	54	G1	70	90
E05	57	G1	90	90
E06	41	G2	100	100
E07	44	G2	80	60
E08	51	G2	100	100
E09	44	G2	100	90
E10	60	G1	90	90
E11	53	G2	80	70
E12	54	G1	100	70
E13	42	G2	100	80
E14	57	G1	90	80
Metric	53.5 (Median)		92.14(Ave)	86.42 (Ave)
SD	7.30		9.74	12.77

RST score: Max=70; RST span groups: G1=High, G2=Low¹⁹

Table 3.3: Scores of fourteen English native speakers

3.2.1.1. Comprehension Accuracy Results by English Native Speakers

The following figure shows the comprehension accuracy rates of the English subject-gap and object-gap sentences by the English native speakers. The previous studies have shown that English object-gap sentences are more difficult to comprehend than English subject-gap sentences. In order to confirm this previous finding, an independent-samples t-test was conducted to compare the sentence comprehension accuracy rates of the English subject-gap and object-gap sentences by the English native speakers. A numerical difference approaching significance was found in the

¹⁸ The following abbreviations are used in the tables and figures: Eng=English, Jpn=Japanese, and prof=proficiency.

¹⁹ Note that High and Low in RSTs are only relative to the participant groups within this study, i.e. not absolute classification.

comprehension accuracy rates for the English subject-gap ($M=92.14$, $SD=9.750$) and object-gap ($M=83.57$, $SD=14.169$) sentences; $t(26)=1.838$, $p<.077$).

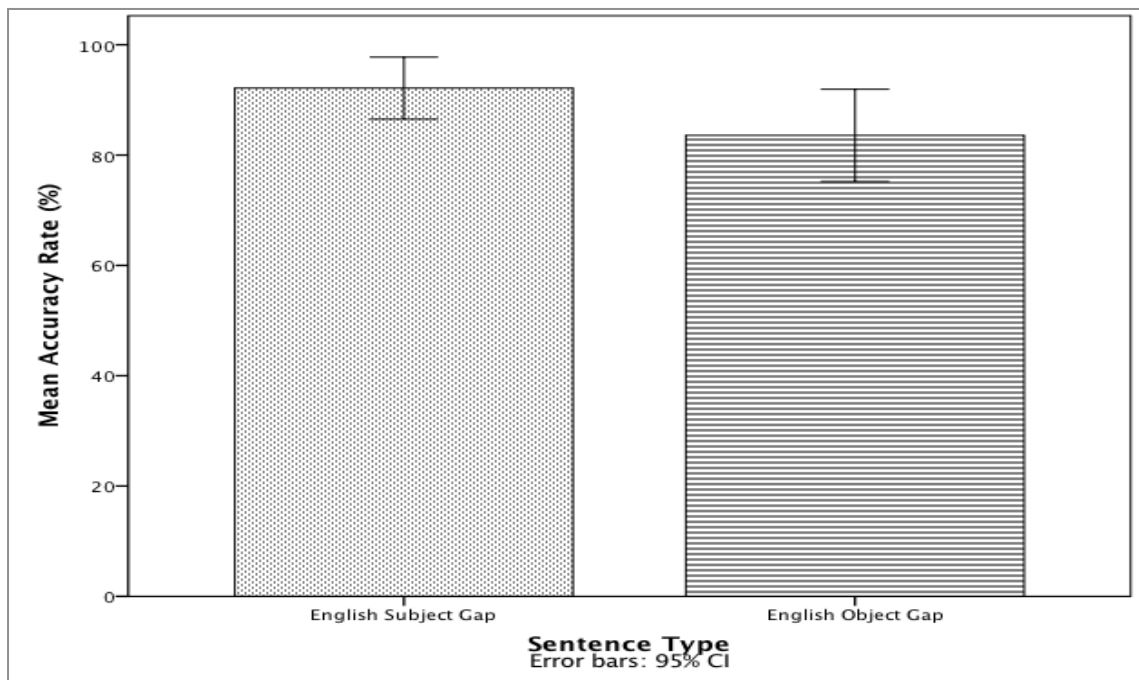


Figure 3.1: English sentence comprehension accuracy by English native speakers

Next, whether different L1 English RST span sizes affected the comprehension accuracy rates of the English subject-gap and object-gap sentences was examined. The following figure shows English native speakers' comprehension accuracy rates for the English gap sentences according to their L1 English RST groups.

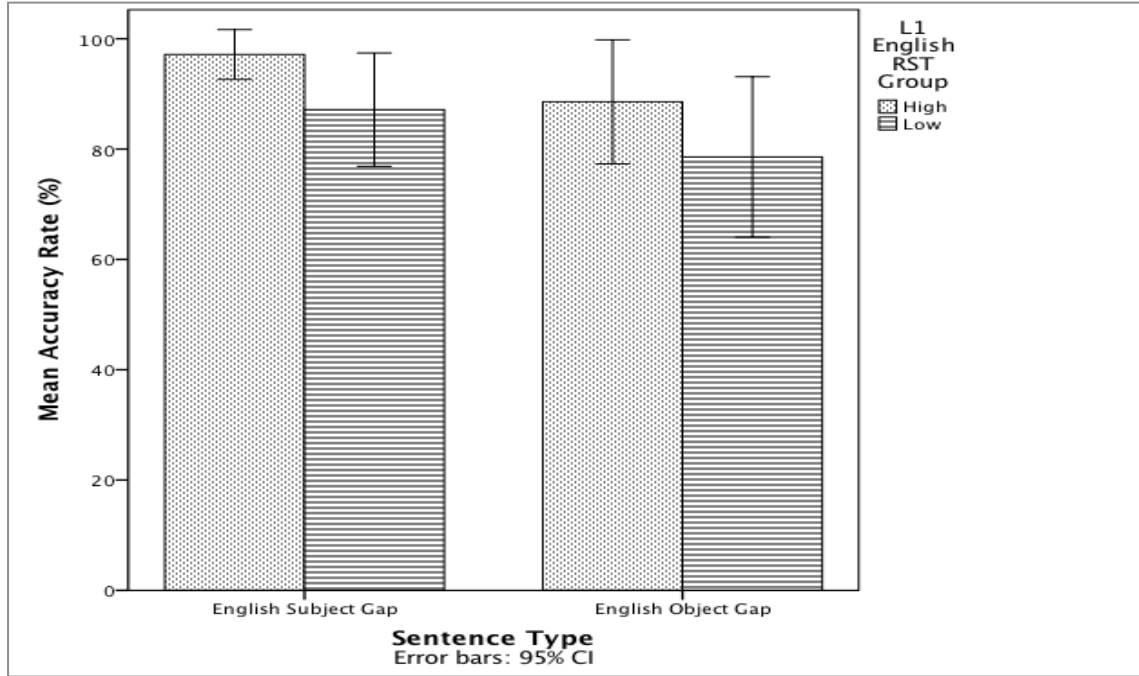


Figure 3.2: English sentence comprehension accuracy by L1 English RST

Independent sample t-tests were conducted and found that there was a significant difference in the comprehension accuracy rates of the English subject-gap sentences by the L1 RST High ($M=97.14$, $SD=4.880$) and Low ($M=87.14$, $SD=11.127$) groups; $t(12)=2.178$, $p<.05$. On the contrary, there was no significant difference in the comprehension accuracy rates of the English object-gap sentences by the L1 RST High ($M=88.57$, $SD=12.150$) and Low ($M=78.57$, $SD=15.736$) groups; $t(12)=1.331$, $p<.208$.

When the English subject-gap and object-gap accuracy rates were compared within the same L1 RST span size group, no significance was found in the L1 English RST High group between the comprehension accuracy rates of the English subject-gap ($M=97.14$, $SD=1.844$) and object-gap ($M=88.57$, $SD=4.592$) sentences; $t(12)=1.732$,

$p < .109$. Similarly, no significant difference was found in the L1 English RST Low group between the comprehension accuracy rates of the English subject-gap ($M=87.14$, $SD=11.127$) and object-gap ($M=78.57$, $SD=15.736$) sentences; $t(12)=1.177$, $p < .262$.

3.2.1.2. L1 RRTs by English Native Speakers

The following table shows the two types of English gap type sentences being used in this study. The difference in the two types of sentences first appears in Region 3, where the embedded verb appears in the English subject-gap sentences, and in the English object-gap sentences, the embedded subject NP appears. Region 4 is also different among the two gap type sentences. In the Region 4 of the English subject-gap sentences, the embedded object NP appears whereas in the English object-gap sentences, the embedded verb appears. These Regions 3 and 4 are particularly of interest in the English sentence processing analyses.

Region	1	2	3	4	5	6	7
English subject-gap	The client	who	irritated	the businessman	paid	the monthly bill	.
English object-gap	The client	who	the businessman	irritated	paid	the monthly bill	.

Table 3.4: Example English subject-gap and object-gap sentences

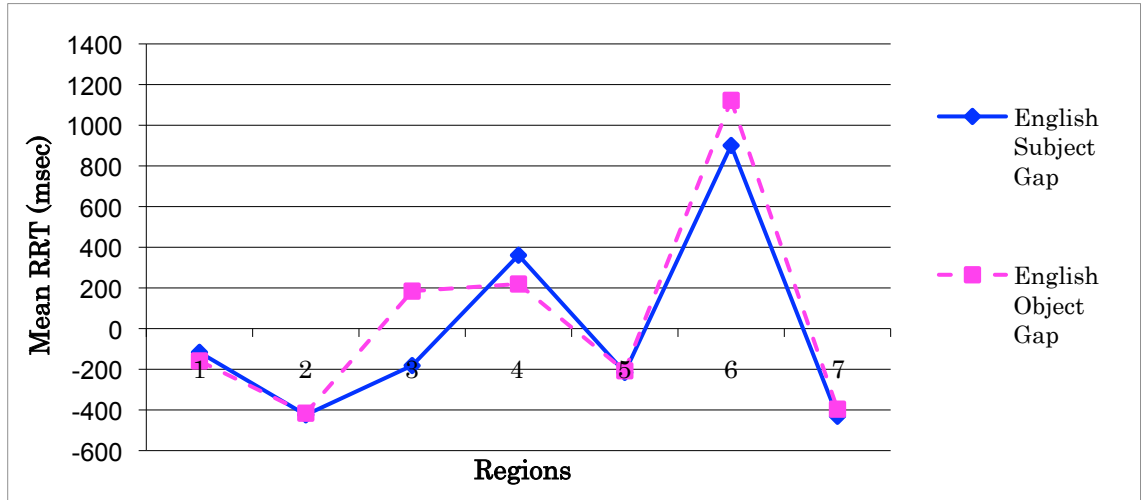


Figure 3.3: Mean RRTs of English gap sentences by English native speakers

Figure 3.3 shows the mean RRTs of the English gap sentences by English native speakers. Indeed, the difference in RRTs seems to appear in Region 3. There was a significant difference in the two types of English gap sentences in Region 3 [$F(1, 13)=11.045$, $p<.005$, $F(1, 19)=25.052$, $p<.000$]. There was no significant difference in Region 4 [$F(1, 13)=.002$, $p<.964$, $F(1, 19)=.005$, $p<.945$].

In the figure above, the RRT of Region 3 in the English object-gap sentences (subject NP of RC) is slower than the RRT of Region 3 in the English subject-gap sentences (RC verb). The reason why the RRT of Region 3 in the object-gap sentences is elevated may be due to a surprise effect of the non-canonical word order in the object-gap sentences. Therefore, comparing the Region 3 RRTs of the two gap type sentences and finding a difference, in a way, is not surprising. Region 4 of the English object-gap sentences shows relatively the same speed as Region 3 whereas Region 4 of the subject-gap sentences shows elevation from the previous region. It is said that verb information

helps the parser to predict subsequent elements and provides semantic and syntactic information of upcoming elements (Altman and Kamide, 1999; Frazier, 1987; Frazier and Clifton, 1996, MacDonald, Pearlmutter, and Seidenberg, 1994). If so, it is expected to have faster RRT in Region 4 of the subject-gap sentences, which was not obtained in this study. In order to investigate the structural effect in the RC verb regions of the two gap type sentences and to examine whether processing is done incrementally and affects the reading times, Region 3 of the English subject-gap sentences and Region 4 of the English object-gap sentences were compared. A numerical difference approaching significance was found by subject and a significant difference was found by item [$F(1, 13)=4.406$, $p<.056$; $F(1, 9)=25.312$, $p<.001$].

Next, a closer look at the sentence reading patterns show similar patterns among the different L1 English RST groups of the English native speakers. That is, for the English subject-gap sentences, the L1 English RST High and Low groups both showed a peak at Regions 4 and 6. For the English object-gap sentences, their reading time is longer at Region 3 and stays relatively at the same long reading time at Region 4, followed by a drop at Region 5 and a peak at Region 6. These reading patterns are clearly seen in the following figure.

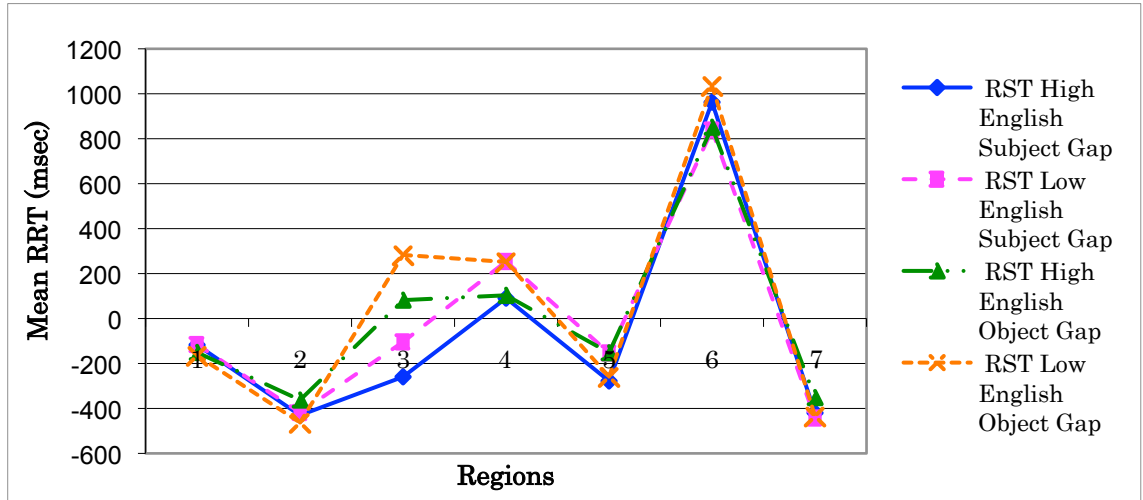


Figure 3.4: Mean RRTs of English gap sentences by L1 English RST

Comparing the English subject-gap sentences of the L1 English High and Low groups, there was no significant difference by subject, but a numerical difference approaching significance was found by item in Region 3 [$F(1, 13)=2.283, p<.157$; $F(1, 19)=4.435, p<.056$] and in Region 4 [$F(1, 13)=2.617, p<.132$; $F(1, 19)=3.184, p<.091$]. There was also no significance in the English object-gap sentences by subject, but significance was found by item in Region 3 [$F(1, 13)=1.301, p<.276$; $F(1, 19)=5.481, p<.031$]. No other regions yielded any significance.

The L1 English RST High group showed that there was a significant difference in Region 3 between the English subject-gap and object-gap sentences [$F(1, 6)=11.025, p<.006$; $F(1, 19)=17.799, p<.001$], but no difference was found in Region 4 [$F(1, 6)=.006, p<.940$; $F(1, 19)=.039, p<.845$]. The L1 English RST Low group showed the same results as the L1 English RST High group in Region 3 [$F(1, 6)=4.723, p<.05$; $F(1, 19)=13.318, p<.002$] and in Region 4 [$F(1, 6)=.000, p<.997$; $F(1, 19)=.000$;

$p < .993$]. There was also a significant difference between Region 3 of the English subject-gap sentences and Region 4 of the English object-gap sentences by the L1 English RST High group [$F(1, 6) = 6.399$, $p < .013$; $F(1, 19) = 6.079$, $p < .015$], but the L1 English RST Low group did not yield significance between the two regions [$F(1, 6) = .114$, $p < .736$; $F(1, 19) = .099$, $p < .754$].

3.2.1.3. Discussion

The results of comparing the comprehension accuracy rates of the English subject-gap and object-gap sentences by the English native speakers showed that the English object-gap sentences were slightly more difficult to comprehend than the English subject-gap sentences. Further analysis revealed that the comprehension accuracy rates of the English subject-gap and object-gap sentences were not different within the same L1 English RST group, although the L1 English High RST group was close to showing a numerical difference approaching significance ($p < .109$).

When the comprehension accuracy rates of the two L1 English RST groups were compared in the same gap type sentences, there was a significant difference in the English subject-gap sentences, but not in the English object-gap sentences. This result may indicate that the English subject-gap sentences were definitely easier for the L1 English High group, but not so much for the L1 English RST Low group in terms of comprehension. The more difficult sentence structure, i.e. English object-gap sentences, stays mostly the same in terms of the difficulty in comprehension for both the L1 English RST High and L1 English RST Low groups.

Comparing the RRTs of the sentence regions, when no L1 English RST groups were taken into account, there was a significant difference between the subject-gap and object-gap sentences in Region 3 (subject-gap=V, object-gap=NP), but not in Region 4 (subject-gap=NP, object-gap=V). However, significance was found in the comparison of Region 3 of the subject-gap sentences and Region 4 of the object-gap sentences. These results seem to suggest that the integration of syntactic elements is being done in our memory incrementally and it is affecting the reading times of different regions in the sentences.

Further analysis with the comparison of the two different L1 English RST groups revealed that there were no meaningful significances in Regions 3 and 4 in both the gap type sentences. An additional analysis, however, has shown that there was a significant difference in Region 3 of the subject-gap sentences and Region 4 of the object-gap sentences only by the L1 English RST High group. Combining the results of comprehension accuracy differences seen in the L1 English RST High and Low groups in the subject-gap sentences and the current RRT comparison results, it is not too strange to say that the effect of having larger L1 WM capacity appears positively and more strongly on the sentence type that is easier to comprehend than the sentence type that is more difficult to comprehend in comprehension accuracy. From this, it is confirmed that WM capacity influences L1 sentence processing.

English subject-gap and object-gap sentences were discussed based on the two theories in Chapter 2: Gibson's Dependency Locality Theory (DLT) and O'Grady's Structural Distance Hypothesis (SDH). Both of these explanations predict English object-gap sentences to be more difficult to comprehend and the result of this English gap

sentence processing experiment by itself cannot tell which theory is at work. We will discuss this issue later in the Japanese sentence processing section.

Here, we will consider Gibson's DLT by looking at our RRTs in the two English gap sentences. In the English subject-gap sentences, the English native speakers' reading pattern showed two peaks, one at Region 4 and the other at Region 6. In the English object-gap sentences, the longer RRTs were obtained in Regions 3 and 4, and then in Region 6. The longer RRTs in Region 6 of both sentence types can be better explained by the wrap-up effect because it is at the end of the sentence. However, the longer RRTs in both Regions 3 and 4 of the English object-gap sentences were unpredicted. With the DLT, the difference in the cost between the two gap type sentences at Region 3 is 1 (subject-gap=1; object-gap=0) and at Region 4 is 2 (subject-gap=1; object-gap=3). The current result did not exactly match with the integration cost predicted by the DLT (see Figure 3.3). We saw a significant difference in Region 3 (cf. subject-gap=*attacked*; object-gap=*the senator*), but not in Region 4 (c.f. subject-gap=*the senator*; object-gap=*attacked*).

An alternative hypothesis to account for the current result is the "expectation-based" hypotheses. For instance, Gibson (1998, 2000) first proposed it in the storage component of the DLT. In the "expectation-based" hypotheses, it is supposed that the human sentence processor is sensitive to the number of syntactic heads that are required to form a grammatical sentence (Gibson, 2006; Grodner and Gibson, 2005).²⁰

²⁰ There are other expectation-based hypotheses such as the anticipation hypothesis (Konieczny and Döring, 2003) and the probabilistic parser (Levy, 2008), which consider additive burden on memory when the input did not match the readers' expectations. However in this study, only the storage component of the DLT will be discussed because Gibson quantifies the cost, which makes it easier to compare with the participants' RRT performances.

Syntactic expectation hypothesis: People are sensitive to the lexical and syntactic expectations at each word, giving rise to a probability distribution of expectations at each word, including expectations for the immediately following syntactic head.

(Gibson, 2006: 366)

Thus, a difficulty is experienced when a new expectation is added to WM or when the input does not match one's expectation and it is necessary to reanalyze. The expectation cost is added when a new nominative NP is encountered because each nominative NP is associated with the expectation of a verb. Consider the following two gap type sentences again based on the storage cost proposed in the DLT.

Region	1	2	3	4	5	6
Eng subject-gap	The reporter	who	attacked	the senator	admitted	the error
Predicted verbs	V1	V1 V2	V1	V1	-	-
Cost	1	2	1	1	0	0
Eng object-gap	The reporter	who	the senator	attacked	admitted	the error
Predicted verbs	V1	V1 V2	V1 V2	V1	-	-
Cost	1	2	2	1	0	0

Table 3.5: Cost predictions based on expectation-based hypothesis

In the English subject-gap sentences, only one verb is predicted for NP1 *the reporter* and in the object-gap sentences, two verbs are predicted for NP1 *the reporter* and NP2 *the senator* in Region 3. The current experiment result also showed that there was a significant difference between the two gap type sentences at Region 3, but not at Region 4 as predicted by the integration cost of the DLT. Thus, the current result seems to be explained well by the expectation-based theory based on the storage cost component of the DLT.

3.2.2. L2 English

For the 14 Japanese-speaking L2 learners of English data, the average comprehension accuracy rate for all English sentences (including the fillers) in the processing experiment was 76.07% (range=66.67-91.67, SD=8.5). Similar to previous studies on the relationship between L1 and L2 WM capacity, the Japanese native learners of English in this study also showed a correlation between L1 Japanese RST and L2 English RST scores [$r(12)=.718$, $p<.01$].²¹ The score used to separate High and Low groups in L1 Japanese RST was 41.5 and in L2 English RST was 38.5, which divided the 14 participants into seven participants in each RST group. Table 3.6 shows the details of the participants' scores.

²¹ There was a correlation between L2 English RST and L2 English proficiency scores [$r(12)=0.713$, $p<.01$], but no correlation was found between L1 Japanese RST and L2 English proficiency scores [$r(12)=0.257$, $p<.375$].

Participant #	L1 Jpn RST Score	L1 Jpn RST Group	L2 Eng RST Score	L2 Eng RST Group	L2 Eng Prof Score (%)	Eng subject-gap accuracy (%)	Eng object-gap accuracy (%)
J21	41	G2	36	G2	64.70	40	60
J22	45	G1	35	G2	64.70	70	70
J23	56	G1	56	G1	100	80	60
J24	33	G2	43	G1	88.24	90	60
J25	50	G1	56	G1	94.12	90	80
J26	40	G2	42	G1	88.24	100	90
J27	39	G2	39	G1	82.35	80	60
J28	42	G1	38	G2	82.35	70	50
J29	32	G2	34	G2	82.35	70	60
J30	42	G1	40	G1	88.24	100	100
J31	49	G1	48	G1	94.12	90	80
J32	34	G2	33	G2	76.47	50	50
J33	33	G2	37	G2	88.24	30	30
J34	43	G1	32	G2	76.47	90	50
Metric	41.5 (Median)		38.5 (Median)		83.61 (Ave)	75.00 (Ave)	60.00 (Ave)
SD	7.09		7.78		10.36	21.75	18.27

RST score: Max=70; RST span groups: G1=High, G2=Low

Table 3.6: Scores of fourteen L2 learners of English

3.2.2.1. L2 Comprehension Accuracy by Japanese-Speaking Learners of English

The following figure shows the comprehension accuracy rates of the English subject-gap and object-gap sentences by the Japanese-speaking L2 learners of English. It shows higher comprehension accuracy rates for the English subject-gap sentences than the English object-gap sentences.

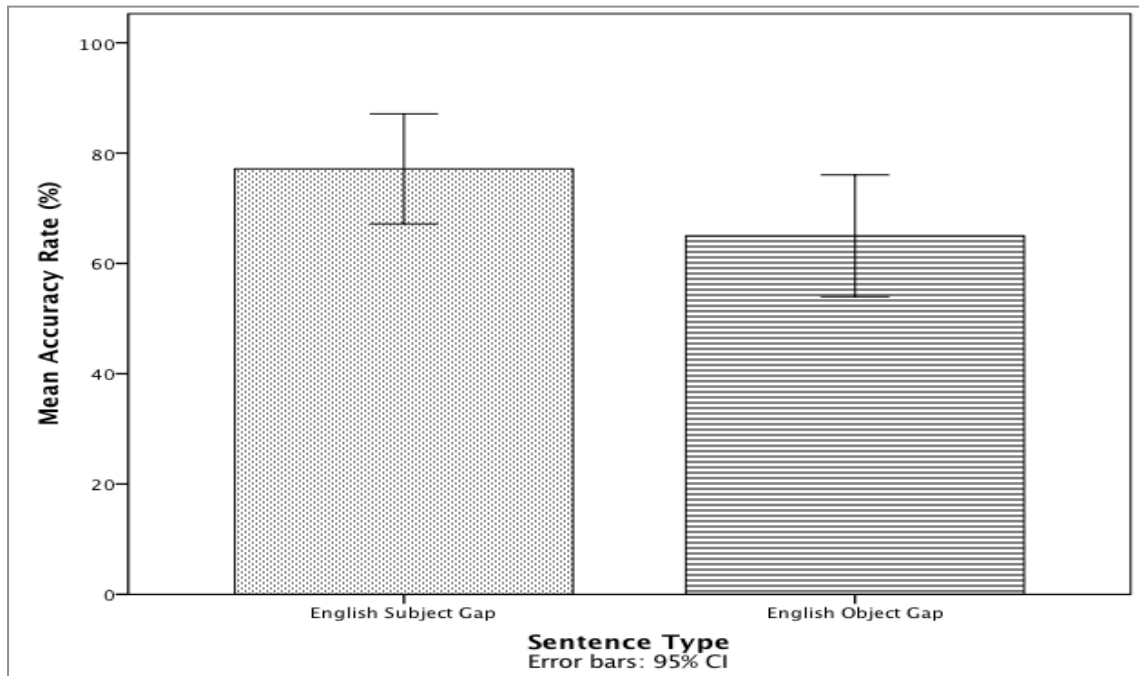


Figure 3.5: English gap comprehension accuracy by L2 RST of learners

An independent-samples t-test was conducted to compare the sentence comprehension accuracy rates of the English subject-gap and object-gap sentences. A numerical difference approaching significance was found in the accuracy rates for the English subject-gap ($M=77.14$, $SD=17.289$) and object-gap ($M=65.00$, $SD=19.115$) sentences; $t(26)=1.763$, $p<.090$.

Next, whether the different L2 English RST span sizes affected the comprehension accuracy rates of the English subject-gap and object-gap sentences was examined. Figure 3.6 shows the effect of L2 English RST span size on the comprehension accuracy rates of the two English gap type sentences.

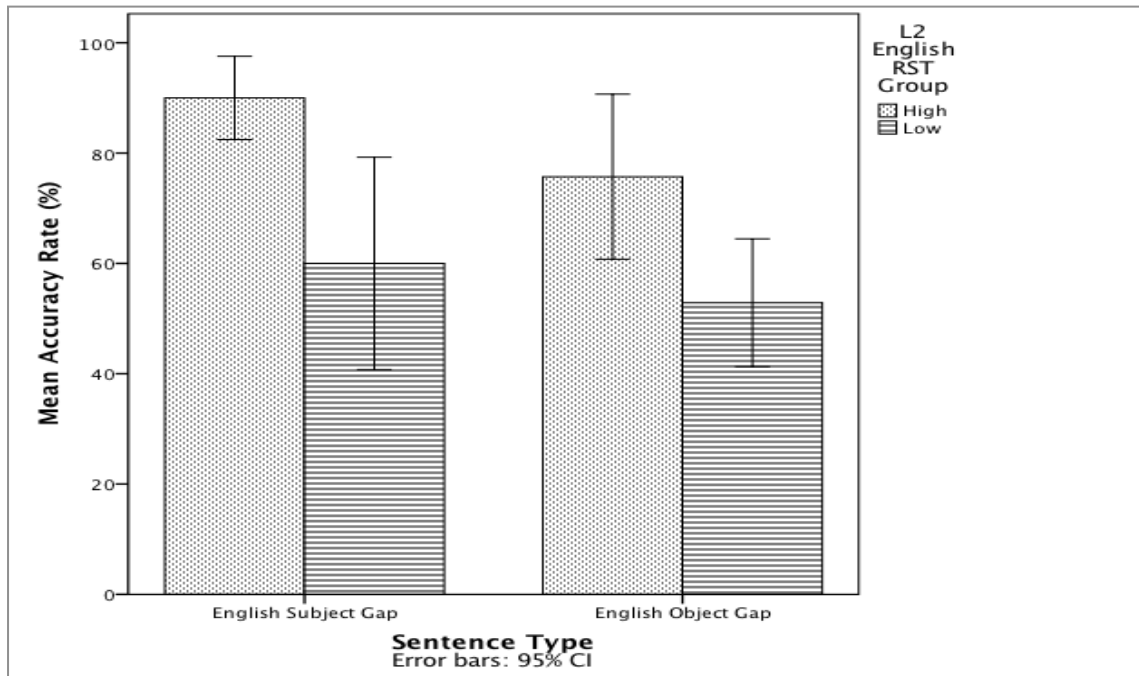


Figure 3.6: English gap comprehension accuracy by L2 RST of learners

Independent t-tests were conducted and a significant difference was found in the accuracy rates of the English subject-gap sentences by the L2 English RST High ($M=90.00$, $SD=8.165$) and L2 English RST Low ($M=60.00$, $SD=20.817$) groups; $t(12)=3.550$, $p<.004$. Similarly, a significant difference was found in the comprehension accuracy rates for the English object-gap sentences by the L2 English RST High ($M=75.71$, $SD=16.183$) and the L2 English RST Low ($M=52.86$, $SD=12.536$) groups; $t(12)=2.954$, $p<.012$.

When the comprehension accuracy rates of the English subject-gap and object-gap sentences were compared within each L2 English RST span group, a numerical difference approaching significance was found in the comprehension accuracy rates of the L2 English RST High group between the English subject-gap ($M=90.00$, $SD=8.165$) and object-gap ($M=75.71$, $SD=16.183$) sentences; $t(12)=2.085$, $p<.059$. However, no

significance was found in the accuracy rates of the L2 English RST Low group by the English subject-gap ($M=60.00$, $SD=20.817$) and object-gap ($M=52.86$, $SD=12.536$) sentences; $t(12)=.778$, $p<.452$.

3.2.2.2. L2 RRTs by Japanese-Speaking Learners of English

The following figure shows the mean RRTs of the English gap type sentences by the Japanese-speaking learners of English. The reading patterns of the English subject-gap sentences show that there are two peaks, one at Region 4 and the other at Region 6. The reading patterns of the English object-gap sentences show longer reading times for Regions 3, 4, 5, and 6.

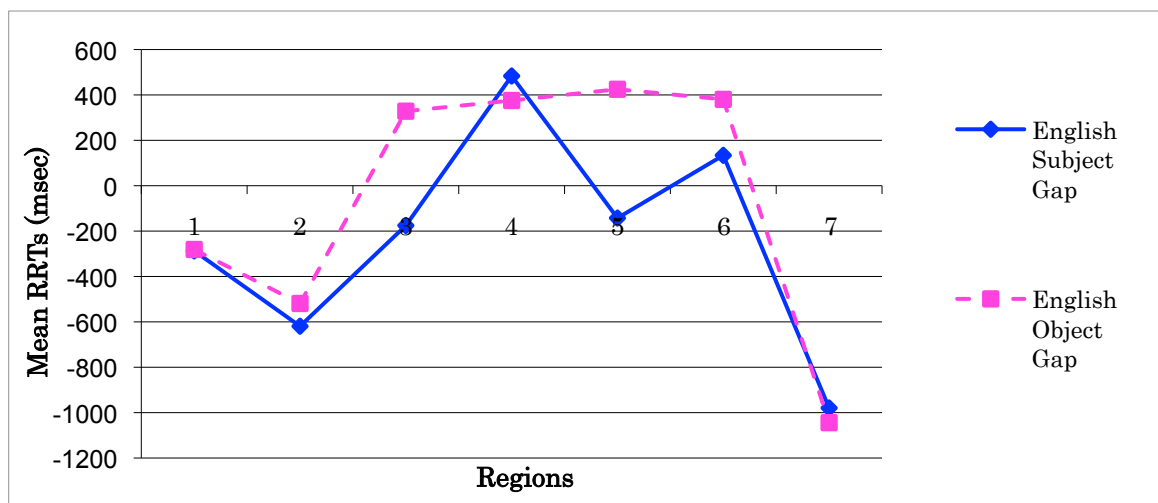


Figure 3.7: Mean RRTs of English gap sentences by L2 learners of English

Statistical analyses showed that there was a significant difference in the English subject-gap and object-gap sentences by the Japanese-speaking learners of English in Region 3

[$F(1, 13)=25.154, p<.000, F(1, 19)=12.768, p<.002$]. No difference was found in Region 4 [$F(1, 13)=.465, p<.507, F(1, 19)=.688, p<.428$]. Region 5 also showed a significant difference [$F(1, 13)=9.386, p<.008, F(1, 19)=34.893, p<.000$]. No difference was found in Region 6 [$F(1, 13)=3.022, p<.106, F(1, 19)=1.927, p<.188$]. Additionally, a comparison of Region 3 of the English subject-gap sentences and Region 4 of the English object-gap sentences revealed that there was a significant difference between the two types of sentences [$F(1, 13)=8.341, p<.013; F(1, 19)=3.973, p<.047$].

The following figure shows the mean RRTs of the English gap sentences by the L2 learners of English based on their L2 English RST groups.

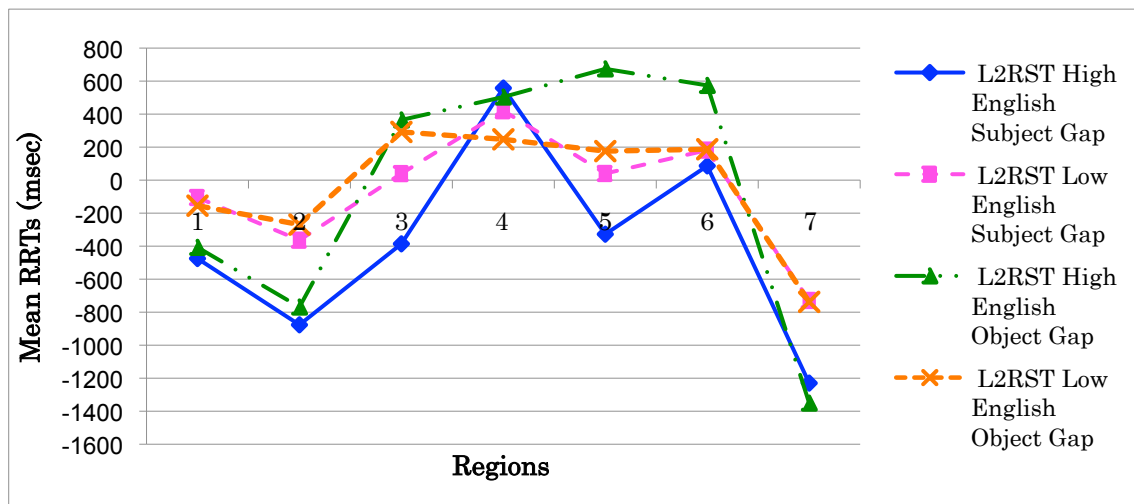


Figure 3.8: Mean RRTs of English gap sentences by L2 RST of learners

With the English subject-gap sentences, the L2 learners of both the L2 English RST High and Low groups seem to have two peaks at Regions 4 and 6. With the English object-gap

sentences, the peaks are not distinct after Region 3 for both L2 English RST groups. Unlike a zigzag reading pattern seen among the performances of Japanese as a foreign language learners in Sawasaki (2007), the L2 learners' English object-gap sentence reading patterns in this study illustrate relatively slow reading times over several regions. These narrow plateau reading times may be indicating a ceiling effect in the L2 learners' parsing of the English object-gap sentences, which are more difficult to comprehend.

Comparing the English subject-gap sentences of the L2 English RST High and Low groups, there was a significant difference in Region 3 [$F(1, 13)=4.534, p<.055$; $F(1,19)=24.891, p<.000$], but no meaningful difference was found in Regions 4, 5 and 6 [Region 4: $F(1, 13)=.169, p<.688$; $F(1,19)=.402, p<.534$; Region 5: $F(1, 13)=1.502, p<.244$; $F(1,19)=20.645, p<.000$; Region 6: $F(1, 13)=.735, p<.408$; $F(1,19)=.756, p<.396$]. On the contrary, Regions 3, 4, 5, and 6 of the English object-gap sentences showed no significance between the L2 English RST High and Low groups [Region 3: $F(1, 13)=.22, p<.885$; $F(1, 19)=.250, p<.703$; Region 4: $F(1, 13)=.473, p<.521$; $F(1, 19)=2.535, p<.129$; Region 5: $F(1, 13)=.825, p<.382$; $F(1, 19)=6.375, p<.021$; Region 6: $F(1, 13)=.612, p<.449$; $F(1, 19)=3.440, p<.080$].

Within the same L2 English RST span group, the L2 English RST High group showed a significant difference in Regions 3 and 5 between the English subject-gap and object-gap sentences [Region 3: $F(1, 6)=6.729, p<.023$; $F(1, 19)=16.314, p<.001$; Region 5: $F(1, 6)=4.973, p<.046$; $F(1, 19)=25.709, p<.000$], but not in Regions 4 and 6 [Region 4: $F(1, 6)=.040, p<.845$; $F(1, 19)=.048, p<.829$; Region 6: $F(1, 6)=2.388, p<.148$; $F(1, 19)=4.841, p<.041$]. The L2 English RST Low group showed a significant difference in Region 3 [Region 3: $F(1, 6)=7.383, p<.019$; $F(1, 19)=19.110, p<.000$],

but no meaningful difference was found in Regions 4, 5, and 6 [Region 4: $F(1, 6)=.475$, $p<.504$; $F(1, 19)=.002$, $p<.961$; Region 5: $F(1, 6)=1.459$, $p<.250$; $F(1, 19)=.001$, $p<.970$; Region 6: $F(1, 6)=.379$, $p<.550$; $F(1, 19)=.034$, $p<.856$].

A comparison of Region 3 of the English subject-gap sentences and Region 4 of the English object-gap sentence revealed that there is a significant difference between the two regions by the L2 English RST High group [$F(1, 6)=6.042$, $p<.015$, $F(1, 19)=6.187$, $p<.014$], but the L2 English RST Low group did not yield such significance [$F(1, 6)=.472$, $p<.493$, $F(1, 19)=.508$, $p<.477$].

3.2.2.3. Discussion

The comprehension accuracy rates of the Japanese-speaking learners of English for the English gap sentences showed similar trends for the comprehension accuracy as the native speakers and other previous L2 English studies. That is, the English subject-gap sentences were easier to comprehend than the English object-gap sentences. Further analyses showed that the L2 English RST High and Low groups were different in the comprehension accuracy rates of both the English subject-gap and object-gap sentences. Moreover, the L2 English RST High group was able to show a numerical difference approaching significance between the English subject-gap and object-gap sentences, but the L2 English RST Low group failed to do so. Because only the High group showed a significant difference between the comprehension accuracy rates of the English subject-gap and object-gap sentences, it is reasonable to say that only the High group was able to show the comprehension difficulty difference in their L2 performance. The discussion of

the comparison between the performance of English native speakers and Japanese-speaking learners of English will be provided in Chapter 4.

Let us now turn to the reading patterns of the English subject-gap and object-gap sentences by the L2 learners of English. The reading patterns have shown that the L2 learners illustrate different reading patterns between the two English gap type sentences. The reading pattern of the English subject-gap sentences had two peaks at Regions 4 and 6 whereas the English object-gap sentences had slower RRTs from Regions 3 to 6. It is possible that the difficulty of the English object-gap sentences had an influence on the L2 learners' parsing and it might have appeared as slower RRTs over several regions. In other words, it is likely that the L2 learners' WM had become overloaded by the difficult English object-gap sentence structure and thus, their reading pattern may be showing a ceiling effect and/or spillover effect.

The combination of the reading patterns and the RRT analyses suggest that the L2 learners of English were affected by the structural difference of the English subject-gap and object-gap sentences when reading those sentences. The comparison of embedded verb regions of the English subject-gap and object-gap sentences revealed that there was a difference between the two regions of the two different gap structures. However, whether their performance was similar or the same as that of the L1 English native speakers is questionable because the L2 learners demonstrated quite interesting reading patterns for the English object-gap sentences. This issue will also be closely examined in Chapter 4.

The RRTs of Regions 4, 5, and 6 in the L2 English RST High group for the English object-gap sentences were slower than those of the L2 English RST Low group.

Despite the seemingly huge RRT differences between the L2 English RST High and Low groups, there was no meaningful significance between the two RST groups in the English object-gap sentences other than a numerical difference approaching significance by item in Regions 5 and 6, [Region 5: $F(1, 13)=.825$, $p<.382$; $F(1, 19)=6.375$, $p<.021$; Region 6: $F(1, 13)=.612$, $p<.449$; $F(1, 19)=3.440$, $p<.080$]. This suggests that although different items might have affected the reading times in some regions of different RST groups, generally, the RRTs of both RST groups were not different in English object-gap sentences. This means that the unique reading pattern of English object-gap sentences is attributed to all Japanese-speaking L2 learners of English regardless of their L2 WM capacity.

The result discussed above showed no difference between the two L2 English RST groups. However, it is also possible that this result was obtained because of not having a large enough variance between the two L2 RST groups. In order to see a clearer effect of WM capacity on L2 English sentence processing, the RRTs of the English subject-gap and object-gap sentences were examined by reducing the number of participants in each RST group. The 14 participants were first ordered from 1 (=high score) to 14 (=low score) based on the participant's L2 proficiency score. If there was a tie score in the L2 proficiency test scores, then the L1 RST score was used to determine the order. This was based on the assumption that the L2 proficiency test score is likely to represent the overall L2 proficiency of the participant better than the L2 RST score. The L1 RST score was also used when there was a tie score because the previous L1 WM studies have provided abundant evidence to support the correlation between L1 RST score and L1 comprehension/reading skill. Thus by using the L1 RST score, it was

assumed to capture the individual's WM capacity to the fullest extent without getting affected by other L2 factors such as vocabulary knowledge, *kanji* reading and the overall experience in L2. The four participants who were in the middle were eliminated from the following analyses. The table below shows the details of the 10 participants' scores.

Participant #	L1 Jpn RST Score	L2 Eng RST Score	L2 Eng Prof Score (%)	L2 Eng RST Group	Eng subject-gap accuracy (%)	Eng object-gap accuracy (%)
J21	41	36	64.70	G2	40	60
J22	45	35	64.70	G2	70	70
J23	56	56	100	G1	80	60
J24	33	43	88.24	G1	90	60
J25	50	56	94.12	G1	90	80
J29	32	34	82.35	G2	70	60
J30	42	40	88.24	G1	100	100
J31	49	48	94.12	G1	90	80
J32	34	33	76.47	G2	50	50
J34	43	32	76.47	G2	90	50

RST score: Max=70; RST span groups: G1=High, G2=Low

Table 3.7: Scores of ten L2 learners of English

Similar to the analysis with 14 participants, there was a correlation between L1 Japanese RST and L2 English RST scores [$r(8)=.724$, $p<.018$]. The relationship between L2 English RST and L2 English proficiency test scores was also considered and it was found to be correlated [$r(8)=.767$, $p<.010$]. No correlation was found between L1 Japanese RST score and L2 English proficiency test score [$r(8)=.331$, $p<.350$].

The figure below shows the mean RRTs of English gap sentences by 10 Japanese native speakers' L2 RST groups.

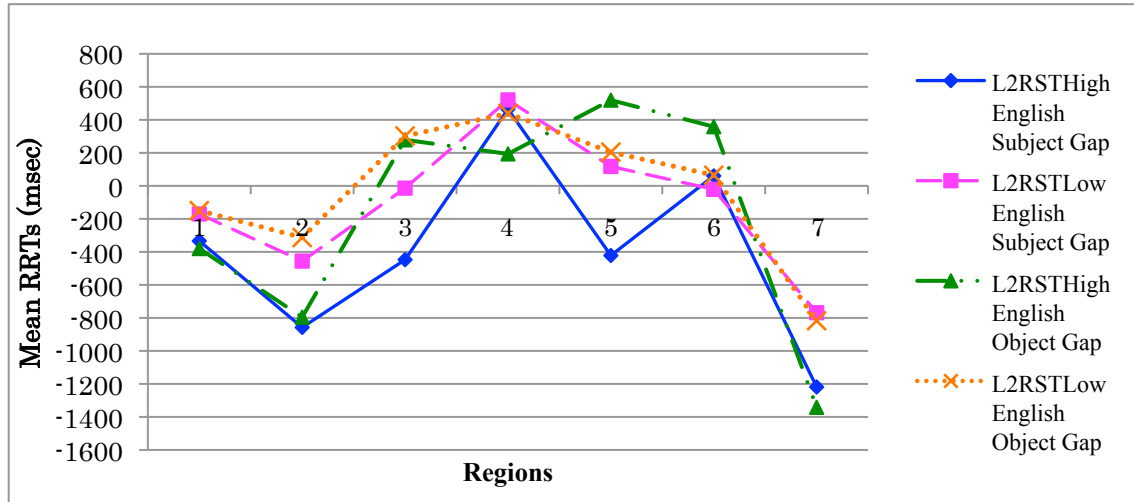


Figure 3.9: Mean RRTs of English gap sentences by L2 RST of ten learners

The reading pattern of the L2 English RST High group in the English subject-gap sentences shows two peaks; the highest peak in Region 4, and another peak in Region 6. The reading pattern of the L2 English RST Low group shows only one highest peak in Region 4. As for the reading patterns of the English object-gap sentences, the L2 English RST High group shows a rise in RRT in Region 3 and then a slight dip in Region 4, followed by the highest peak in Region 5 and a decrease in Region 6. The L2 English RST Low group shows a rise in RRT in Region 3, followed by a slight increase in RRT in Region 4, then a gradual decrease of the RRTs in Regions 5 to 6.

Statistical analyses showed that there was a numerical difference approaching significance in the RRTs of the English subject-gap sentences between the L2 RST High

and Low groups in Regions 2 and 3 [Region 2: $F(1, 8) = 3.516$, $p < .098$; $F(1, 19) = 16.433$, $p < .001$; Region 3: $F(1, 8) = 3.371$, $p < .100$; $F(1, 19) = 18.870$, $p < .000$] and significance was found by item in Region 5 ($F(1, 8) = 3.217$, $p < .11$; $F(1, 19) = 19.955$, $p < .000$). In the English object-gap sentences, there was a numerical difference approaching significance by subject and a significant difference by item in Region 2 ($F(1, 8) = 3.572$, $p < .095$; $F(1, 19) = 60.08$, $p < .000$). No other regions yielded significance in the object-gap sentences. This suggests that the effect of WM capacity was seen as early as Region 2 in the two gap type sentences. Moreover, the reading patterns of the English subject-gap and object-gap sentences were quite different. The former shows two peaks in Regions 4 and 6, which is somewhat similar to that of the native speakers. The latter, on the other hand is quite distinct from that of the native speakers. This infers that the utilization of WM resources by the L2 learners may be distinctively different, compared to that of the native speakers, especially in the more difficult to comprehend English object-gap sentences. The comparison between L1 native speakers and L2 learners will be discussed in detail in Chapter 4.

Let us now go back to Figure 3.7, which illustrated the mean RRTs of English gap type sentence, and consider whether the L2 learners' English gap sentence processing corresponds to the integration cost of the DLT by Gibson. Considering the reading patterns of the English gap sentences by Japanese-speaking learners of English, they do not appear to be consistent with the integration cost of the DLT. The slow RRT in Regions 4 and 6 of the English subject-gap sentences can be explained from the wrap-up effect at the end of the clause or the sentence. However, the slow RRT in Region 3 of the object-gap sentences cannot be explained from the integration cost of the DLT (Region

3=1EU, Regions 4/5=3EU each). The expectation-based hypothesis explains the performance of L2 learners to some extent, but the long reading times in Region 5 of the English object-gap sentences do not fit what the hypothesis predicted. Thus, it makes more sense to consider that the current performance of the L2 learners corresponds to neither integration nor storage components of the DLT. Rather, it makes more sense to consider that the current performance of the L2 learners was showing the ceiling-effect, especially in the processing of more difficult to comprehend English object-gap sentences.

3.3. Results of Japanese Relative Clause Sentences

This section reports the results of the Japanese gap sentence processing experiments by Japanese native speakers (L1) and English native speakers (L2). First, the results of Japanese native speakers will be discussed in terms of sentence comprehension accuracy, RRTs and from the different L1 Japanese RST span groups. Second, the results of English-speaking learners of Japanese will be discussed in terms of sentence comprehension accuracy, RRTs and from the different L2 Japanese RST span groups. Lastly, discussion of this section will be given.

3.3.1. L1 Japanese

For the 14 Japanese native speakers' L1 Japanese data, the average comprehension accuracy rates for all Japanese sentences (including the fillers) in the sentence reading experiment was 83.33% (range=68.33-98.33, SD=6.92). The score used to determine the High and Low groups for L1 Japanese RST was 41.5. The table below shows the details of the participants' scores.

Participant #	L1 Jpn RST Score	L1 Jpn RST Group	Jpn subject-gap accuracy (%)	Jpn object-gap accuracy (%)
J21	41	G2	40	90
J22	45	G1	60	80
J23	56	G1	50	100
J24	33	G2	30	90
J25	50	G1	80	100
J26	40	G2	70	100
J27	39	G2	40	100
J28	42	G1	60	100
J29	32	G2	70	100
J30	42	G1	30	90
J31	49	G1	60	100
J32	34	G2	60	90
J33	33	G2	90	20
J34	43	G1	20	100
Metric	41.5 (Median)		54.28 (Ave)	90 (Ave)
SD	7.09		20.27	21.12

RST score: Max=70; RST span groups: G1=High, G2=Low

Table 3.8: Scores of fourteen Japanese native speakers

3.3.1.1. Comprehension Accuracy Results by Japanese Native Speakers

The following figure shows the comprehension accuracy rates of the Japanese subject-gap and object-gap sentences by the Japanese native speakers. The previous L1 Japanese studies have shown inconclusive results in the comprehension accuracy studies of Japanese gap sentences (Ishizuka, 2005; Ishizuka, Nakatani, and Gibson, 2006; Miyamoto and Nakamura, 2003; Kahraman, 2011; Ozeki, 2005, 2008; Ueno and Garnsey, 2008). Gibson's DLT predicts Japanese object-gap sentences to be easier to comprehend. On the contrary, O'Grady's SDH predicts Japanese subject-gap sentences to be easier to comprehend.

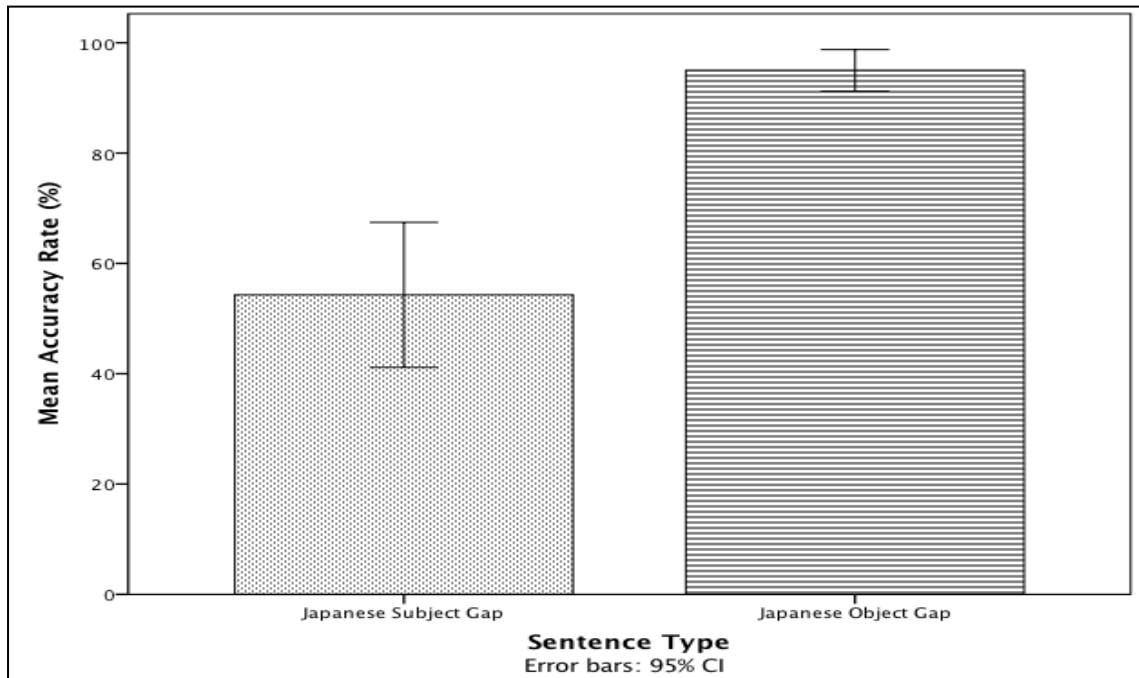


Figure 3.10: Japanese gap comprehension accuracy by Japanese native speakers

An independent-samples t-test was conducted to compare the sentence comprehension accuracy rates of the Japanese subject-gap and object-gap sentences. There was a significant difference in the accuracy rates for the Japanese subject-gap ($M=54.29$, $SD=22.775$) and object-gap ($M=95.00$, $SD=6.504$) sentences; $t(26)=-6.432$, $p<.000$.

Next, the Japanese gap comprehension accuracy rates were examined between different L1 Japanese RST span groups. The following figure shows Japanese gap sentence comprehension accuracy rates according to the L1 Japanese RST groups.

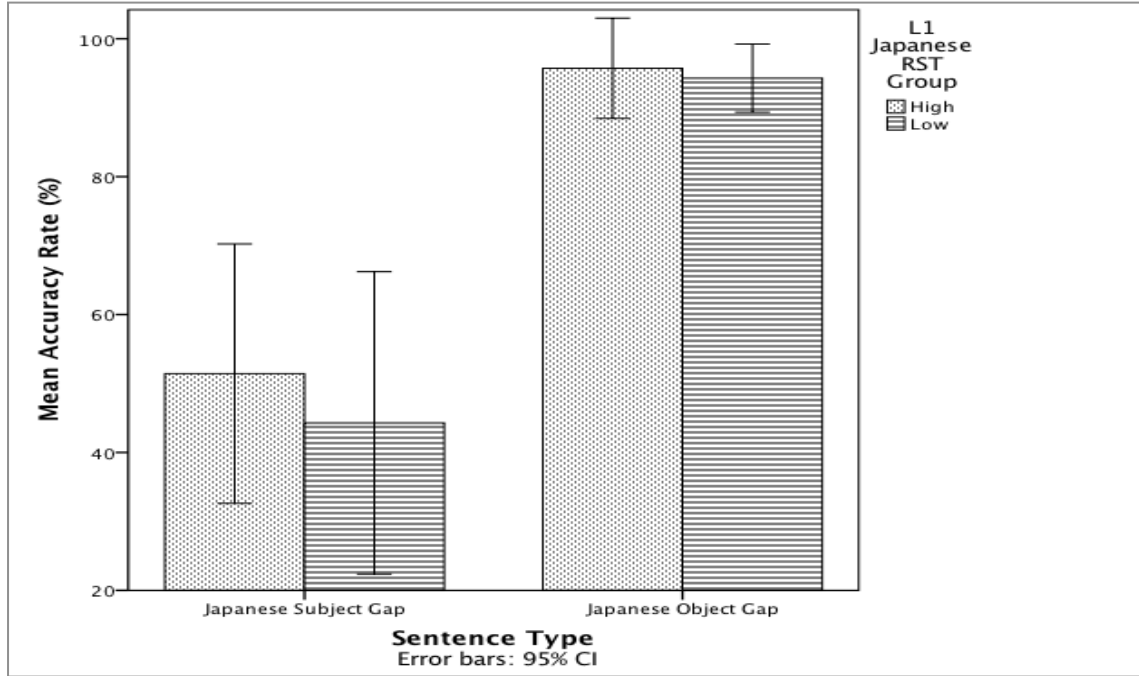


Figure 3.11: Japanese gap sentence comprehension accuracy by L1 Japanese RST

Within the L1 Japanese RST High group, there was a significant difference in the accuracy rates of the Japanese subject-gap ($M=51.43$, $SD=20.354$) and object-gap ($M=95.71$, $SD=7.868$) sentences; $t(12)=-5.369$, $p<.000$. Within the L1 Japanese RST Low group, there was a significant difference in the accuracy rates of the Japanese subject-gap ($M=44.29$, $SD=23.705$) and object-gap ($M=94.29$, $SD=5.345$) sentences; $t(12)=-5.444$, $p<.000$.

Among the Japanese subject-gap sentences, there was no significant difference in the accuracy rates between the L1 Japanese RST High ($M=51.43$, $SD=20.354$) and Low ($M=44.29$, $SD=23.705$) groups; $t(12)=.605$, $p<.557$. The Japanese object-gap sentences also did not show any significance between the L1 Japanese RST High ($M=95.71$, $SD=7.868$) and Low ($M=94.29$, $SD=5.345$) groups; $t(12)=.397$, $p<.698$.

3.3.1.2. L1 RRTs by Japanese Native Speakers

The following table shows example sentences of the Japanese gap sentences used in the sentence reading task. Unlike English, Japanese uses case markers to show overt case. It also does not employ relative pronouns to relate RCs to their heads and the RCs appear immediately before the NP. In the example sentences, the subject-gap and object-gap sentences are only different in Region 1 on surface, with different case markers.

Regions	1	2	3	4	5	6
Japanese subject-gap	Uenosan-o Ueno-acc	miokutta saw off	ojisn-ga uncle-nom	omocha-o toy-acc	hirotta picked up	。 .
Japanese object-gap	Uenosn-ga Ueno-nom	miokutta saw off	ojisn-ga uncle-nom	omocha-o toy-acc	hirotta picked up	。 .

Table 3.9: Example Japanese subject-gap and object-gap sentences

Since Japanese is a pro-drop language with SOV canonical word order, some ambiguities remain until the verb is encountered. The following two sentences (5) and (6) are equally grammatical and comprehensible as they are.

(5) Uenosn-o miokutta.

Ueno-acc saw off.

‘(I) saw Ueno off.’

(6) Uenosn-ga miokutta.

Ueno-nom saw off.

‘Ueno saw him/her/them off.’

Hence, in the two types of Japanese gap test sentences in the previous table, the participants would not know whether the sentences that they are reading are finished or not until the appearance of Region 3, the relative head noun.²² Upon encountering Region 3, the parser would presumably reanalyze its original interpretation to a structure with a relative clause.

The figure shown below illustrates the mean RRTs of the Japanese gap sentences by the native speakers. Both the Japanese subject-gap and object-gap reading patterns show two peaks, one at Region 2 (RC verb) and at Region 4 (main NP-*o*). Comparing the regions of two Japanese gap type sentences, there was a numerical difference approaching significance in Region 2 [$F(1, 13)=3.354$, $p<.090$; $F(1, 19)=3.475$, $p<.072$]. Regions 3, 4, and 5 did not show any significance other than a numerical difference approaching significance by item in Region 4 [Region 3: $F(1, 13)=.551$, $p<.471$; $F(1, 19)=1.666$, $p<.213$; Region 4: $F(1, 13)=1.378$, $p<.262$; $F(1, 19)=3.399$, $p<.082$; Region 5: $F(1, 13)=.017$, $p<.897$; $F(1, 19)=1.378$, $p<.256$].

²² Despite stating this, a moving-window paradigm allows one to see dots for the length of the sentence that one is reading.

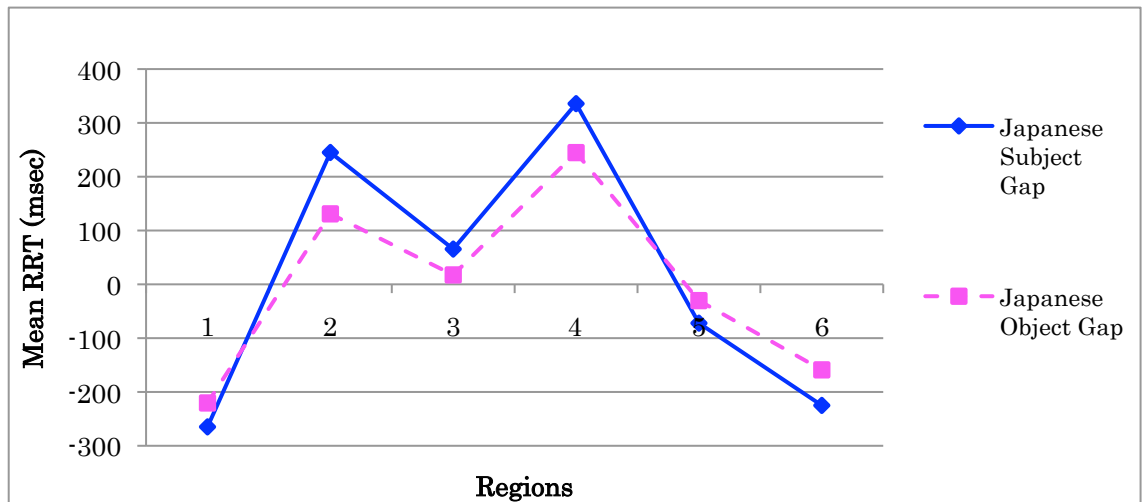


Figure 3.12: Mean RRTs of Japanese gap sentences by Japanese native speakers

Next, the Japanese native speakers' RRTs were compared based on their L1 Japanese RST groups. In terms of the reading patterns, the RRTs of the L1 Japanese RST High and Low groups seem to follow the same trend. Both the L1 Japanese RST High and Low groups show slower reading times in Regions 2 and 4. The figure below shows the mean RRTs of the Japanese gap sentences according to the L1 Japanese RST groups.

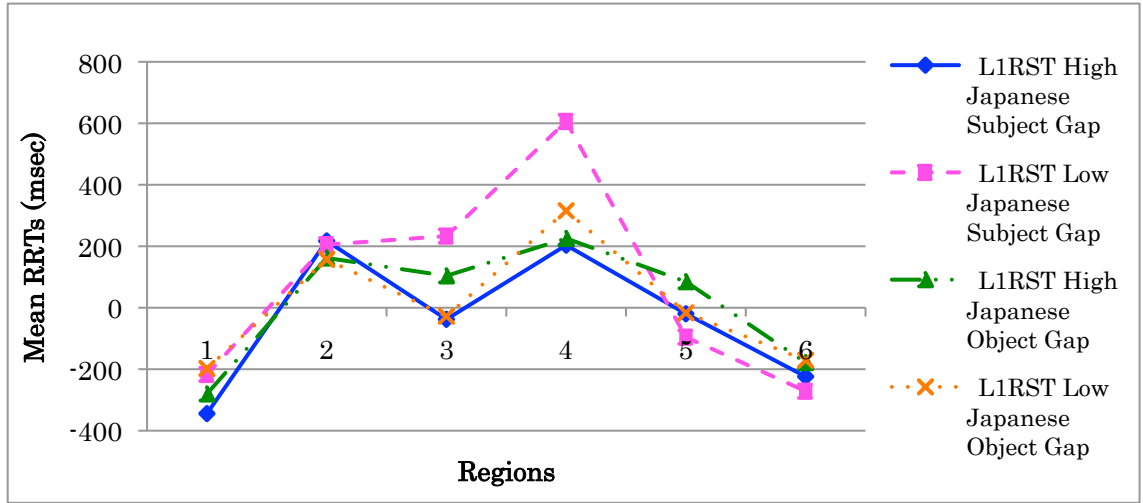


Figure 3.13: Mean RRTs of Japanese gap sentences by L1 Japanese RST

Comparing the Japanese subject-gap sentences of the L1 Japanese RST High and Low groups, there was no significant difference in Region 2 [$F(1, 13)=.059$, $p<.815$; $F(1, 19)=.188$, $p<.670$]. There was a significant difference by item in Region 3 [$F(1, 13) = 2.014$, $p<.181$; $F(1, 19) = 19.714$, $p<.000$] and in Region 4 [$F(1, 13)=3.619$, $p<.081$; $F(1, 19)=18.394$, $p<.000$]. No significance was found in the Japanese object-gap sentences in Regions 2, 3, and 4 [Region 2: $F(1, 13)=2.792$, $p<.121$; $F(1, 19)=3.054$, $p<.106$; Region 3: $F(1, 13)=1.937$, $p<.189$; $F(1, 19)=1.342$, $p<.262$; Region 4: $F(1, 13)=.460$, $p<.510$; $F(1, 19)=.498$, $p<.490$].

Within the same L1 Japanese RST span group, the L1 RST High group did not show any significant difference between the Japanese subject-gap and object-gap sentences in Regions 2, 3, and 4 [Region 2: $F(1, 6)=.202$, $p<.660$; $F(1, 19)=1.008$, $p<.328$; Region 3: $F(1, 6)=1.607$, $p<.227$; $F(1, 19)=1.038$, $p<.321$; Region 4: $F(1, 6)=.005$, $p<.947$; $F(1, 19)=.003$, $p<.959$]. However, the L1 RST Low group showed

significant differences in Regions 2, 3, and 4 [Region 2: $F(1, 6)=13.6957$, $p<.003$; $F(1, 19)=4.879$, $p<.040$; Region 3: $F(1, 6)=8.736$, $p<.011$; $F(1, 19)=9.712$, $p<.006$; Region 4: $F(1, 6)=2.619$, $p<.081$; $F(1, 19)=5.526$, $p<.036$].

3.3.1.3. Discussion

The comprehension accuracy rates of the Japanese subject-gap and object-gap sentences by the Japanese native speakers were significantly different. The result showed that the Japanese subject-gap sentences were more difficult to comprehend than the object-gap sentences. Thus, the current study has added supporting evidence to the previous findings that Japanese subject-gap sentences are more difficult to comprehend than Japanese object-gap sentences and supported Gibson's DLT prediction rather than O'Grady's SDH. Further analyses with the L1 Japanese RST groups revealed that the different WM capacity did not affect the comprehension accuracy rates of the two Japanese gap type sentences. In other words, the Japanese subject-gap sentences were more difficult for both the L1 Japanese RST High and Low groups and the Japanese object-gap sentences were easier for both L1 Japanese RST groups. Also, no difference was found between the L1 Japanese RST High and Low groups within the same sentence type. This outcome of not seeing any difference between the two L1 Japanese RST groups was not beyond our expectation because the test sentences in this study might have been too easy for the Japanese native speakers to show the effect of the differences in their L1 WM capacity.

The regional analyses revealed that there was a difference in Region 2 between the Japanese subject-gap and object-gap sentences. Assuming incremental processing is

at work, having the difference at Region 2 (RC verb) between the two gap type sentences may be from the parser trying to predict the relation of empty category and a soon appearing co-indexed head noun as well as predicting an upcoming sentence structure. Taking the L1 Japanese RST span groups into account, the RRTs of L1 RST High group did not show any significant difference in regions between the Japanese subject-gap and object-gap sentences. This means that for the L1 Japanese RST High group, the two sentences were read with similar speeds, which indicates the burden on the processing is about the same or the sentences were too easy to show the difference. On the other hand, the RRTs of the L1 RST Low group showed significance in Regions 2, 3, and 4 between the two gap type sentences. Clearly, L1 WM capacity was affecting their parsing of the Japanese gap sentences.

Let us now consider whether the current result can be explained by the integration cost of the DLT. In Japanese subject-gap sentences, the integration cost predicted in Region 2 is 2EU and in Region 3 is 3EU. In Japanese object-gap sentences, the integration cost predicted in Region 2 is 1EU and in Region 3 is 3EU. The maximal predicted cost for both the subject-gap and object-gap sentences is in Region 3. The Figure 3.12, which illustrates the mean RRTs of the Japanese gap sentences show a peak (=slower) in Region 2. This, at first glance seems not to coincide with the prediction of the integration cost. However, if the wrap-up effect was taken into consideration in the RRT, a peak in Region 2 and finding a difference between the RRTs of the subject-gap and the object-gap can be explained. The storage cost of the DLT (expectation-based hypothesis) predicts that there is no cost difference between the two Japanese gap type sentences. Thus, the current result seems to be better suited to the prediction of the

integration cost rather than the storage cost of the DLT. For a reference, the table below shows the cost prediction based on the expectation-based hypothesis.

Region	1	2	3	4	5
Jpn subject-gap	Uenosan-acc	saw off	uncle-nom	toy-acc	picked up
Predicted verbs	V1	-	V2	V2	-
Cost	1	0	1	1	0
Jpn object-gap	Uenosan-nom	saw off	uncle-nom	toy-acc	picked up
Predicted verbs	V1	-	V2	V2	-
Cost	1	0	1	1	0

Table 3.10: Cost prediction based on expectation-based hypothesis

3.3.2. L2 Japanese

For the 14 English native speakers' L2 Japanese data, the average comprehension accuracy rate for all Japanese sentences (including the fillers) in the processing experiment was 83.10% (range=66.67-93.33%, SD=8.05). Dissimilar to the previous studies, the L2 learners of Japanese in this study did not show a correlation between L1 English RST and L2 Japanese RST scores [$r(12)=.440$, $p<.116$].²³ The score used to determine High and Low groups for L2 Japanese RST was 40.5 and for L1 English RST was 53.5. The following table shows the details of the participants' scores.

²³ No correlation was found between L2 Japanese RST and L2 Japanese proficiency scores [$r(12)=.156$, $p<.593$] and L1 English RST and L2 Japanese proficiency test scores [$r(12)=.119$, $p<.685$].

Participant #	L1 Eng RST Score	L1 Eng RST Group	L2 Jpn RST Score	L2 Jpn RST Group	L2 Jpn Prof test Score (%)	Jpn subject-gap accuracy (%)	Jpn object-gap accuracy (%)
E01	56	G1	42	G1	82.50	60	90
E02	64	G1	47	G1	82.50	70	80
E03	44	G2	36	G2	92.50	70	100
E04	54	G1	34	G2	95	60	80
E05	57	G1	38	G2	90	70	100
E06	41	G2	40	G2	85	70	100
E07	44	G2	34	G2	95	60	30
E08	51	G2	45	G1	72.5	50	50
E09	44	G2	43	G1	95	50	90
E10	60	G1	44	G1	92.5	40	80
E11	53	G2	34	G2	87.50	50	50
E12	54	G1	54	G1	100	20	90
E13	42	G2	33	G2	70	80	100
E14	57	G1	41	G1	92.5	50	90
Metric	53.5 (Median)		40.5 (Median)		88.95	60 (Ave)	90 (Ave)
SD	7.30		6.04		9.13	15.40	22.00

RST score: Max=70; RST span groups: G1=High, G2=Low

Table 3.11: Scores of fourteen L2 learners of Japanese

3.3.2.1. L2 Comprehension Accuracy by English-Speaking Learners of Japanese

The following figure shows the comprehension accuracy rates of the Japanese subject-gap and object-gap sentences by the English-speaking learners of Japanese.

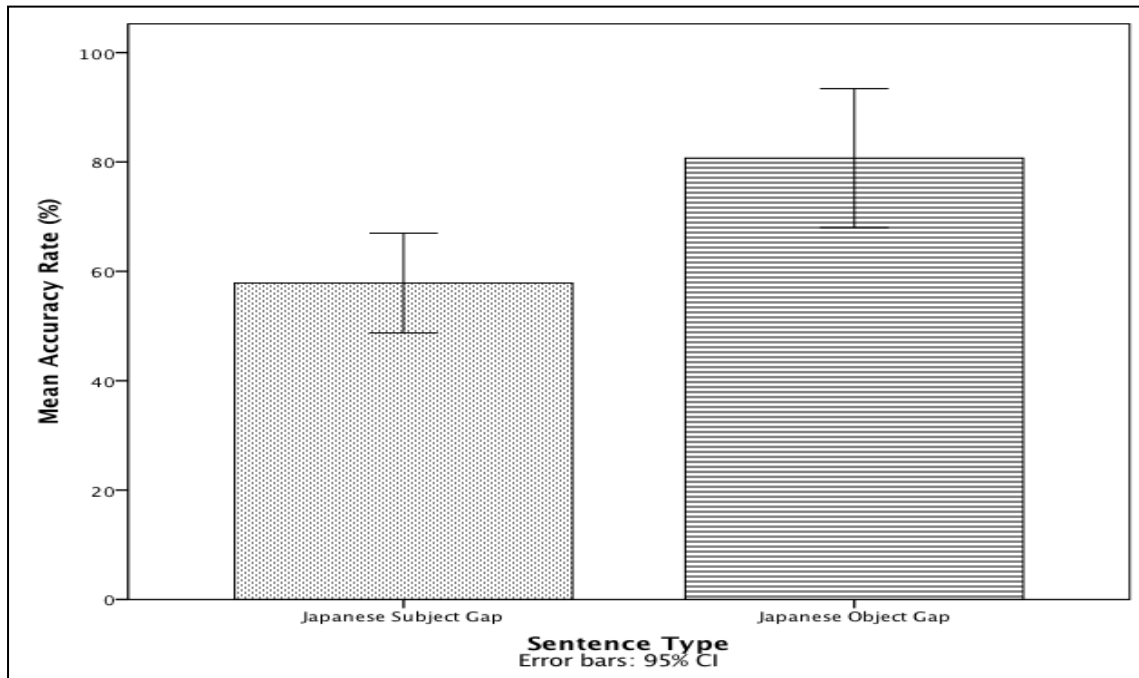


Figure 3.14: Japanese comprehension accuracy by L2 learners of Japanese

An independent-samples t-test was conducted to compare the sentence comprehension accuracy rates of the Japanese subject-gap and object-gap sentences. There was a significant difference in the accuracy rates between the Japanese subject-gap ($M=57.86$, $SD=15.777$) and the Japanese object-gap ($M=80.71$, $SD=22.001$) sentences; $t(26)=-3.159$, $p<.004$. The current result shows that the Japanese object-gap sentences are easier to comprehend than the Japanese subject-gap sentences for the L2 learners. This result is compatible with the DLT, which predicts that the Japanese subject-gap sentences are more difficult to process, rather than the SDH.

Next, the Japanese gap comprehension accuracy rates of the L2 learners were examined using the L2 Japanese RST groups. The following figure shows the Japanese gap comprehension accuracy rates by the L2 Japanese RST groups. Strangely, the L2

Japanese RST High group showed a lower accuracy rate in the Japanese subject-gap sentences than the L2 Japanese RST Low group.

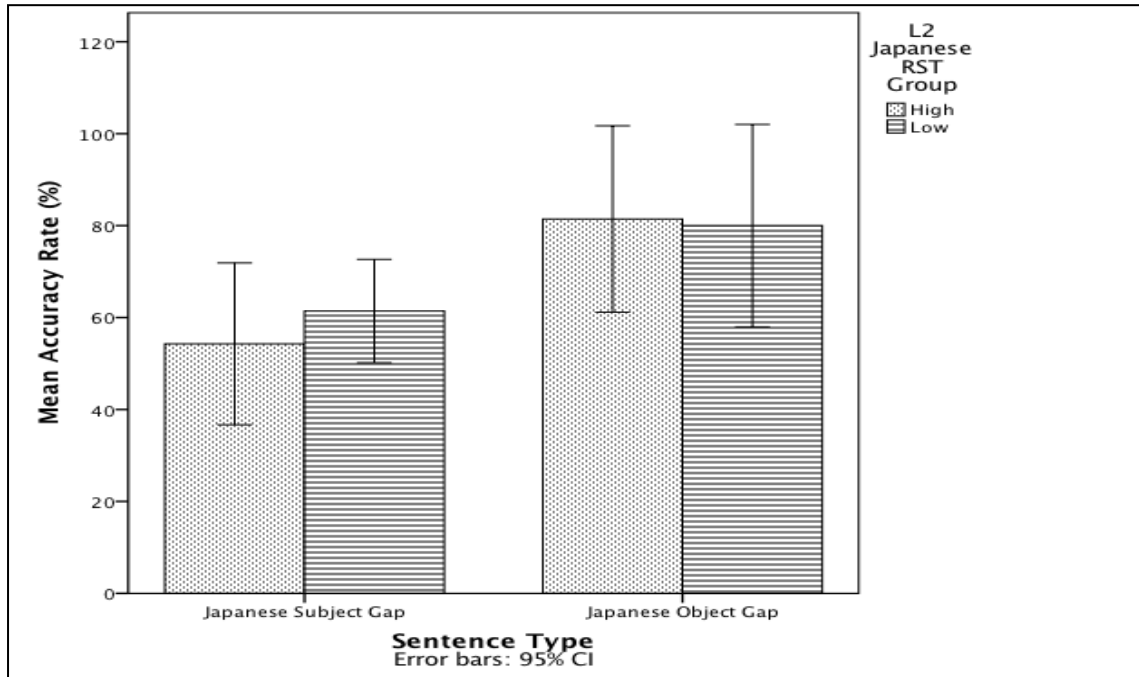


Figure 3.15: Japanese gap comprehension accuracy by L2 RST of learners

Within the L2 RST High group, there was a significant difference between the comprehension accuracy rates of the Japanese subject-gap ($M=54.29$, $SD=19.024$) and the object-gap ($M=81.43$, $SD=21.931$) sentences; $t(12)=-2.474$, $p<.029$. Within the L2 RST Low group, there was a numerical difference approaching significance between the comprehension accuracy rates of the Japanese subject-gap ($M=61.43$, $SD=12.150$) and object-gap ($M=80.00$, $SD=23.805$) sentences; $t(12)=-1.838$, $p<.091$.

Among the Japanese subject-gap sentences, there was no significant difference in the comprehension accuracy rates by the L2 Japanese RST High ($M=54.29$, $SD=19.024$) and Low ($M=61.43$, $SD=12.150$) groups; $t(12)=-0.837$, $p<.419$. Thus, although the figure shows a lower comprehension accuracy rate for the L2 Japanese RST High group than the Low group in Japanese subject-gap sentences, it does not mean that the High group did worse in the comprehension performance. Among the Japanese object-gap sentences, there was also no significant difference in the comprehension accuracy rates by the L2 Japanese RST High ($M=81.43$, $SD=21.931$) and Low ($M=80.00$, $SD=23.805$) groups; $t(12)=0.117$, $p<.909$.

3.3.2.2. L2 RRTs by English-Speaking Learners of Japanese

The figure below shows the mean RRTs of the Japanese gap sentences by the English-speaking learners of Japanese. Although the L2 learners demonstrated a higher comprehension accuracy rate in the Japanese object-gap sentences than in the Japanese subject-gap sentences, they showed slower RRTs in Region 3, and especially in Region 4 of the Japanese object-gap sentences.

Comparing the regions of the two Japanese gap type sentences, there was no significance in Region 3 between the Japanese subject-gap and object-gap sentences [$F(1, 13)=.509$, $p<.488$, $F(1, 19)=1.745$, $p<.202$]. However, there was a significant difference in the two types of Japanese gap sentences in Region 4 [$F(1, 13)=4.643$, $p<.050$, $F(1, 19)=16.031$, $p<.001$].

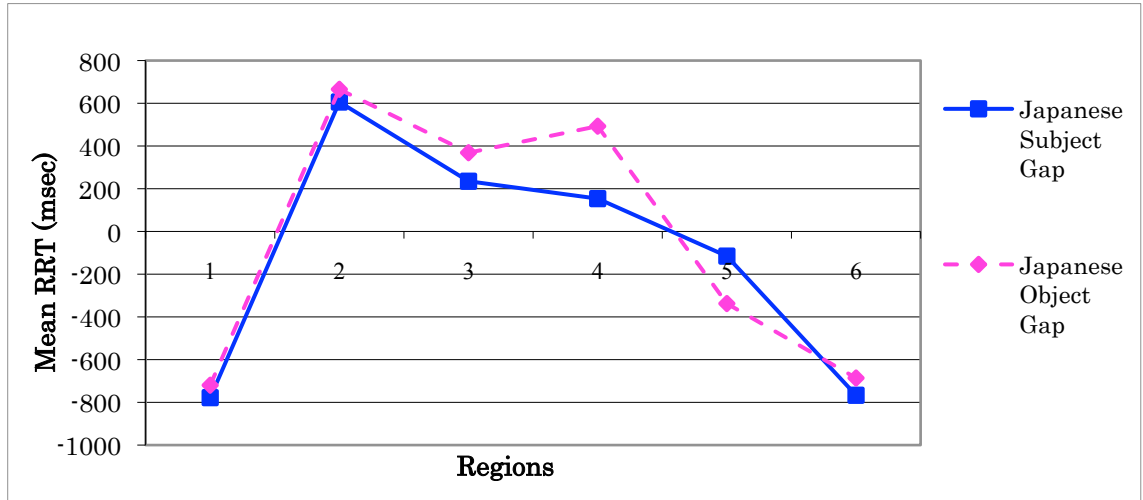


Figure 3.16: Mean RRTs of Japanese gap sentences by L2 learners of Japanese

Next, the L2 learners' RRTs were compared based on their L2 Japanese RST groups to examine whether L2 WM capacity size had any effect on L2 Japanese sentence processing. The figure shows that L2 Japanese RST Low group has a distinctive reading pattern of the subject-gap sentences compared to the L2 Japanese RST High group's Japanese gap sentence reading patterns and the L2 Japanese RST Low group's Japanese object-gap reading pattern. It shows one peak at Region 2, and then a drop in Region 3. Afterwards, reasonably steady RRTs were maintained through Regions 3 to 5. On the other hand, the other three reading patterns demonstrated peaks and/or relatively similar slow RRTs in Regions 2, 3, and 4.

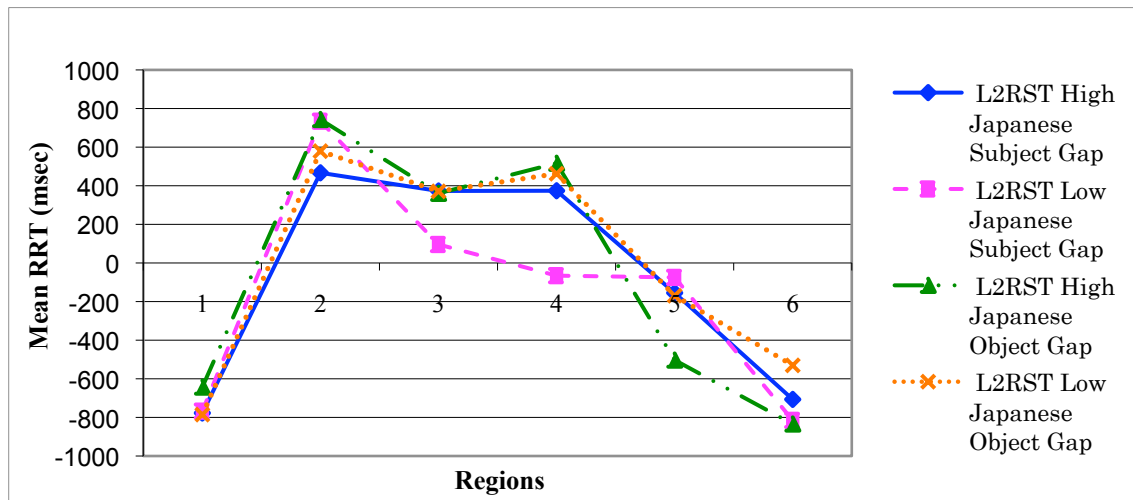


Figure 3.17: Mean RRTs of Japanese gap sentences by L2 RST of learners

Comparing the Japanese subject-gap sentences of the L2 Japanese RST High and Low groups, there was no significance by subject, but significances were found by item in Regions 2, 3, and 4 [Region 2: $F(1, 13)=1.492$, $p<.244$; $F(1, 19)=6.678$, $p<.018$; Region 3: $F(1, 13)=.402$, $p<.537$; $F(1, 19)=6.261$, $p<.022$; Region 4: $F(1, 13)=1.926$, $p<.189$; $F(1, 19)=8.588$, $p<.009$]. On the contrary, no significance was found neither by subject nor by item in the Japanese object-gap sentences in Regions 2, 3, and 4 [Region 2: $F(1, 13)=.113$, $p<.742$; $F(1, 19)=1.506$, $p<.236$; Region 3: $F(1, 13)=.584$, $p<.460$; $F(1, 19)=1.311$, $p<.267$; Region 4: $F(1, 13)=.011$, $p<.920$; $F(1, 19)=.032$, $p<.861$].²⁴

²⁴ Another surprising finding was the RRTs being slower with the sentence structure which was easier to comprehend, i.e. Japanese object-gap sentences, than Japanese subject-gap sentences. The lower accuracy rate of Japanese subject-gap sentences by English-speaking learners of Japanese due to their L2 Japanese ability may have affected the RRTs (Average comprehension accuracy rate of 60% for the Japanese subject-gap; 90% for Japanese object-gap) because this means more reading times of Japanese subject-gap sentences were being replaced by the average reading time of the individual region. For a comparison, I looked at the raw reading time data of the two Japanese gap type sentences. The following data are unmodified and no reading time was replaced regardless of the comprehension questions being answered correctly or incorrectly. One-way ANOVAs were conducted to see if there were any significant differences between Japanese subject-gap and object-gap sentences using this raw reading times. They showed no

Within the same L2 Japanese RST span group, the L2 Japanese RST High group showed no significant difference by subject but a numerical difference approaching significance was found by item in Region 2 between the Japanese subject-gap and object-gap sentences [$F(1, 6)=.374$, $p<.552$; $F(1,19)=3.648$, $p<.072$]. Regions 3 and 4 showed no significance [Region 3: $F(1, 6)=.002$, $p<.970$; $F(1, 19)=.006$, $p<.939$; Region: 4 $F(1, 6) =.124$, $p<.731$; $F(1, 19)=.943$, $p<.344$]. The L2 Japanese RST Low group showed no significance in Region 2 [Region 2: $F(1, 6)=.318$, $p<.583$; $F(1, 19)=2.188$, $p<.156$], but Region 3 showed a numerical difference approaching significance by item but not by subject [$F(1, 6)=.654$, $p<.434$; $F(1, 19)=3.229$, $p<.089$]. On the contrary, a significant difference was found in Region 4 [$F(1, 6)=8.574$, $p<.013$; $F(1, 19)=7.885$, $p<.012$].

3.3.2.3. Discussion

The comprehension accuracy rates of the Japanese subject-gap and object-gap sentences by the English-speaking L2 learners of Japanese were significantly different in this study. They showed that the Japanese object-gap sentences were easier to comprehend than the Japanese subject-gap sentences. From this, Gibson's DLT was supported. Further analysis based on the L2 Japanese RST groups showed that the Japanese subject-gap sentences are more difficult to comprehend than the Japanese

significance in the six regions. Thus, even 200 ~ 300 msec apart and the object-gap sentences being slower in the reading times, there was no difference between the two gap type sentences in terms of reading times.

Regions	1	2	3	4	5	6
Jpn subject-gap	577.81	2578.94	1855.056	2316.14	1669.51	1302.39
Jpn object-gap	604.96	2609.15	2128.54	2512.94	1619.11	1568.91

Crosschecking with individual raw data, there was a certain participant who constantly read slower than the other participants. Two participants' raw reading times were slower in two object-gap sentences in Regions 3 and 4, but those shouldn't have affected the RRTs in Figure 3.17 because those reading times lied outside of 2SD. Therefore, they were replaced with their mean RRTs.

object-gap sentences for both the L2 Japanese RST groups. Moreover, both the Japanese subject-gap and object-gap sentences showed no difference in the comprehension accuracy rates between the L2 RST High and Low groups. Thus, the current results indicated that L2 WM capacity did not affect the comprehension accuracy rates of either Japanese gap type sentences.

Turning to the results of RRT comparisons between the Japanese subject-gap and object-gap sentences, overall, the English-speaking L2 learners of Japanese showed significance only in Region 4 (matrix NP-*o*). This is interesting because the difference between the Japanese subject-gap and object-gap sentences is only in Region 1 where Japanese subject-gap sentences had NP-*o* and Japanese object-gap sentences had NP-*ga* in the RC. If the parser were to reanalyze the interpretation of the sentence structure, the difference should have appeared earlier, presumably in Region 3 where the parser links the RC head noun to an earlier co-indexed null pronoun and with it, restructure the prediction of an upcoming sentence structure. Otherwise, the difference could have appeared in Region 2, right after the regional difference of case marker NP-*ga* and NP-*o* in Region 1. Since sentence-initial accusative *o*-marked NPs are not canonical, and effects in self-paced reading times often seem to be delayed by a word (Ueno and Garnsey, 2008), seeing a difference in Region 2 would have been understandable. A spillover effect could be a reason as well, but the question still remains why the difference was only seen in Region 4 and not in other regions.

One explanation to account for this result could be due to inefficient and ineffective use of case marker information to integrate parts of a sentence to form a grammatical structure. The difference between the current two Japanese gap type

sentences only appears in the case markers *-ga* and *-o* in Region 1, and there are no other differences including the phrase lengths in all of the regions. It is known that Japanese native speakers are keen to the case markers and the previous studies in L1 Japanese have shown that case markers help the parser to predict the structure of sentences (Kamide, Altman and Haywood, 2003; Kamide and Mitchell, 1999; Nagata, 1993; Yamashita, 1995, 1997, 2003). English-speaking L2 learners of Japanese, on the other hand, seem to rely on word order to assign case to NPs and tend to neglect the case marker information (Yamashita, 2003).

Let us assume that this discussion of inefficient use of case marker information by L2 Japanese learners is true. The reading patterns of the Japanese subject-gap and object-gap sentences by the native speakers demonstrated a similar tendency between the two gap types with peaks in Regions 2 and 4. In contrast, the L2 learners demonstrated different reading patterns between the two gap type sentences. Different reading patterns between the two gap type sentences may indicate that in the Japanese subject-gap sentences, the L2 parser did not or was unable to consider the second NP-*o* in Region 4 as a part of the matrix transitive sentence structure due to the previous appearance of NP-*o* in Region 1. It can be speculated that after a simple transitive sentence structure was built with the appearance of Region 2, the parser was unable to reanalyze it as a RC and construct another simple transitive structure. Thus, the reading pattern of the Japanese subject-gap sentences shows one peak (=slower reading time) in Region 2 and then, steadily goes down (=faster reading time) until the end of sentence in Region 6.

In the Japanese object-gap sentences, the infrequencies of ‘NP-*ga* VP NP-*ga*’ structure (Ueno and Polinsky, 2009) and the appearance of two NPs with *-ga*, which both

could be a potential subject of the sentence alerted the L2 parser to reanalyze the sentence structure once more. Hence, the reading pattern of Japanese object-gap sentences showed two peaks in Regions 2 and 4 and the reanalysis to obtain the correct object-gap RC sentence structure has likely led to a longer reading time in Region 4, and a higher comprehension accuracy rate.

The L2 learners of Japanese read the Japanese object-gap sentences slower than the subject-gap sentences in many regions. One may wonder about this finding because in this study, the Japanese object-gap sentences were easier to comprehend than the Japanese subject-gap sentences. As discussed previously, the appearance of NP-*ga* in Region 3 may be the factor for slower reading times in the Japanese object-gap sentences. Several previous L1 Japanese studies provided the evidence of having multiple nominative cases (-*ga*, -*ga*) in sequences being difficult to process and most of the time, this difficulty is avoided by the uses of the topic marker *wa* in the first NP position (Lewis and Nakayama, 2002; Miyamoto, 2002; Nakayama, Lee and Lewis, 2005; Nakayama, Vasishth, and Lewis, 2006; Uehara, 1997; Uehara and Bradley, 2002). Additionally, the corpus study by Ueno and Polinsky (2009) shows that the frequency of ‘NP-*ga* VP NP-*ga*’ is not as high as ‘NP-*o* VP NP-*ga*’. Although these previous findings are from L1 Japanese studies, if input has any effect on L2 acquisition, the infrequency of NP-*ga* could have affected the reading times of the Japanese object-gap sentences.

Now, let us turn back to Figure 3.16 and consider whether the L2 learners’ RRT performances correspond to the prediction of the DLT. In the current study, the reading patterns of overall Japanese subject-gap and object-gap sentences show peaks in Regions 2 and 4, but only Region 4 yielded a significant difference between the two gap type

sentences. Although cost prediction based on the structural integration predicts higher load on memory in Region 2 between the two sentence types, a difference in Region 4 is not predicted. The same can be said for the expectation-based hypothesis, which predicts no cost difference between the two sentence types. The current finding may be unique to this particular L2 learner group and more studies are necessary to draw any conclusion. However, the current study seems to show that they do not necessarily follow either the expectation-based or structural integration hypotheses' cost predictions.

Another interesting result found in the analyses of the RRTs by the L2 learners of Japanese was that there was no significance despite seemingly large RRT differences in Region 4 between the L2 Japanese RST High and Low groups in the Japanese subject-gap sentences. The cause for this finding may be due to not having a large enough difference between the two RST groups. Therefore, the 10 participants' data were divided into High and Low groups (5 participants each) and analyzed to have a clearer view. The following table shows the details of the 10 English-speaking learners of Japanese's scores.

Participant #	L1 Eng RST Score	L2 Jpn RST Score	L2 Jpn Prof Score (%)	L2 Jpn RST Group	Jpn subject-gap accuracy (%)	Jpn object-gap accuracy (%)
E01	56	42	82.50	G2	60	90
E02	64	47	82.50	G2	70	80
E04	54	34	95	G1	60	80
E06	41	40	85	G2	70	100
E07	44	34	95	G1	60	50
E08	51	45	72.5	G2	50	50
E09	44	43	95	G1	50	90
E10	60	44	92.5	G1	40	80
E12	54	54	100	G1	20	90
E13	42	33	70	G2	80	90

RST score: Max=70; RST span groups: G1=High, G2=Low

Table 3.12: Scores of ten L2 learners of Japanese

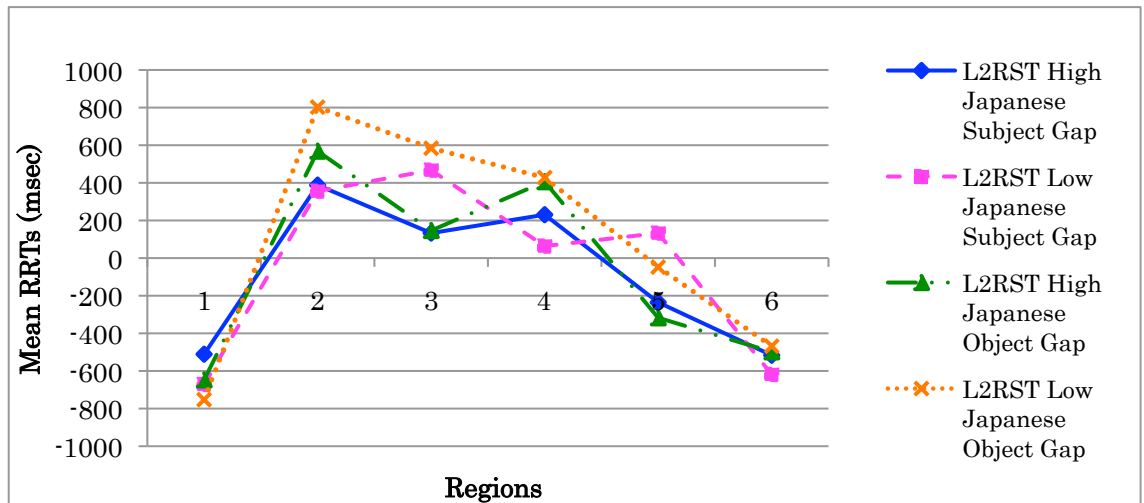


Figure 3.18: Mean RRTs of Japanese gap sentences by L2 RST of ten learners

The above figure shows the mean RRTs of the Japanese gap sentences based on L2 Japanese RST groups by the 10 English-speaking L2 learners. Compared to the 14 participants' RRT figure based on their L2 English RST, the 10 participants' figure shows more distinct reading patterns depending on their RST span groups. For instance,

the L2 RST High group shows similar reading patterns for both the Japanese subject-gap and object-gap sentences. On the other hand, the L2 RST Low group shows different reading patterns for the two gap type sentences. Another difference that was found compared to the 14 participants' reading patterns is that the L2 Japanese RST Low group shows a slow-down in their RRT in Region 3 of the Japanese subject-gap sentences instead of getting faster.

Statistical analyses of the 10 participants' RRTs have revealed that there was a significant difference between the L2 Japanese RST High and Low groups in the Japanese subject-gap sentences in Region 3 [$F(1, 9)=5.498$, $p<.047$, $F(1, 19)=10.581$, $p<.004$]. However, no meaningful difference was found in the other regions. In the Japanese object-gap sentences, there was no significance found in any regions between the L2 Japanese High and Low groups, other than significance by item in Region 5 [$F(1, 9)=3.355$, $p<.104$; $F(1, 19)=37.492$, $p<.000$]. These results indicate that the L2 Japanese RST High and Low groups are different in L2 Japanese sentence processing, especially in more difficult to comprehend Japanese subject-gap sentences.

The analyses within the L2 Japanese RST High group showed a significant difference between the Japanese subject-gap and object-gap sentences in Region 5 [$F(1, 4)=7.861$, $p<.049$, $F(1, 19)=3.208$, $p<.090$]. Significance was found, but in different regions within the L2 Japanese RST Low group. The L2 Japanese RST Low group showed a significant difference between the Japanese subject-gap and object-gap sentences in Region 2 [$F(1, 4)=4.653$, $p<.097$, $F(1, 19)=5.390$, $p<.032$], and a significant difference only by item in Region 4 [$F(1, 4)=1.259$, $p<0.325$, $F(1,$

19)=9.422, $p<.007$]. These analyses suggest that L2 WM capacity is affecting the RRTs of L2 sentence processing for the Japanese gap type sentences differently.²⁵

3.4. Summary

In this chapter, the results of online experiments by English native speakers and Japanese native speakers in their respective L1 and L2 sentence processing and the relationship to L1 and L2 WM capacity were discussed along with their sentence reading patterns. In this section, we will summarize the findings from this chapter. We will first summarize the findings of English subject-gap and object-gap sentences and L1 RST and L2 RST span size. Then, we will summarize the finding of Japanese subject-gap and object-gap sentences and L1 RST and L2 RST span sizes.

3.4.1. English Relative Clause Sentences and L1/L2 RST Span Size

The table below summarizes the findings of English comprehension accuracy rates by L1 native speakers and L2 learners according to the sentence type and RST group.

²⁵ In the 10 participants' analyses, there was no significant difference in the accuracy rates of the Japanese subject-gap sentences among the L2 RST High ($M=56.00$, $SD=23.022$) and Low ($M=54.00$, $SD=11.402$) groups; $t(8)=0.174$, $p<.866$. On the contrary, there was a significant difference in the accuracy rates of the Japanese object-gap sentences among the L2 RST High ($M=92.00$, $SD=8.367$) and Low ($M=60.00$, $SD=24.495$) groups; $t(8)=2.764$, $p<.025$. Moreover, there was a significant difference in the accuracy rates of the Japanese subject-gap ($M=56.00$, $SD=23.022$) and the object-gap ($M=92.00$, $SD=8.367$) sentences in the L2 RST High group; $t(8)=-3.286$, $p<.011$. On the other hand, there was no significant difference in the accuracy rates of the Japanese subject-gap ($M=54.00$, $SD=11.402$) and the object-gap ($M=60.00$, $SD=24.495$) in the L2 RST Low group; $t(8)=-0.497$, $p<.633$.

Participant Group	Comprehension	By RST Groups	Comprehension	By Sentence Type	Comprehension
English native	SG>OG	L1 RST High	SG = OG	subject-gap	High > Low
		L1 RST Low	SG = OG	object-gap	High = Low
L2 learner	SG>OG	L2 RST High	SG > OG	subject-gap	High > Low
		L2 RST Low	SG = OG	object-gap	High > Low

*SG=subject-gap, OG=object-gap; > indicates greater accuracy in comprehension; = indicates no difference

Table 3.13: Summary of English comprehension accuracy by L1 native speakers and L2 learners

For the English native speakers, the English object-gap sentences were more difficult to comprehend than the English subject-gap sentences. Within each L1 English RST group, no difference was found between the comprehension accuracy rates of the English subject-gap and object-gap sentences. Between the L1 English RST High and Low groups, only the English subject-gap sentences that were easier to comprehend showed a difference between the two RST groups. Thus, it is possible to say that the positive effect of having higher L1 WM capacity seems to appear more robust in the sentence types that are easier to comprehend than the more difficult to comprehend ones.

Two predictions were also discussed in L1 English sentence processing based on Gibson's Dependency Locality Theory (DLT) and O'Grady's Structural Distance Hypothesis (SDH). Both of these explanations predict the English object-gap sentences to be more difficult to comprehend which coincides with the current result. As for the memory cost spent to process the English gap type sentences, Gibson's storage

component of the DLT (expectation-based theory) seems to fit the current RRT performances of the English gap sentences by the English native speakers.

The Japanese-speaking learners of English also showed the higher comprehension accuracy rate for the English subject-gap sentences than the English object-gap sentences. However, only the L2 English RST High group showed a significant difference between the comprehension accuracy rates of the English subject-gap and object-gap sentences. The difference in structural difficulty between the English subject-gap and object-gap sentences may have influenced only L2 English RST High group's performance. Furthermore, both the English subject-gap and object-gap sentences showed a difference between the two RST groups in terms of comprehension accuracy. More explicitly, the L2 English RST High group had higher comprehension accuracy rates than the Low group in both gap type sentences. This means a higher WM capacity affected the L2 comprehension performance positively. Note that because there was a correlation between L2 English RST and L2 English proficiency test score, this result also infers that the higher ones' L2 proficiency level is, the better one does in L2 comprehension performance of the English gap type sentences.

The reading patterns and the RRT analyses of the two English gap sentences by the L2 learners indicate that they process the subject-gap and object-gap sentences differently. The reading patterns seem to be somewhat consistent with the 'expectation-based' hypothesis. However, the long RRT in an unpredicted region in the English object-gap sentences does not fit what the hypotheses predicted. Rather, the L2 learners' performance may better be explained as showing the ceiling effect. Since the long RRT in the unexpected region was only seen in the processing of the English object-gap sentences

that were more difficult to comprehend, it can be concluded that the WM capacity affected L2 sentence reading differently depending on the difficulty of the sentence structure.

3.4.2. Japanese Relative Clause Sentences and L1/L2 RST Span Size

The table below summarizes the findings of Japanese comprehension accuracy rates by L1 native speakers and L2 learners according to the sentence type and RST group.

Participant Group	Comprehension	By RST Groups	Comprehension	By Sentence Type	Comprehension
Japanese native	SG<OG	L1 RST High	SG < OG	subject-gap	High = Low
		L1 RST Low	SG < OG	object-gap	High = Low
L2 learner	SG<OG	L2 RST High	SG < OG	subject-gap	High = Low
		L2 RST Low	SG < OG	object-gap	High = Low

*SG=subject-gap, OG=object-gap; > indicates greater accuracy in comprehension; = indicates no difference

Table 3.14: Summary of Japanese comprehension accuracy by L1 native speakers and L2 learners

For the Japanese native speakers, the Japanese object-gap sentences were easier to comprehend than the Japanese subject-gap sentences. This result supports the Gibson's DLT prediction, rather than O'Grady's SDH. Further analysis with L1 Japanese RST groups revealed that the different RST group did not affect the comprehension accuracy rates of the two Japanese gap type sentences. Within each L1 RST group, the comprehension accuracy rates of the subject-gap and object-gap sentences were different for both the RST groups. This means that the subject-gap sentences were more difficult

regardless of ones' WM capacity. The Japanese native speakers illustrated similar reading patterns in both the Japanese subject-gap and object-gap sentences. Therefore, whether one has a higher WM capacity or a lower WM capacity, similar reading patterns were seen across the two different gap type sentences and the RST groups. Additionally, the analyses of RRTs revealed that the native speakers' gap processing is somewhat in accordance with the integration cost of the DLT.

For the English-speaking learners of Japanese, the Japanese object-gap sentences were also easier to comprehend than the subject-gap sentences. Moreover, the results indicated that L2 WM capacity did not affect the comprehension accuracy rates of both Japanese gap type sentences. This means the Japanese subject-gap sentences were more difficult to comprehend regardless of one's L2 WM capacity. The results of the RRT comparisons between the two gap type sentences showed an indication of inefficient use of Japanese case markers. In addition, the reading patterns of the L2 learners did not necessarily follow the integration nor expectation-based hypotheses' cost prediction. It was indicated that their real time Japanese gap sentence processing may be uniquely different from that of the Japanese native speakers.

CHAPTER 4

COMPARISON BETWEEN L1 AND L2 SENTENCE PROCESSING

Native speakers' acquisition of L1 is successful most of the time, whereas L2 learning is often not. The evidence for this deficiency is held to be the lack of completeness of L2 grammars and/or the fossilization in L2 learning where the learner cannot progress beyond some particular stage (Schachter 1988; Selinker 1992). Much of the L2 research has focused on why L2 learners are unsuccessful, often times looking at lexical, syntactic, or pragmatic development and achievement. The reasons for L2 learners' unsuccessfulness are discussed in terms of psychological factors, learning strategies, critical period, L1 transfer and so on, but not so much from processing strategies and WM constraints.²⁶

In Chapter 3, both the L1 native speakers and L2 learners showed similar performance in the comprehension of the English and Japanese subject-gap and object-gap sentences. It was also shown that WM capacity has some effect on L2 sentence comprehension. Furthermore, it was shown that L2 sentence processing and reading patterns are somewhat different from those of L1.

²⁶ DeKeyser (2000, 2003) argues that although it is true that there is a critical period, only implicit language learning mechanisms are affected by maturational constraints, and thus, adult L2 learners may still be able to learn L2 perfectly.

In this chapter, the comparisons of L1 and L2 sentence processing in English and Japanese will be provided with the focus on the L2 learners' reading patterns. After the comparisons between L1 and L2 English and L1 and L2 Japanese, we will discuss the learners' data on an individual level. This will allow us to uncover whether the L2 learners' reading patterns were consistent or not consistent with those of the native speakers, which may not have been visible in the group level analyses. By doing so, we intend to examine the L2 learners' language performance from the viewpoints of processing and WM constraints. The following questions (1) and (2) are addressed in this chapter.

- (1a) Do the performances of the L1 native speakers and L2 learners differ in subject-gap/object-gap sentence comprehension accuracy rates in English and in Japanese?
- (1b) Do the performances of the L1 native speakers and L2 learners differ in subject-gap/object-gap sentence processing in English and in Japanese?
- (2a) Is the tendency in individual sentence reading patterns of the L2 learners similar to that of L1 native speakers?
- (2b) Is the tendency in the individual sentence reading patterns of L1 native speakers and L2 learners influenced by their WM capacity?
- (2c) Do the individual sentence reading patterns of L1 native speakers and L2 learners affect comprehension accuracy?

4.1. Comparison of English Natives' L1 English and Japanese Natives' L2 English

In the previous chapter, it was observed that L1 English speakers and Japanese-speaking L2 learners of English demonstrate similar comprehension tendencies for English gap type sentences. Despite this result, it was indicated that the native speakers and L2 learners of English seemed to have demonstrated different sentence reading patterns. Here, we will directly compare the data of L1 English native and L2 English learner groups to further investigate whether this difference in reading patterns can be explained by their WM capacity.

The following figure shows the comprehension accuracy rates of English gap sentences by L1 native and L2 learner RST groups. As it was shown in the previous chapter, both the L1 speaker and L2 learner groups show higher comprehension accuracy rates for English subject-gap sentences than English object-gap sentences.

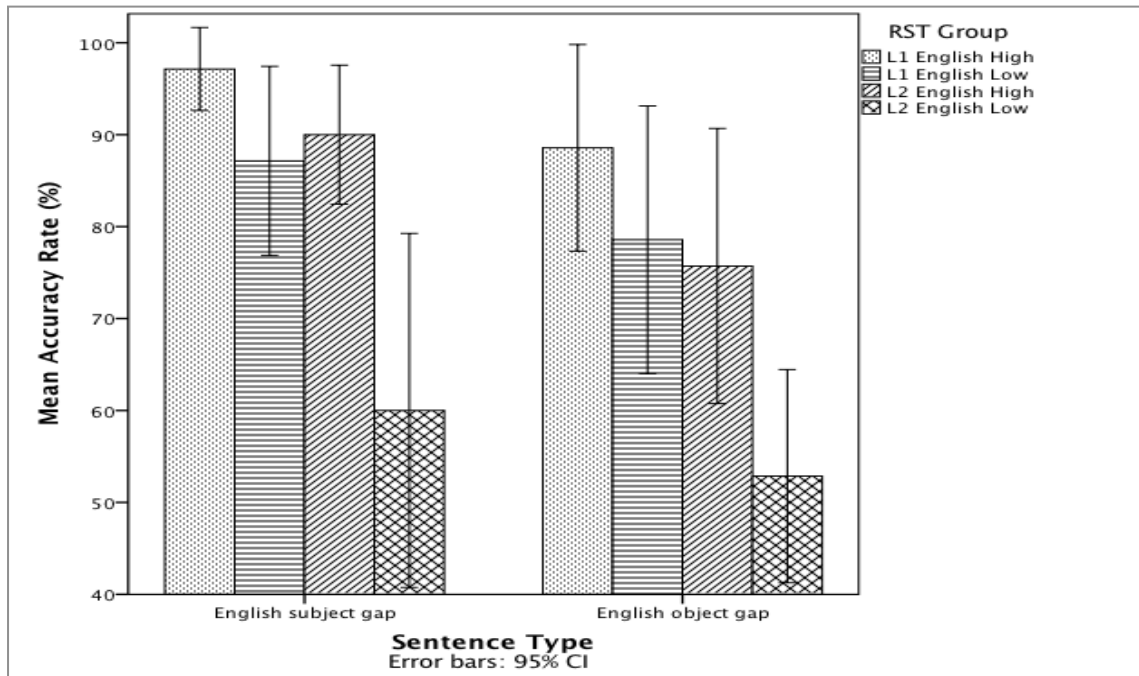


Figure 4.1: English sentence comprehension accuracy by RST of L1 native speakers and L2 learners

A one-way ANOVA showed that there was a significant difference in the English subject-gap sentence comprehension accuracy rates among L1 English RST High, L1 English RST Low, L2 English RST High and L2 English RST Low groups [$F(3, 24)=11.441, p<.000$]. The post-hoc Tukey's HSD test showed that the comprehension accuracy rate of L2 English RST Low group was significantly different from the other three groups at the .05 level. All other comparisons were not significant. The English object-gap sentence comprehension accuracy rates also showed a significant difference among the four groups [$F(3, 24)=7.830, p<.001$]. The post-hoc Tukey's HSD test showed the comprehension accuracy rates of L2 English RST Low and L1 English RST High

groups were significantly different at the .05 level. All other comparisons were not significant.

The comparisons of the English gap sentence comprehension accuracy rates between L1 native and L2 learner groups revealed that only L2 English RST Low group is different from the other three groups in the English subject-gap sentences. In the English object-gap sentences, the L2 English RST Low and L1 English RST High groups were the groups that differed significantly. Provided that the comprehension of the English object-gap sentences is more difficult than the English subject-gap sentences as discussed earlier, the current results point to at least some differences between the L2 English RST Low and L1 English RST High groups in the comprehension of both gap type sentences. Additionally, the current results seem to imply that the comprehension accuracy rates of the L2 English RST High group in English subject-gap sentences may not be different from that of the L1 native groups (L1 English RST High and L1 English RST Low). Consequently, the results raise a question of whether the L2 English RST High learners process the gap type sentences similarly to the native speakers.

The following figure shows the mean Residual Reading Times (RRTs) of the English subject-gap sentences by L1 native and L2 learner groups based on their respective L1 English RST groups and L2 English RST groups. The reading patterns of both L1 English RST and both L2 English RST groups generally show similar tendencies in their English subject-gap sentences as far as in which regions they slow down in reading (Regions 4 and 6). However, differences still exist. More specifically, the two L1 native groups have the slowest reading time in Region 6, whereas the L2 learner groups show the slowest reading time in Region 4.

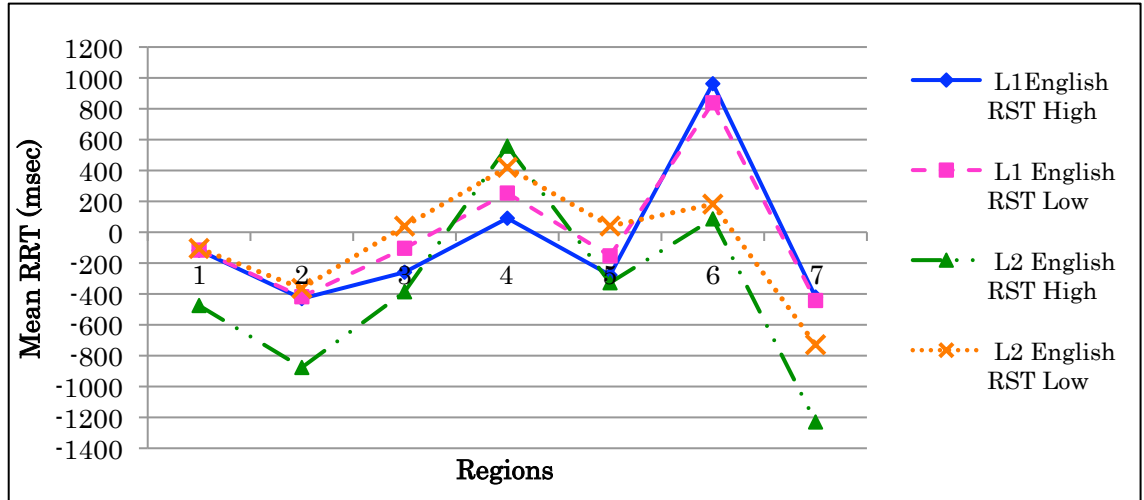


Figure 4.2: Mean RRTs of English subject-gap sentences by RST of L1 native speakers and L2 learners

Comparing the RRTs of the L1 English RST High, L1 English RST Low, L2 English RST High and L2 English RST Low groups, a series of ANOVAs showed that there were differences in all regions in the initial analyses, but the post-hoc Tukey's HSD did not show any difference at the .05 level among the four RST groups. The current case of significant omnibus F-ratio and non-significant pair-wise comparison results indicate that there is variability in the means within each RST group.²⁷ Thus, the similar comparison was performed with 10 participants per language group. The 10 participants per language group were selected in the same manner as described in Chapter 3.

²⁷ Using larger samples could also minimize this problem because it makes sampling errors decrease toward zero.

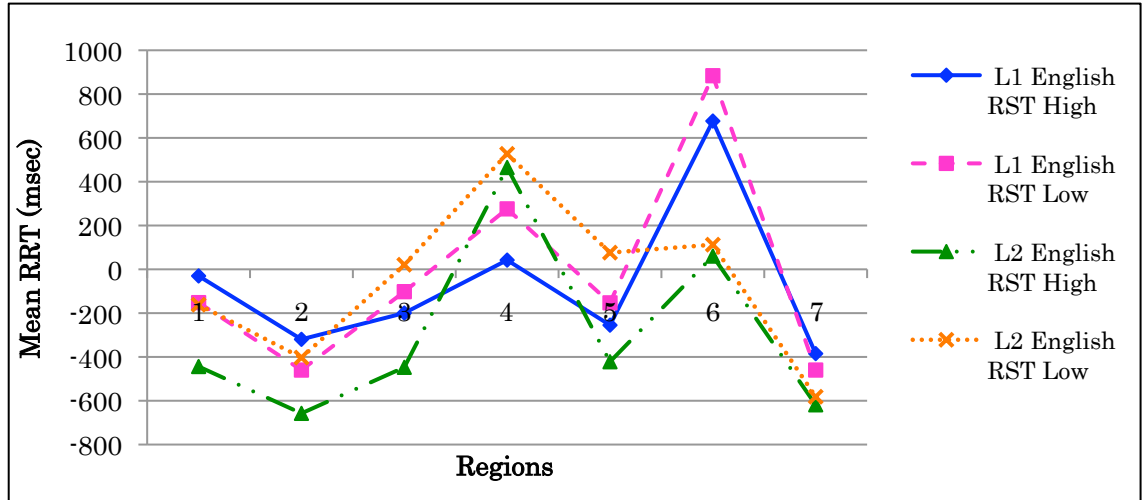


Figure 4.3: Mean RRTs of English subject-gap sentences by RST of ten L1 native speakers and ten L2 learners

Figure 4.3 (10 participants per language group; 5 participants per RST group) illustrates a unique reading pattern for the English subject-gap sentences, particularly by the L2 English RST Low group. Specifically, the L2 English RST Low group shows relatively similar RRTs in Regions 5 and 6. ANOVAs were conducted and no meaningful significance was found in Regions 2, 3, 4, and 5 among the four RST groups in the English subject-gap sentences. However, a significant difference was found among the four groups in Region 6 [$F(3, 16)=3.462, p<.0041$; $F(3, 36)=30.079, p<.000$]. The post-hoc Tukey's HSD showed the difference among L1 English RST High group vs. L2 English RST High and L2 English RST Low groups, and L1 English RST Low group vs. L2 English RST High and L2 English RST Low groups.

The reading patterns of the native groups and the L2 learner groups in the English object-gap sentences showed quite dissimilar patterns. Figure 4.4 below demonstrates that the L1 native groups showed slow reading times in Regions 3 and 4 followed by a

dip (=faster reading time) in Region 5. The slowest reading time was seen, again, in Region 6. The L2 learner groups kept relatively similar slow reading times from Regions 3 to 6.

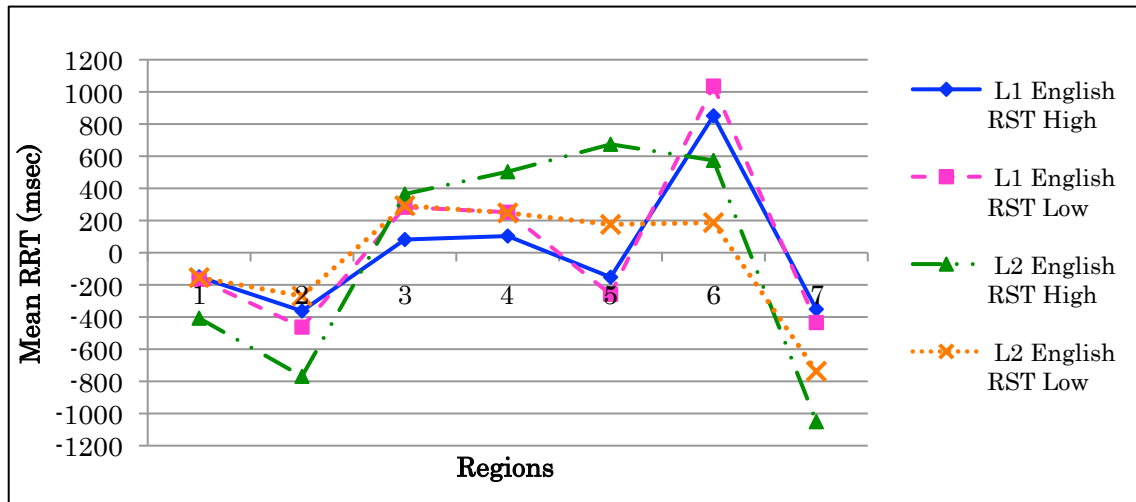


Figure 4.4: Mean RRTs of English object-gap sentences by L1 native speakers and L2 learners

Again, ANOVAs with the 14 participants in each language group showed that there were significant differences in all regions in the initial analyses, but the post-hoc Tukey's HSD did not show any difference at the .05 level among the four RST groups. Thus, the comparison was performed with 10 participants per language group.

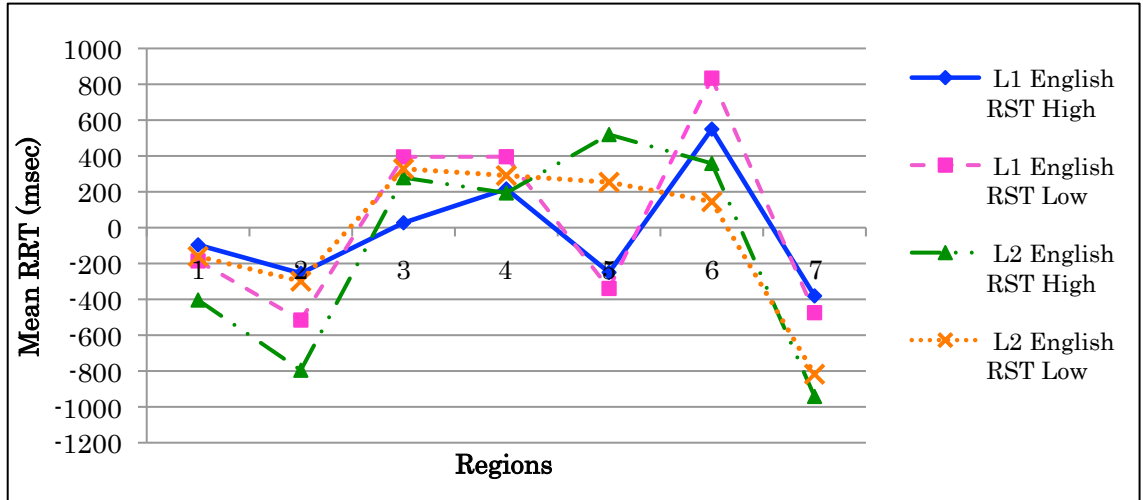


Figure 4.5: Mean RRTs of English object-gap sentences by RST of ten L1 native speakers and ten L2 learners

Similar to the previous Figure 4.4 with the 14 participants per language group, Figure 4.5 with the 10 participants per language group illustrates similar reading patterns within the same language group. The L1 English RST groups showed slower reading times in Regions 3 and 4 followed by a dip in Region 5 and the slowest reading time in Region 6. The L2 English RST groups kept relatively the same slow, or slower, reading times from Regions 3 to 6. No meaningful significance was found in Regions 2, 3, and 4 between the four RST groups. However, a significant difference was found among the four RST groups in Region 5 [$F(3, 16) = 7.172, p < .003$, $F(3, 36) = 34.977, p < .000$]. The post-hoc Tukey's HSD showed that the difference was among L1 English RST High and L1 English RST Low groups vs. L2 English RST High group at .05 level. As well, the L1 English RST Low and L2 English RST Low groups were found to be different as well, at .05 level in the same region.

4.1.1. Summary

The comparisons of L1 native and L2 learner groups' English gap sentences revealed that L2 learner groups, especially L2 English RST Low group, demonstrated lower accuracy in comprehending English gap sentences. Further analyses of English gap sentence RRTs revealed that the L1 native and L2 learner groups seem to show differences in English gap sentence processing. In the English subject-gap sentences, both the L1 English RST High and Low groups showed slow reading times in Regions 4 and 6, with the slowest reading time in the latter region. On the other hand, despite the slow reading times in Regions 4 and 6, both the L2 English RST High and Low groups showed the slowest reading time in Region 4. In the English object-gap sentences, both the L1 English RST High and Low groups showed slow reading times in Regions 3, 4 and 6, with the slowest reading time in Region 6. On the other hand, both the L2 English RST High and Low groups showed slow reading times in Regions 3, 4, 5, and 6. In other words, the part(s) of the sentences bearing much burden on WM among the L1 native speakers and L2 learners was slightly different. What was more interesting is that the L1 native groups and the L2 learner groups showed similar, if not the same, tendencies in the reading patterns of the English subject-gap sentences, which were easier to comprehend, but dissimilar reading patterns of the English object-gap sentences, which were more difficult to comprehend. This indicates that with the English subject-gap sentences that are easier to comprehend, the L2 learners were able to utilize their WM somewhat similarly to the native speakers. Nonetheless, the utilization of their WM was not so successful in the English object-gap sentences that were more difficult to comprehend. Additionally, when the RRT differences were found in a region, they were found between

the two L1 English RST groups and the two L2 English RST groups. The differences were found, for instance, in Region 6 of the English subject-gap sentences. The region was read the slowest by the L1 English native groups, but not by the L2 learner groups. This difference between the participant groups may come from the different way of utilizing their WM. For the English native speakers, the English subject-gap sentences were not so burdensome on their WM, such that they processed incoming parts of the sentence rapidly and wrapped up all of the information at the end of the sentence. This might have caused a hike in L1 native groups, slowing down the reading in Region 6. For the L2 learners, the English subject-gap sentences, especially the RC part of the sentence, were burdensome enough to their WM such that their reading time slowed down the most in Region 4. With the English object-gap sentences, the English native speakers, again, read the sentences with the slowest reading time at the end of the sentence (Region 6). Similar to the English subject-gap sentences, we can assume that the wrapping up of the information had occurred at Region 6. For the L2 learners, the English object-gap sentences were so burdensome on their WM that they constantly read the parts of the sentence slowly after the relative pronoun in Region 2. It can be assumed that the L2 learners' WM was reaching its capacity peak so that different parts of the sentence did not reflect on their reading times. Collectively, these results seem to point to the conclusion that the WM utilization and the reading process of the native speakers and the L2 learners are not necessarily different. However, the results also suggest when WM experiences much more load, such as when parsing more difficult sentences, the WM utilization and the reading process of the native speakers and the L2 learners are quite different.

4.2. Comparison of Japanese Natives' L1 Japanese and English Natives' L2 Japanese

In the previous chapter, it was observed that L1 Japanese speakers and English-speaking L2 learners of Japanese similarly demonstrated higher comprehension accuracy rates in the Japanese object-gap sentences than the subject-gap sentences. Despite this, the performance of the L1 Japanese speakers and English-speaking L2 learners of Japanese suggest that they may have reached the sentence comprehension with different reading patterns. In this section, we will directly compare the performances of the L1 Japanese native and L2 Japanese learner groups to further investigate whether this difference can be accounted for by their WM capacity.

The following figure shows the comprehension accuracy rates of Japanese gap sentences by the L1 native and L2 learner RST groups. One-way ANOVAs were performed and no significant difference was found between the L1 Japanese RST High, L1 Japanese RST Low, L2 Japanese RST High and L2 Japanese RST Low groups for both the Japanese subject-gap and object-gap sentence comprehension accuracy rates [Japanese subject-gap: $F(3, 24)=.389$, $p<.762$; Japanese object-gap: $F(3, 24)=.587$, $p<.629$].

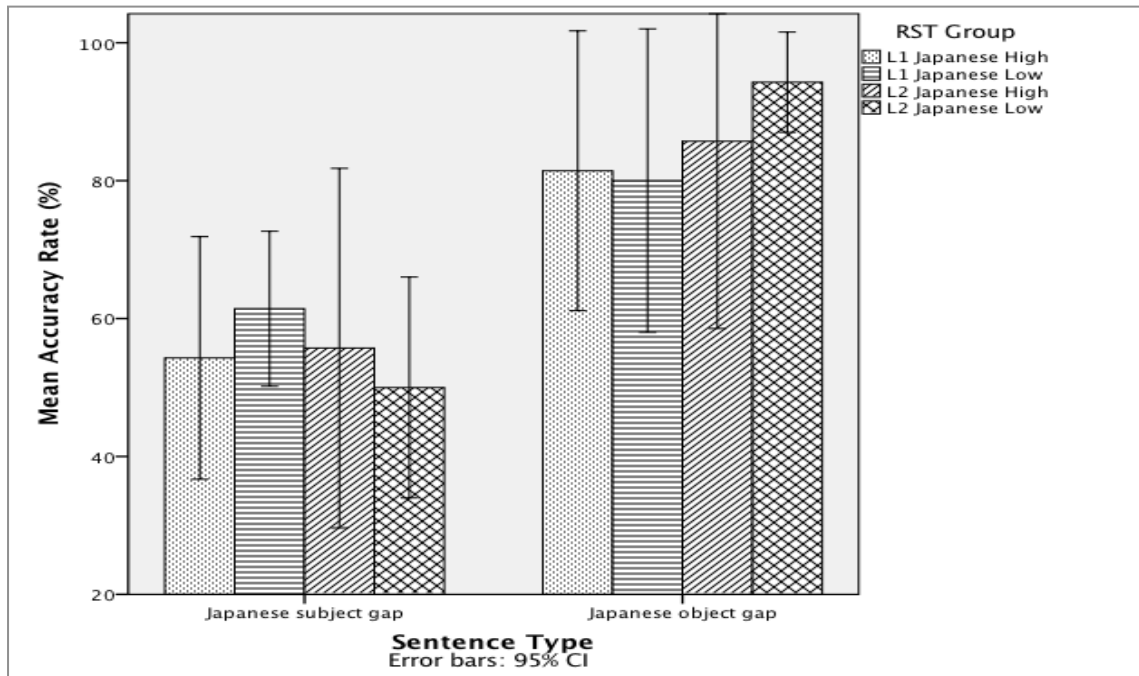


Figure 4.6: Japanese sentence comprehension accuracy by RST of L1 native speakers and L2 learners

No significance in the comprehension accuracy rates between the Japanese native and the L2 learner groups suggests that their comprehension performances of the Japanese subject-gap and object-gap sentences are not distinguishable from one another. Perhaps the English-speaking L2 learners of Japanese had high proficiency level in their L2 Japanese language. It is also possible that the test sentences may have been too easy for the learners. Either way, it seems valid to question whether the performance of the participants had created large variances within the group. Thus, let us now look at the performance of the 10 participants in each language group. The following figure shows the Japanese gap sentence comprehension accuracy rates by the 10 L1 native speakers and the 10 L2 learners.

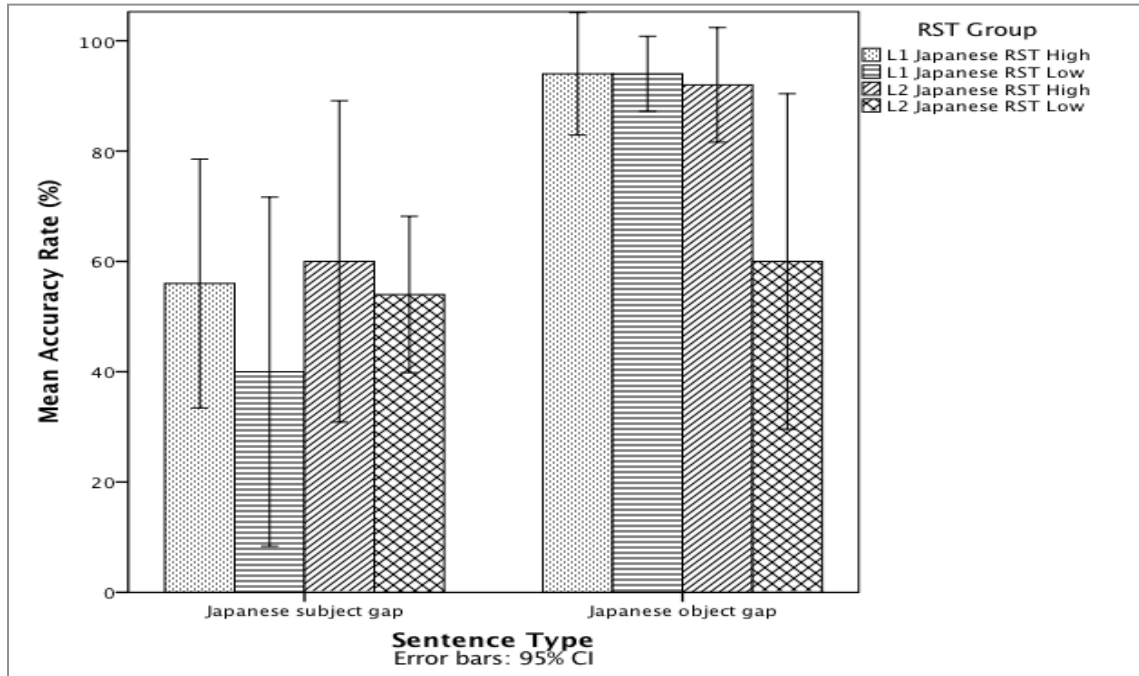


Figure 4.7: Japanese sentence comprehension accuracy rates by RST of ten L1 native speakers and ten L2 learners

Eliminating the data of four participants around the mean of L1 RST and L2 proficiency scores from the original 14 ones, the remaining 10 participants per language were divided into five participants per RST group. The comparison of the Japanese subject-gap sentence comprehension accuracy rates by the L1 Japanese RST High, L1 Japanese RST Low, L2 Japanese RST High and L2 Japanese RST Low groups showed that there was no significant difference among them. On the contrary, there was a significant difference between the L1 Japanese RST High, L1 Japanese RST Low, L2 Japanese RST High, and L2 Japanese RST Low groups in the Japanese object-gap sentences [$F(3, 16) = 7.145$, $p < .003$]. The post-hoc Tukey's HSD showed that there was a difference among the L2

Japanese RST Low group and the L2 Japanese RST High, L1 Japanese RST High, and L1 Japanese RST Low groups at .05 level.

The 10 participants' analyses showed a clearer difference between the groups. The difference was found in the Japanese object-gap comprehension accuracy rates between the L2 Japanese RST Low group and the other three RST groups. No difference was found in the Japanese subject-gap sentences between the four RST groups. Since the comprehension of the object-gap sentences seems to be easier for the participants of this study, seeing the difference only in the Japanese object-gap sentences between the L2 RST Low group and the other three RST groups makes sense. That is, the effect of WM capacity was seen more robustly in the "easier to comprehend" sentences, i.e. Japanese object-gap sentences.

From another point of view, it can be said that Japanese subject-gap sentences were equally difficult for the Japanese native speaker and L2 learner groups such that no outstanding comprehension accuracy rates were achieved as a group. Following this, one may wonder whether L2 Japanese RST Low group processes Japanese gap sentences differently from the two L1 native RST groups and the L2 Japanese RST High group. One may also wonder whether L2 Japanese RST High group processes Japanese gap sentences similarly to the two L1 native RST groups. Answers to these questions will be discussed next.

The following figure shows the mean RRTs of the Japanese subject-gap sentences by L1 native and L2 learner groups based on their L1 and L2 RST groups. The L1 native groups show different reading patterns between the L1 Japanese RST High and Low groups. The L1 Japanese RST High group showed peaks at Regions 2 and 4 whereas the

Low group showed only one peak at Region 4. The L2 Japanese RST High and Low groups also showed different reading patterns. The L2 Japanese RST High group showed a rise in Region 2 and kept relatively the same reading speed through Region 4, forming a plateau, then a drop in Region 5. The L2 Japanese RST Low group showed a rise in Region 2 then their RRTs drop in Region 3 to Region 5. From these reading patterns of the L1 Japanese speakers and L2 learners, it seems that they were utilizing the WM in a different manner to achieve comprehension.

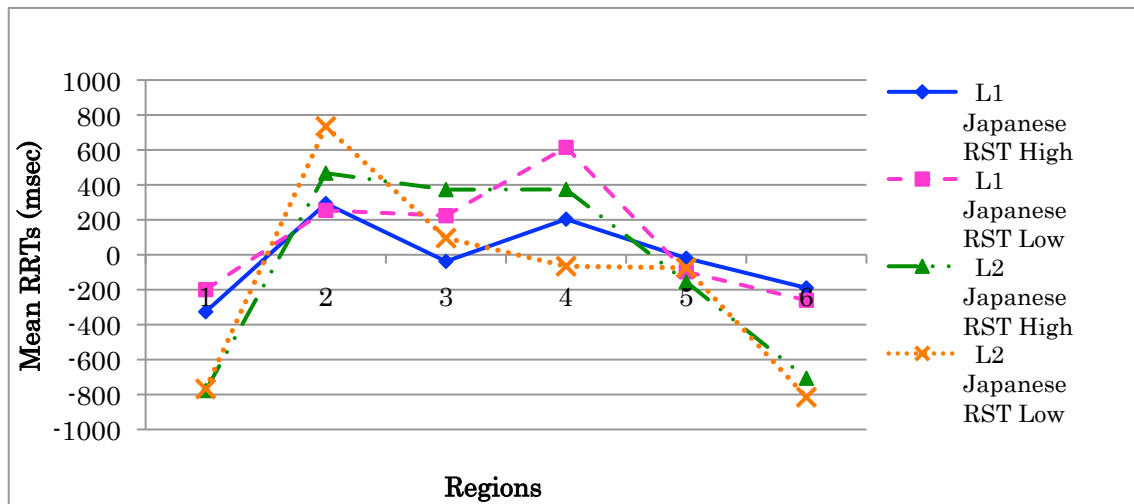


Figure 4.8: Japanese subject-gap sentences by RST of L1 native speakers and L2 learners

ANOVAs comparing the Japanese subject-gap RRTs showed that there were differences in all regions except Region 5 in initial analyses. However, no difference was found at the .05 level in the post-hoc Tukey's HSD test among the L1 and L2 RST groups. Once again, the analyses of 10 participants per language group were conducted. Figure 4.9

below shows the mean RRTs of the Japanese subject-gap sentences by the 10 Japanese native speakers and 10 L2 learners of Japanese. Similar to the 14 participants' reading patterns, the L1 Japanese RST High group showed peaks in Regions 2 and 4 whereas L1 Japanese RST Low group showed only one peak in Region 4. The L2 Japanese RST High group showed a rise in Region 2 and kept relatively slow reading times, but gradually getting faster through Region 4, then a drop in Region 5. The L2 Japanese RST Low group's reading pattern changed drastically from the 14 participants' one and showed a rise in Region 2 and then another rise in Region 3, then a drop in Region 4, followed by a rise in Region 5. ANOVAs showed that there was a significant difference in Region 3 [$F(3, 16)=4.500, p<.018, F2(3, 36)=16.649, p<.000$]. A post-hoc Tukey's HSD test showed the difference among L1 Japanese RST High group vs. L1 Japanese RST Low, L2 Japanese High and L2 Japanese Low groups.

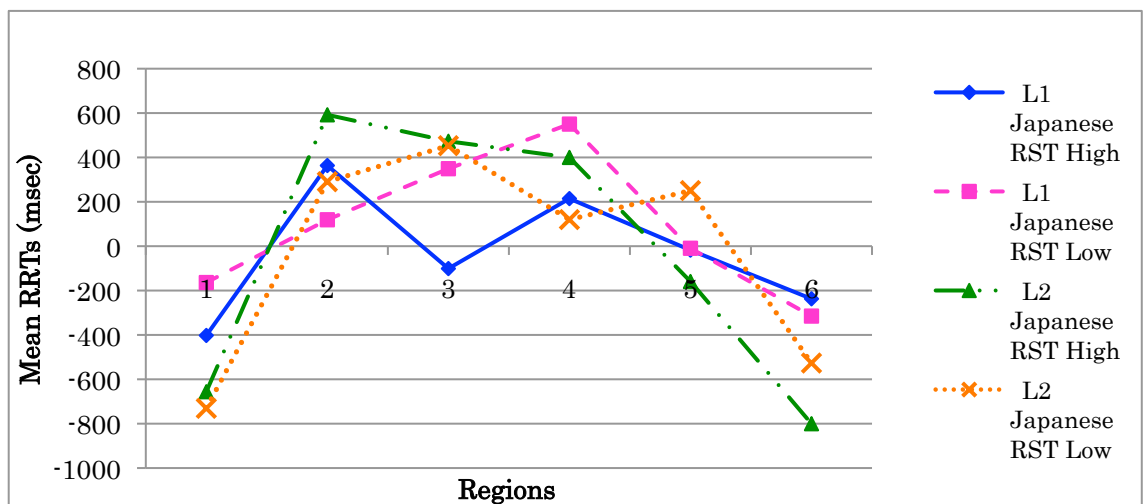


Figure 4.9: Mean RRTs of Japanese subject-gap sentences by RST of ten L1 native speakers and ten L2 learners

Next, the reading patterns of the Japanese object-gap sentences were examined. The L1 Japanese RST High, L1 Japanese RST Low, L2 Japanese RST High and L2 Japanese RST Low groups showed similar reading patterns for the object-gap sentences. The L1 Japanese RST High and Low groups showed peaks in Regions 2 and 4. The L2 Japanese RST High and Low groups also showed peaks in Regions 2 and 4. The difference between the Japanese native and L2 learner groups is that the Japanese native groups read Region 4 slightly slower than Region 2 and the L2 learner groups read Region 2 slower than Region 4. Once again, ANOVAs were performed and there were differences in all regions except Region 4, but post-hoc Tukey's HSD test did not yield any significance.

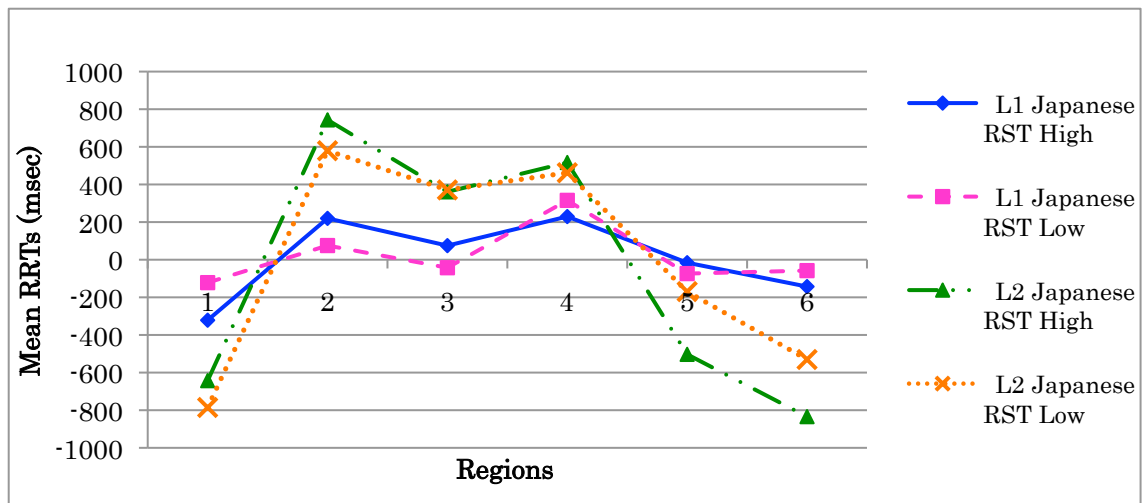


Figure 4.10: Mean RRTs of Japanese object-gap sentences by RST of L1 native speakers and L2 learners

The figure below, which exhibits reading patterns of the 10 participants per language group, showed similar reading patterns to the reading patterns with the 14 participants (the figure above). ANOVAs showed significances in the initial analyses. Although the figure below seems to show a large difference among the four RST groups, especially in Region 2, no significance was found in post-hoc Tukey's HSD comparisons.

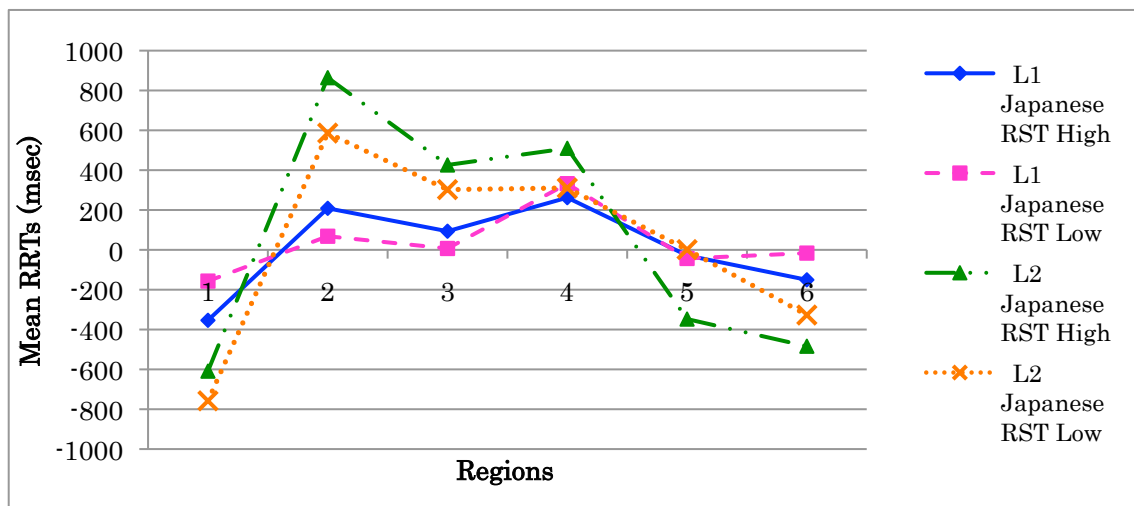


Figure 4.11: Mean RRTs of Japanese object-gap sentences by RST of ten L1 native speakers and ten L2 learners

4.2.1. Summary

Unlike the comparisons of the English gap sentences, the comparisons of Japanese gap comprehension accuracy rates between the Japanese native and L2 learner groups did not show much significance. Only when the numbers were trimmed down to 10 participants by eliminating four participants, were we able to find any difference. Even with that, the significance was only found in the Japanese object-gap sentence

comprehension accuracy rates among L2 Japanese RST Low group and the other three RST groups. Thus, in this study, the comprehension performance of the Japanese native speakers was not necessarily better than that of the L2 learners.

The tendency of the Japanese native speakers not performing differently from L2 learners was carried over to the comparisons of RRTs between the L1 native groups and the L2 learner groups. Similar to the English gap sentences, the post-hoc Tukey's HSD tests using L1 Japanese RST and L2 Japanese RST span groups did not yield any significance with the 14 participants in each language group. We found, however, significances in Region 3 of both the Japanese subject-gap and object-gap sentences when the analyses were conducted on 10 participants for each language group. This difference in RRTs and the reading patterns illustrated in the figures suggest that the L1 Japanese RST High group is processing the Japanese subject-gap sentences differently from the L2 Japanese RST High and Low groups as well as the L1 Japanese RST Low group. Taking into account that the Japanese subject-gap sentences were more difficult to comprehend than the object-gap sentences in this study, L1 Japanese RST High group is processing Japanese subject-gap sentences differently from the other groups. The L1 Japanese RST Low group did not show a difference from the L2 Japanese RST High and Low groups in the RRT analyses. This does not necessarily mean that the way that the L1 Japanese RST Low group and the two L2 Japanese RST learner groups processed the Japanese subject-gap sentences is similar to one another. A close look at the reading patterns exhibited by the L2 Japanese RST High and L2 Japanese RST Low groups shows them distinct from the L1 Japanese RST Low group. Thus, it can be concluded

that the L2 learner groups were processing Japanese subject-gap sentences dissimilarly to the Japanese native groups.

The analyses of RRTs on the Japanese object-gap sentences showed that there were no meaningful differences among the four RST groups. Even when the 14 participants were cut down to 10 participants per language, no significant difference was found in the regions among the L1 native and L2 learner groups. This result seems to indicate that the L1 native speakers and the L2 learners are not distinguishably different in processing Japanese object-gap sentences on the surface. However, clearly, the reading patterns of the L1 native and L2 learner groups illustrate a difference between them. The L2 learner groups show the slowest reading time in Region 2 whereas the L1 native groups show the slowest reading time in Region 4, which indicates that what makes a burden on WM in processing the Japanese object-gap sentences are different among the Japanese native speakers and English-speaking L2 learners of Japanese.

4.3. Individual Differences in L1 and L2 Reading Patterns

Up to this point, we discussed the reading patterns of the participants as if there were only one reading pattern per sentence type for each group. However, as we are aware, there is a great range of individual differences, especially in the learners' L2 performance. Individual differences in sentence processing could originate from any number of factors, from motivation, aptitude in one's language skill, and strategies employed. In this section, we will consider the individual participant's sentence reading patterns and discuss it from the point of view of WM capacity so that what may have been invisible on the group level analysis will be revealed.

4.3.1. Individual Differences in English Subject-Gap Reading Patterns

The English native speakers of L1 English RST High and L1 English RST Low groups showed similar reading patterns throughout the regions in subject-gap sentences regardless of their RST span size. Thirteen out of the fourteen participants demonstrated similar reading patterns for English subject-gap sentences with a peak in Region 4 and a higher peak in Region 6. To provide a representative example that demonstrates the English subject-gap reading pattern of the 13 native speakers, the reading patterns of one L1 English RST High and one L1 English RST Low participant is shown in the following figure.

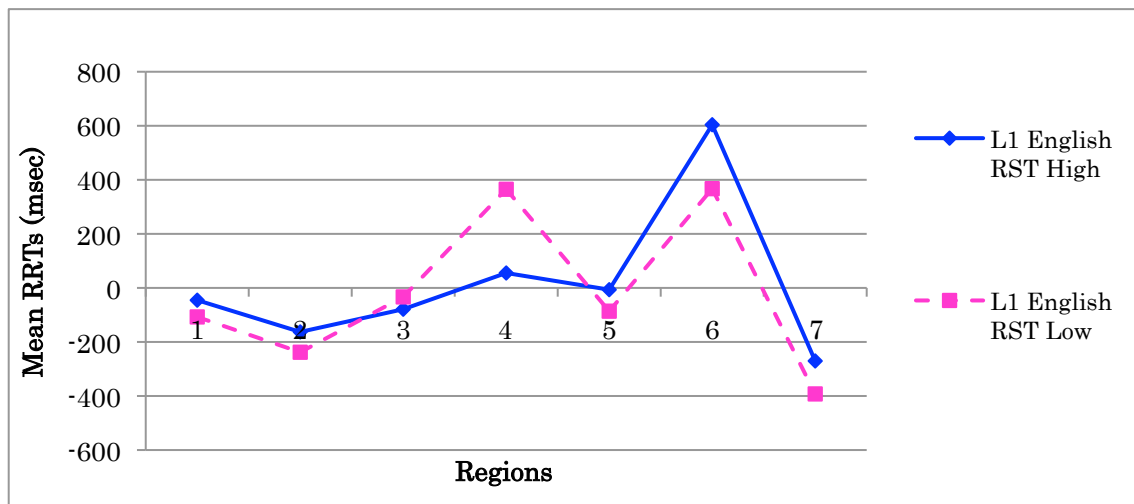


Figure 4.12: English subject-gap by one L1 RST High and one L1 RST Low participant

The one English native speaker who did not show this reading pattern showed peaks in Region 3, instead of Region 4, and then in Region 6 (figure below). This participant, E13,

had relatively low L1 English RST span score, but high comprehension accuracy rate for the English subject-gap sentences as seen in the table below. It may be the case that this individual's low WM capacity affected the English subject-gap sentence processing by having a slow down in an earlier region. In spite of this, it seems that low WM capacity did not affect the comprehension of the sentences.

Participant#	Eng all sentence comprehension (%)	Eng subject-gap accuracy (%)	Eng object-gap accuracy (%)	L1 Eng RST score (Group)
E13	93.33%	100	80	42 (Low)

Table 4.1: Scores of E13

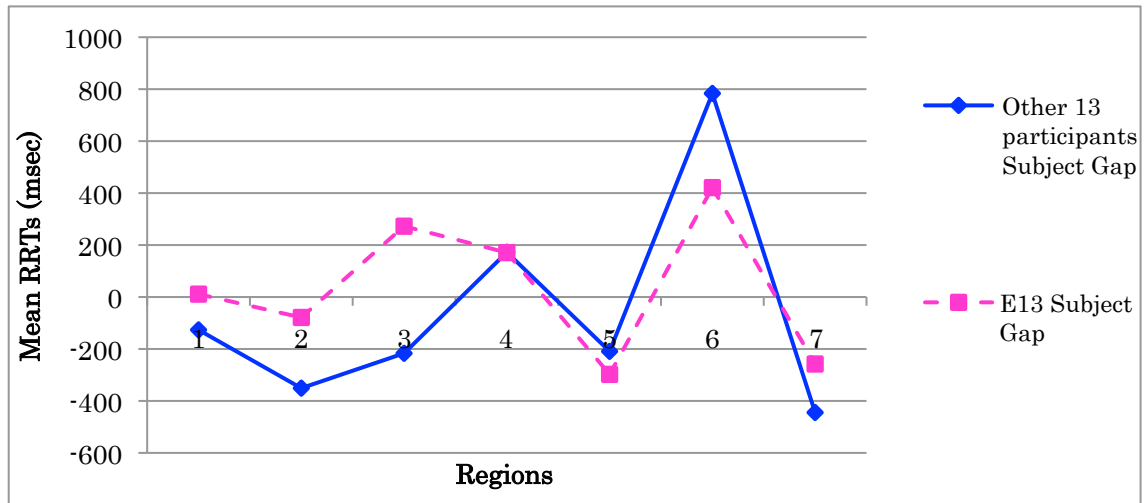


Figure 4.13: English subject-gap by E13 and the other thirteen participants

We will now turn to Japanese-speaking L2 learners of English. Nine learners with both the L2 English RST High (6 participants) and Low (3 participants) span sizes

showed a reading pattern with peaks in Regions 4 and 6 in the English subject-gap sentences. This reading pattern is similar to the “commonly-preferred” reading pattern demonstrated by the native speakers. Hereafter, a “commonly-preferred” way means that the majority or close to the majority of the native speakers who participated in this study demonstrated such a tendency in their reading pattern. The following table shows the scores of those nine L2 learners.

Participant #	Eng all sentence comprehension (%)	Eng subject-gap accuracy (%)	Eng object-gap accuracy (%)	L2 Eng prof test (%)	L2 Eng RST score (Group)	L1 Jpn RST score (Group)
J22	66.67	70	70	68.82	35 (Low)	45 (High)
J23	71.67	80	60	100	56 (High)	56 (High)
J24	78.33	90	60	88.24	43 (High)	33 (Low)
J25	83.33	90	80	94.12	56 (High)	50 (High)
J26	90	100	90	88.24	42 (High)	40 (Low)
J28	68.33	70	50	82.35	38 (Low)	42 (High)
J29	68.33	70	60	82.35	34 (Low)	32 (Low)
J30	91.67	100	100	88.24	40 (High)	42 (High)
J31	85	90	80	94.12	48 (High)	49 (High)

Table 4.2: Scores of nine L2 learners of English

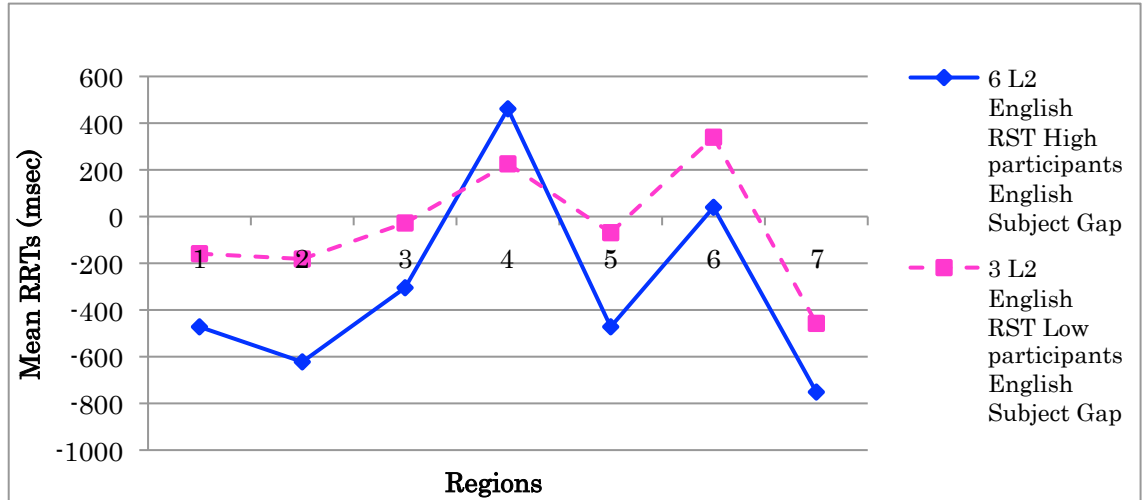


Figure 4.14: English subject-gap by six L2 RST High and three L2 RST Low participants

The other five participants exhibited different reading patterns. The reading pattern of those five participants can be divided into two types; (A) only one peak at Region 4 but no obvious hikes in other regions, and (B) showing peak(s) at different regions. The table below shows the data of those five L2 learners grouped by sentence reading patterns.

Group	Participant #	Eng all sentence comprehension (%)	Eng subject-gap accuracy (%)	Eng object-gap accuracy (%)	L2 Eng prof test (%)	L2 Eng RST score (Group)	L1 Jpn RST score (Group)
A	J21	68.33	40	60	68.82	36 (Low)	41 (Low)
	J27	73.33	80	60	82.35	39 (High)	39 (Low)
	J34	78.33	90	50	76.47	32 (Low)	43 (High)
B	J32	68.33	50	50	76.47	33 (Low)	34 (Low)
	J33	73.33	30	30	88.24	37 (Low)	33 (Low)

Table 4.3: Scores of five L2 learners of English

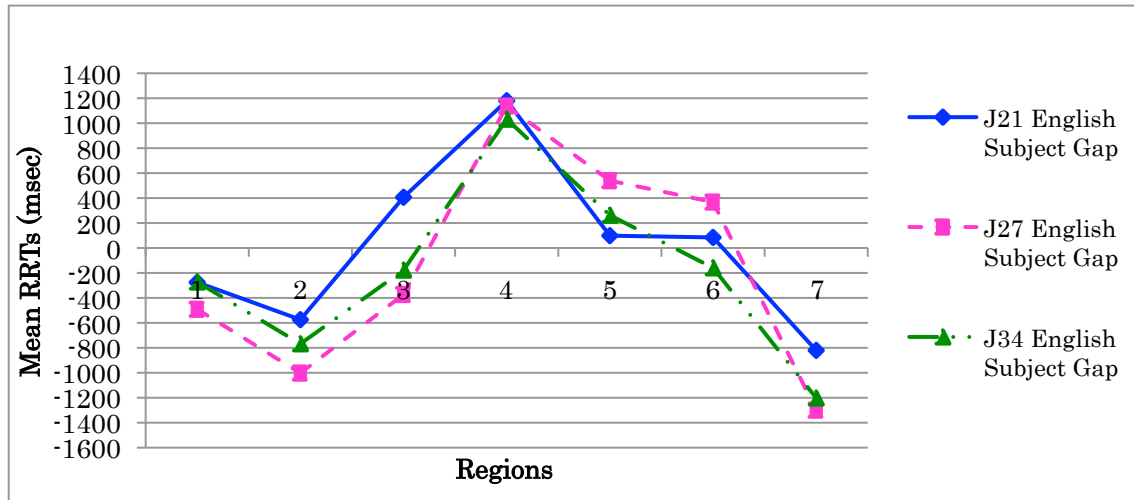


Figure 4.15: English subject-gap by three L2 learners (A)

The first pattern (A) shown above has a peak at Region 4, but no obvious peak in Region 6. This reading pattern of the English subject-gap sentences is particular to the L2 learners since all native speakers showed a slow down in Region 6 (wrap up). Pattern (A) was demonstrated by the participants with mixed L2 English RST span groups, L2 proficiency test scores, and the comprehension accuracy rates of English subject-gap sentences. However, they have relatively low overall English sentence comprehension in the English sentence reading tasks compared to the L2 learner group's total average of 76.07% (range=66.67- 91.67, SD=8.5). Even when these factors were compared to those of the other nine learners who showed a similar reading pattern to the “commonly-preferred” reading pattern of the English native speakers, no outstanding factor can be found to pinpoint the cause of this reading pattern. The most plausible explanation for showing this particular reading pattern may be that it was due to their WM capacity and their low level L2 English proficiency. To be more explicit, while reading the English

subject-gap sentences, much of their WM capacity may have been occupied by processing the incoming information, perhaps due to their low L2 grammatical competence. Surely, the parsers recognized and processed the gap in the RC as the slow reading time indicates in Region 4. However, they did not slow down in Region 6. The reason these three L2 learners did not show the slow reading time in Region 6 can be speculated and explained in two ways. One is that the three L2 learners simply did not ‘wrap-up’ to integrate the information in sentence processing (Just and Carpenter, 1980; Rayner, Kambe, and Duffy, 2000; Rayner, Sereno, Morris, Schmauder, and Clifton, 1989) because they have not acquired the processing strategy of the native-like way. Second, they were unable to ‘wrap-up’ because the WM capacity that remained from the previous processing was limited such that they could not spare their remaining WM for the integrative processing at the end of the sentences. Of the two, the latter explanation may be less applicable because two out of three participants show high comprehension accuracy in English subject-gap sentences regardless of exhibiting this unique reading pattern, which means they were able to process the sentences for the comprehension.

The second pattern (B) shown below exhibits reading patterns with peak(s) at different regions. Two L2 learners have shown this reading pattern. Learner J32 showed one peak at Region 5 and showed low comprehension accuracy rate for English subject-gap sentences. Learner J33 showed two peaks at Regions 3 and 6. The reading pattern by the latter Learner J33 is similar to that of English native speaker, E13. Both J33 and E13 have low L1 and L2 RST span scores. It is possible that they were not processing the English subject-gap sentences effectively. The same can be said for Learner J32 since the

comprehension accuracy rate for the English subject-gap sentences and L1 RST and L2 RST span size of this participant were extremely low.

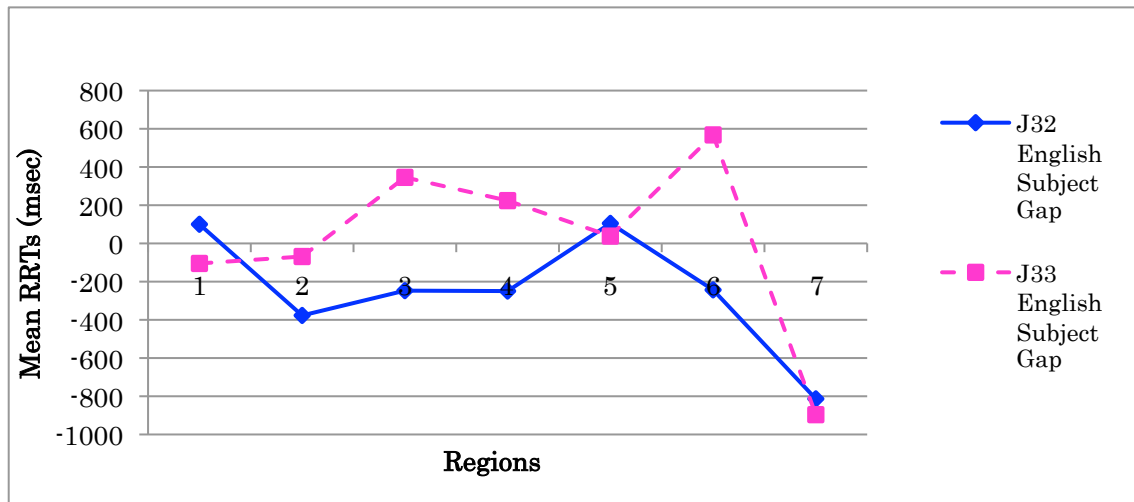


Figure 4.16: English subject-gap by two L2 learners (B)

4.3.2. Individual Differences in English Object-Gap Reading Patterns

The English native speakers of L1 English RST High and L1 English RST Low groups showed relatively similar reading patterns, but they were more diverse in the English object-gap sentences than in English subject-gap sentences. Ten out of fourteen English native speakers demonstrated similar reading patterns with a peak in Region 3 and a higher peak in Region 6. To provide a representative example that demonstrates the reading pattern of the ten native speakers, the English object-gap reading patterns by one L1 English RST High and one L1 English RST Low participant is shown in the figure below.

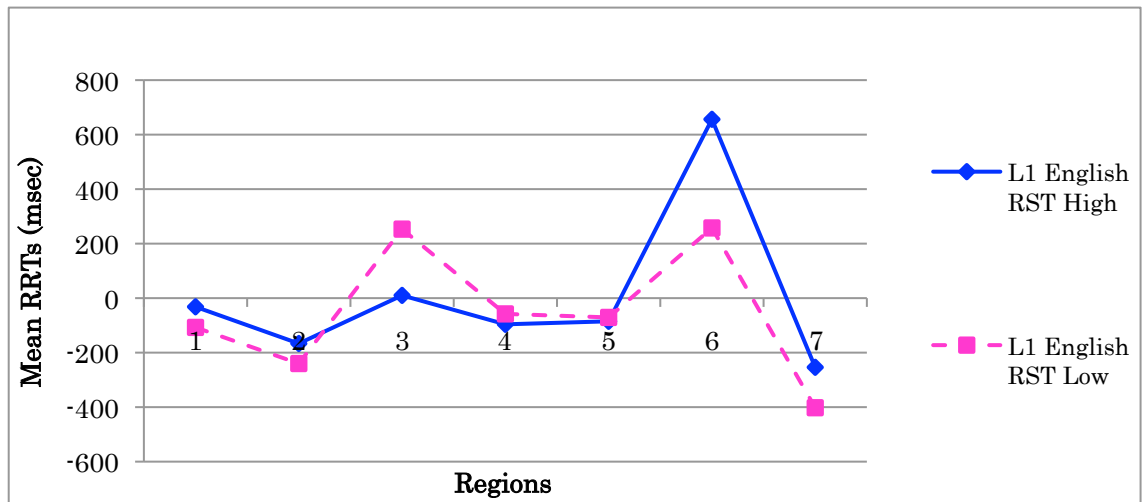


Figure 4.17: English object-gap by one L1 RST High and one L1 RST Low participant

Four participants showed deviations from this reading pattern. The table below provides the participant data for those four English native speakers.

Participant #	Eng all sentence accuracy (%)	English subject-gap accuracy (%)	English object-gap accuracy (%)	L1 English RST score (Group)
E09	98.33	100	90	44 (Low)
E10	93.33	90	90	60 (High)
E12	90	100	70	54 (High)
E14	90	90	80	57 (High)

Table 4.4: Scores of four English native speakers

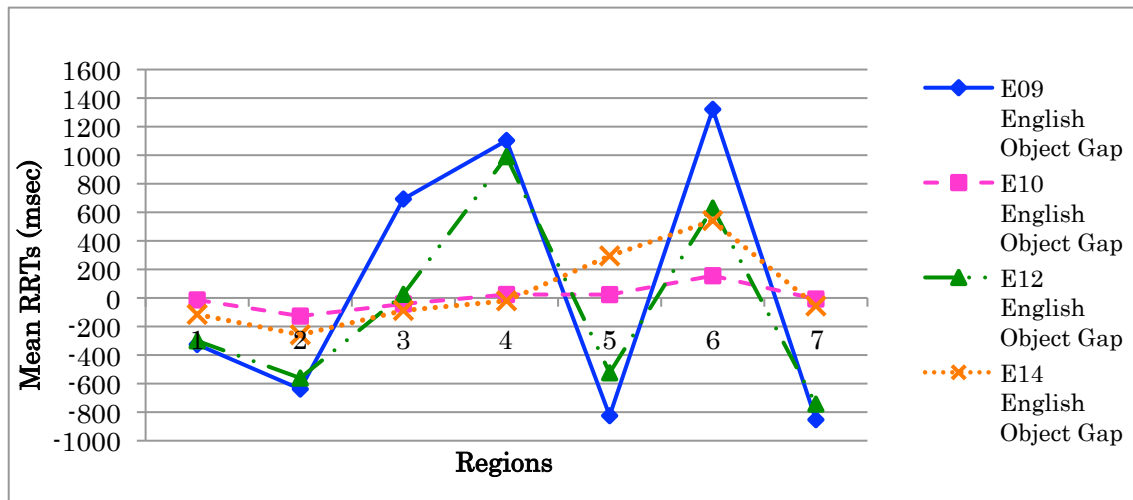


Figure 4.18: English object-gap by four English native speakers

Participant E09 showed slower reading time in Region 4 than in Region 3. Participant E10 showed steady reading time throughout all regions, although Region 6 has a slight incline from Region 5 (Region 3 RRT: 41.84 msec → Region 4: 24.18 msec → Region 5: 23.42 msec → Region 6: 155.71 msec). Participant E12 showed slower reading time in Region 4 than in Region 3. Participant E14 showed gradual increase to Region 6.

A very steep increase in reading time between Regions 2 and 3 and even slower reading time in Region 4 by Participant E09 may have been due to the WM capacity being low. Drastic differences in RRTs throughout the regions may also indicate the WM overload. Note that despite the low score in L1 English RST, the comprehension accuracy for all English sentences including the fillers and the two gap type sentences is relatively high. Participant E12 is in contrast with Participant E09. Although Participant E12 has a reasonably high L1 English RST score, the comprehension accuracy for all English sentences including the fillers and English object-gap sentences is low. As shown

by low comprehension accuracy for English object-gap sentences, Participant E09 may have not appropriately and effectively parsed the English object-gap sentences.

Steady increase in the reading times until Region 6 for Participants E10 and E14 may be due to higher WM capacity as seen in their L1 English RST scores. Surprisingly, Participant E10 exhibited the same reading pattern for the English subject-gap sentences. Thus, it can be inferred that these individuals' high capacity in WM was affecting the processing speed, and high capacity in WM may have helped the processing of English object-gap sentences.

We will now look at the reading patterns of English object-gap sentences by Japanese-speaking learners of English. Many of the English native speakers showed a reading pattern with slower reading times making peaks in Regions 3 and 6. On the contrary, only three out of the fourteen L2 learners exhibited the peaks in Regions 3 and 6 in their reading pattern (figure below). These three L2 learners were among the nine participants who also showed similar reading patterns to those of the English native speakers in the English subject-gap sentences.

Participant#	Eng all sentence comprehension (%)	Eng subject-gap accuracy (%)	Eng object-gap accuracy (%)	L2 Eng prof test (%)	L2 Eng RST score (Group)	L1 Jpn RST score (Group)
J22	66.67	70	70	68.82	35 (Low)	45 (High)
J28	68.33	70	50	82.35	38 (Low)	42 (High)
J31	85	90	80	94.12	48 (High)	49 (High)

Table 4.5: Scores for three L2 learners of English

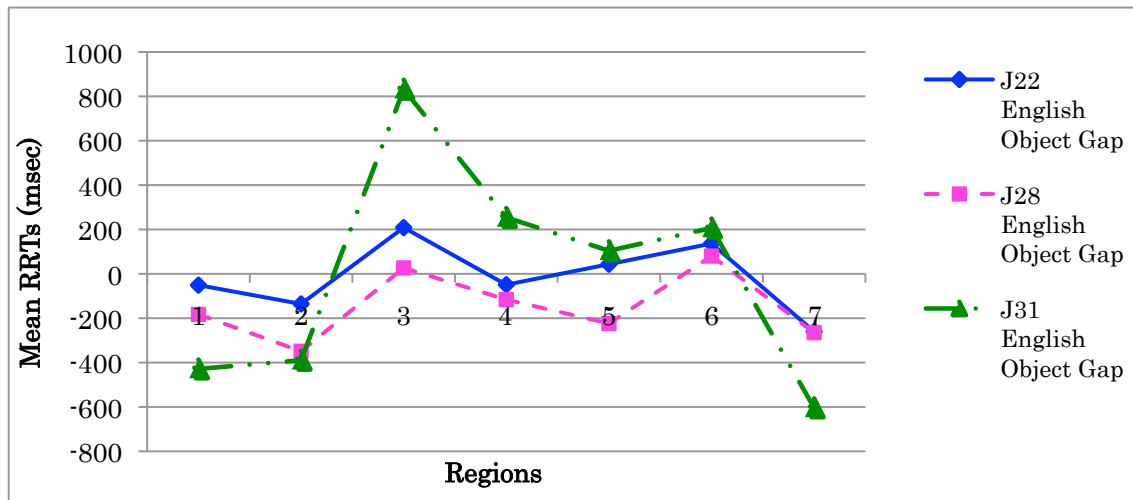


Figure 4.19: English object-gap by three L2 learners of English

Compared to the 10 English native speakers showing a higher peak in Region 6 than in Region 3, these three L2 learners did not show a noticeably high peak in Region 6. The participants' scores indicate the only similarity between these three L2 learners is that they have high L1 Japanese RST scores. The participant data also indicates that other than one learner (Learner J31), the other two learners have low L2 English RST scores and comprehension accuracy for all English sentences including the fillers, English object-gap sentences and L2 English proficiency test scores. Learner J28 especially showed fast reading times but low English object-gap comprehension accuracy of 50%. Two points can be indicated from the reading patterns of these L2 learners. One is that the integration of information at the end of English object-gap sentences, i.e. a slow down in reading time, may be necessary to better comprehend English object-gap sentences. Second, dissociation between the comprehension accuracy and reading pattern may exist

when L2 WM capacity and L2 language proficiency are low. Because the data are too limited to be conclusive, further research is necessary to confirm these points.

The rest of the participants can be divided into four groups: (A) four participants showed two peaks but not in Regions 3 and 6, (B) two participants showed a peak only at Region 4, (C) four participants showed one or two peaks at regions where none of the native speakers showed peaks, and (D) one participant showed relatively the same slow reading times throughout Regions 3 to 6.

Group	Participant #	Eng all sentence comprehension (%)	Eng subject-gap accuracy (%)	Eng object-gap accuracy (%)	L2 Eng Prof test	L2 Eng RST score (Group)	L1 Jpn RST score (Group)
A	J21	68.33	40	60	68.82	36 (Low)	41 (Low)
	J23	71.67	80	60	100	56 (High)	56 (High)
	J25	83.33	90	80	94.12	56 (High)	50 (High)
	J33	73.33	30	30	88.24	37 (Low)	33 (Low)
B	J32	68.33	50	50	76.47	33(Low)	34 (Low)
	J34	78.33	90	50	76.47	32 (Low)	43 (High)
C	J26	90	100	90	88.24	42 (High)	40 (Low)
	J27	73.33	80	60	82.35	39 (High)	39 (Low)
	J29	68.33	70	60	82.35	34 (Low)	32 (Low)
	J30	91.67	100	100	88.24	40 (High)	42 (High)
D	J24	78.33	90	60	88.24	43 (High)	33 (Low)

Table 4.6: Scores of eleven L2 learners of English

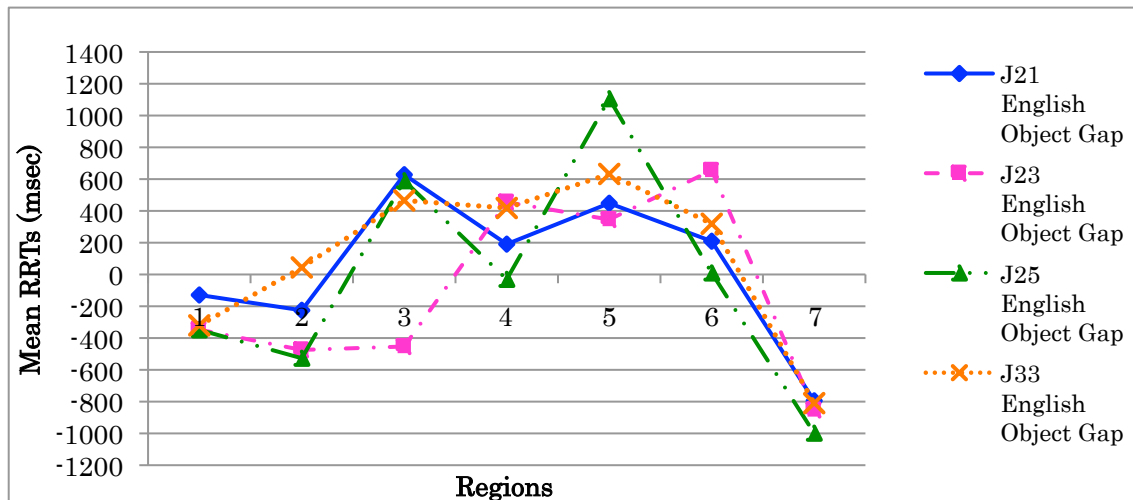


Figure 4.20: English object-gap by four L2 learners of English (A)

The four L2 learners with pattern (A) showed mainly two peaks in their reading patterns, but at different regions from Regions 3 and 6. The three L2 learners, J21, J25, and J33, showed peaks in Regions 3 and 5. Participants J21 and J33 had low scores in L1 Japanese and L2 English RSTs and comprehension accuracy. However, Learner J25 had high scores in L1 Japanese and L2 English RSTs, L2 English proficiency test, and the comprehension accuracy for all English sentences including the fillers and the English object-gap sentences. Learners J21 and J25's zigzag reading patterns are similar to Sawasaki (2007)'s result of JFL learners' simplex sentence processing. On the other hand, the reading pattern of J33 does not distinctively show a zigzag pattern compared to the other two learners. Because J33's English object-gap comprehension accuracy is extremely low with slow reading times from Regions 3, 4 and 5, it can be inferred that this individual was having a hard time comprehending English object-gap sentences. Learners J21 and J25 showed zigzag reading patterns, however, one had high WM

capacity and the other did not. Since there were only two participants, it is difficult to make any conclusion at this time. However, it seems that not only WM, but also something else is affecting the demonstration of a zigzag reading pattern. For instance, it is possible that the zigzag reading pattern was caused by the L2 learner's inability to predict the sentence structure and/or anticipate the upcoming elements like the native speakers. The performance of Learner J25 also indicates that even if one has a reading pattern that is not commonly-preferred by the native speakers, if one has a high WM capacity, then one can comprehend sentences more accurately.

Unlike the other three L2 learners, Learner J23 irregularly shows peaks in Regions 4 and 6. This individual's participant data shows high scores in L1 Japanese and L2 English RSTs as well as excellent L2 English proficiency test score (100%). This leads one to think that this individual has a reasonably high L2 English proficiency level. However, the comprehension accuracy for English object-gap sentences was not so high. Learner J23's reading pattern for the English object-gap sentences is similar to the individual's reading pattern for the English subject-gap sentences. The reading patterns for both English gap type sentences showed peaks in Regions 4 and 6. Thus, it is possible that this individual may have misparsed the English object-gap sentences as the English subject-gap sentences, which lead to lower comprehension accuracy in the English object-gap sentences. The other possibility is that because the English object-gap sentences were more difficult to comprehend than the English subject-gap sentences, J23 was not able to achieve as high comprehension accuracy in the former gap type than the latter. At this time, it is difficult to provide an explanation for this individual's performance. Thus, we will not pursue further discussion.

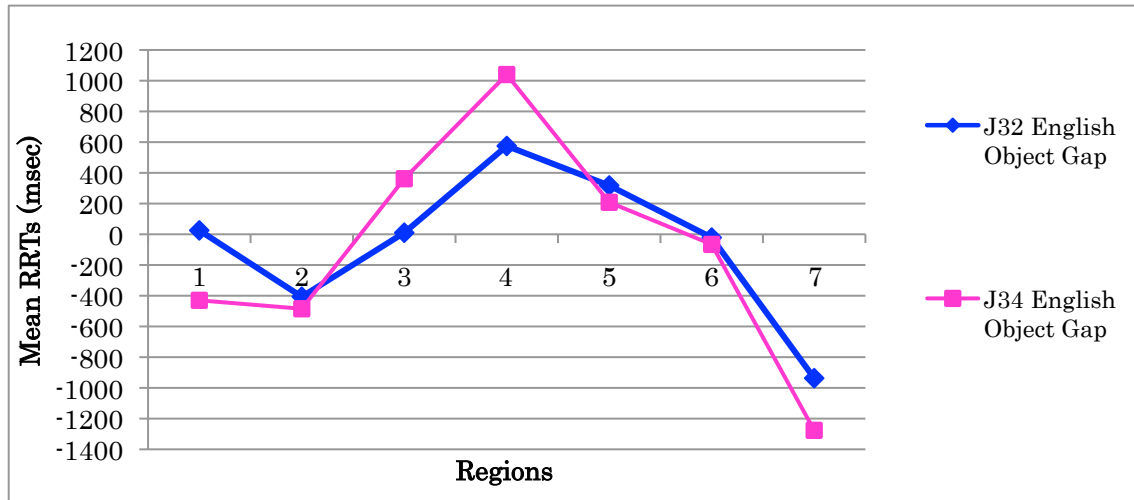


Figure 4.21: English object-gap by two L2 learners of English (B)

In the above figure, Learners J32 and J34 demonstrate a peak at a completely different region compared to the others. The two L2 learners showed only one peak in Region 4. Their participant data indicate that they have low L2 English RST and not so high L1 Japanese RST scores. They also have low L2 English proficiency test scores, and only 50% accuracy in English object-gap sentence comprehension. Together with their reading patterns, it may indicate that these two L2 learners may not have been able to process and comprehend the English object-gap sentences successfully.

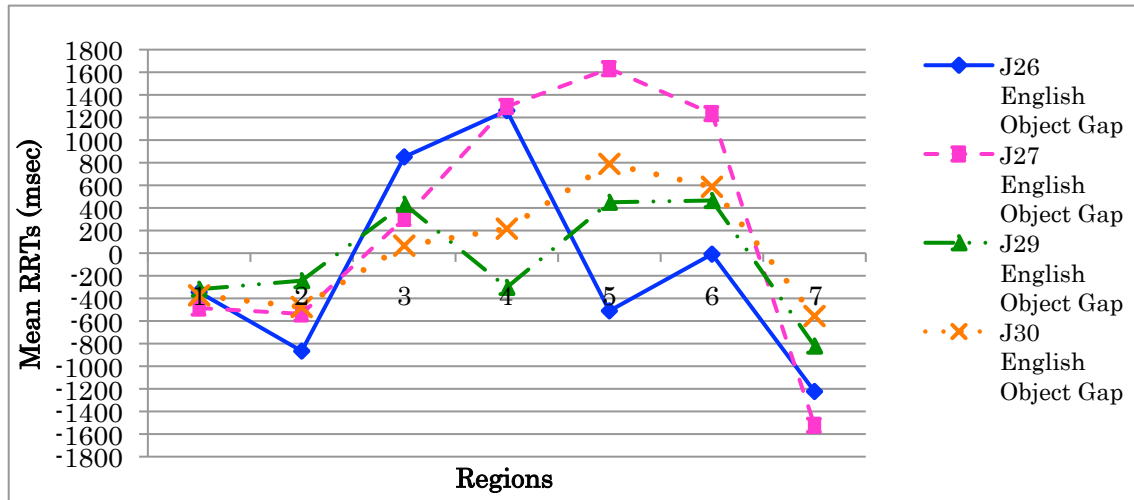


Figure 4.22: English object-gap by four L2 learners of English (C)

The four learners shown in the above figure demonstrated slow reading times in more than two consecutive regions. For example, Learner J27 slowed down in Regions 4, 5, and 6. Learner J29 slowed down in Regions 5 and 6. Participant J30 showed the slow down in RRTs up to Region 5. Learner J26 slowed down in Region 3 and showed even slower RRT in Region 4. Learner J26's reading pattern for the English object-gap sentences was similar to that of Participant E09 and it can also be considered as having two peaks in Regions 4 and 6. The participant data of J26 show that this individual has high L2 English RST span score but low L1 Japanese RST span score, and demonstrated relatively high comprehension accuracy for all sentences and English object-gap sentences. Learners J27's and J30's reading patterns seem similar to one another although their scores were quite different. Learner J27 has low scores in L1 Japanese and L2 English RSTs, low score in L2 English proficiency test as well as low comprehension accuracy for all English sentences and the English object-gap sentences. On the other

hand, Learner J30 has high scores in L1 Japanese and L2 English RSTs, relatively high score in L2 English proficiency test, as well as high comprehension accuracy rates for all English sentences and the English object-gap sentences. These two learners' reading patterns and participant data indicate that having higher WM helps to achieve the accurate comprehension rates even without a reading pattern that is commonly preferred by the native speakers. Learner J29's reading pattern shows slower reading times for both Region 5 (main verb) and Region 6. Having a slower reading time in Region 6 is expected for the wrap-up effect, but slowing down at Region 5 cannot be explained unless the effect of the filler-gap dependency appeared a region later. However, since only one participant has shown such a tendency in English object-gap reading pattern in this study, a concrete conclusion will be left for future research.

Lastly, Figure 4.23 shows the RRTs of Learner J24, who has low L1 Japanese RST span score, but high L2 English RST span score. Learner J24 shows slower RRTs from Regions 3 to 6. Within them, the highest peak was Region 6 followed by Region 3, which would make it similar to the English native speakers' commonly-preferred reading pattern for the English object-gap sentences. However, this individual's RRTs stay relatively slow over several regions and demonstrated low comprehension accuracy in the English object-gap sentences. Therefore, it is likely that this individual was experiencing difficulty in processing the English object-gap sentences, which put a heavy burden on WM. And thus, the RRTs throughout Regions 3 to 6 may be showing a ceiling effect.

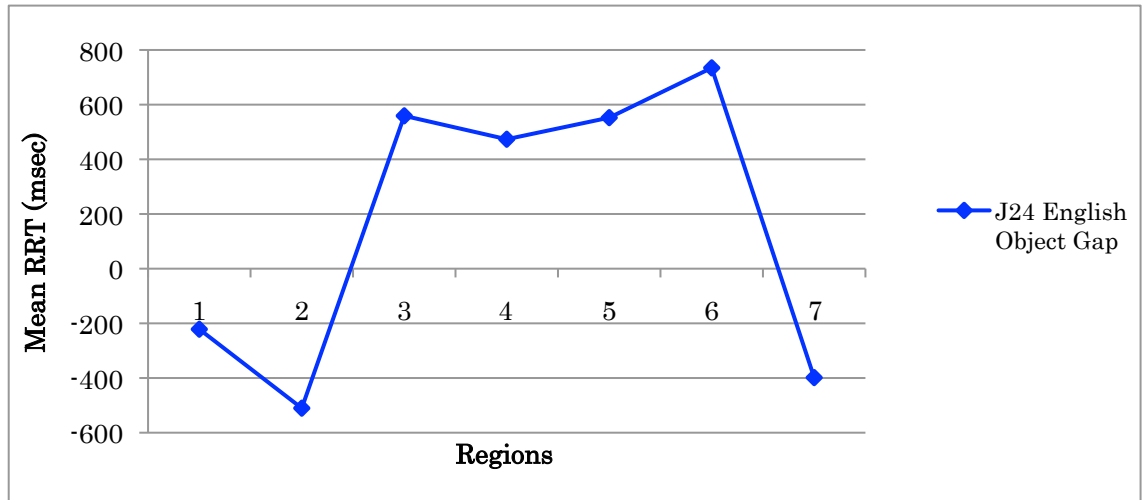


Figure 4.23: English object-gap by J24 (D)

4.3.3. Individual Differences in Japanese Subject-Gap Reading Patterns

Regardless of their L1 Japanese RST scores, the Japanese native speakers showed somewhat similar reading patterns in the Japanese subject-gap sentences, though a number of different reading patterns were seen compared to the Japanese object-gap sentences. As discussed in the previous section, the English object-gap sentences, which were more difficult for the English native speakers to comprehend, also demonstrated diverse reading patterns. Thus, similar to the case of the English object-gap sentences, this is within our expectations since the Japanese subject-gap sentences in this study were more difficult to comprehend for the Japanese native speakers.

Five out of the fourteen Japanese native speakers showed peaks at Regions 2 and 4 in the Japanese subject-gap sentences. The previous studies on Japanese sentence processing show that the parser processes phrases in a sentence incrementally using the case marker information without waiting for the clause-final verb (Kamide, 2006;

Kamide and Mitchell, 1999; Miyamoto, 2002; Yamashita, 1997) This would explain why there was a peak in Region 4. A peak in Region 2 (embedded verb) could also be explained. During the test, seeing a continuation of a dotted line beyond Region 2 with a transitive verb, the parser was likely to have predicted upcoming elements for a sentence structure as well as wrapping up the processing of RC, which lead to the longer RRT in the region.

The figure below shows a representative example that demonstrates the reading pattern of the majority of the native speakers in this sentence type by one L1 Japanese RST High and one L1 Japanese RST Low participant. Their reading patterns show a peak in Region 2 and a slightly higher peak in Region 4. Both L1 Japanese RST High and Low participants (High=3 participants, Low=2 participants) demonstrated this reading pattern.

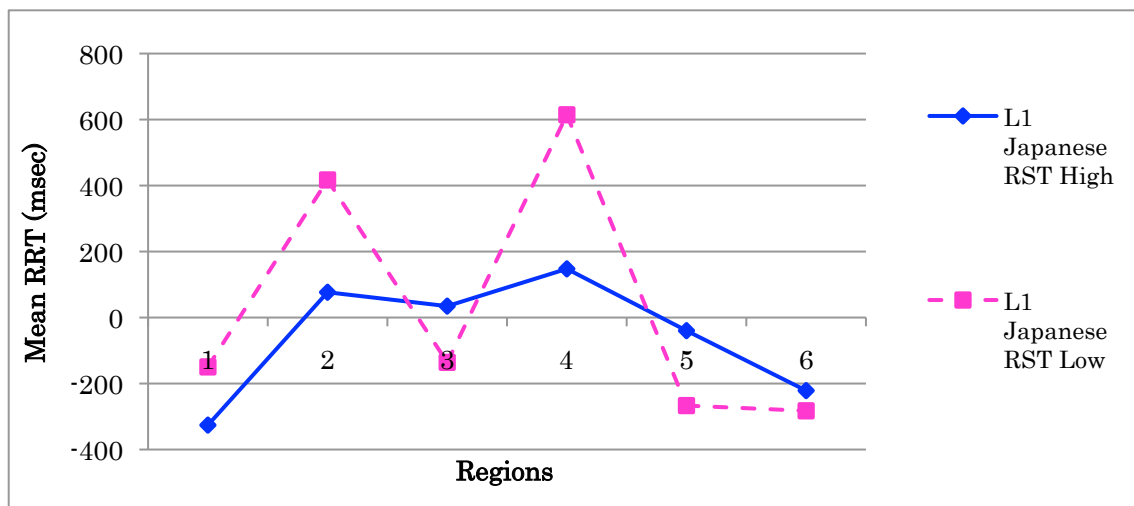


Figure 4.24: Japanese subject-gap by five L1 RST High and Low participants

Among the remaining nine Japanese native speakers, there were three participants who demonstrated extremely low comprehension accuracy in Japanese subject-gap sentences (J24, J30 and J34). Those participants' reading patterns are not reliable for further discussion and thus will not be discussed.

The remaining six participants' reading patterns can be divided into two types: (A) only one peak in Region 2, and (B) the highest peak in Region 4. From the table below, the mixture of high and low L1 Japanese RST span sizes and high and low comprehension accuracy are observed.

Group	Participant #	Jpn all sentence comprehension (%)	Jpn subject-gap accuracy (%)	Jpn object-gap accuracy (%)	L1 Jpn RST score (Group)
A	J25	98.33	80	100	50 (High)
	J26	86.67	70	100	40 (Low)
	J32	81.67	60	90	34 (Low)
B	J29	90	70	100	32 (Low)
	J31	68.33	60	100	49 (High)
	J33	80	90	20	33 (Low)

Table 4.7: Scores of six Japanese native speakers

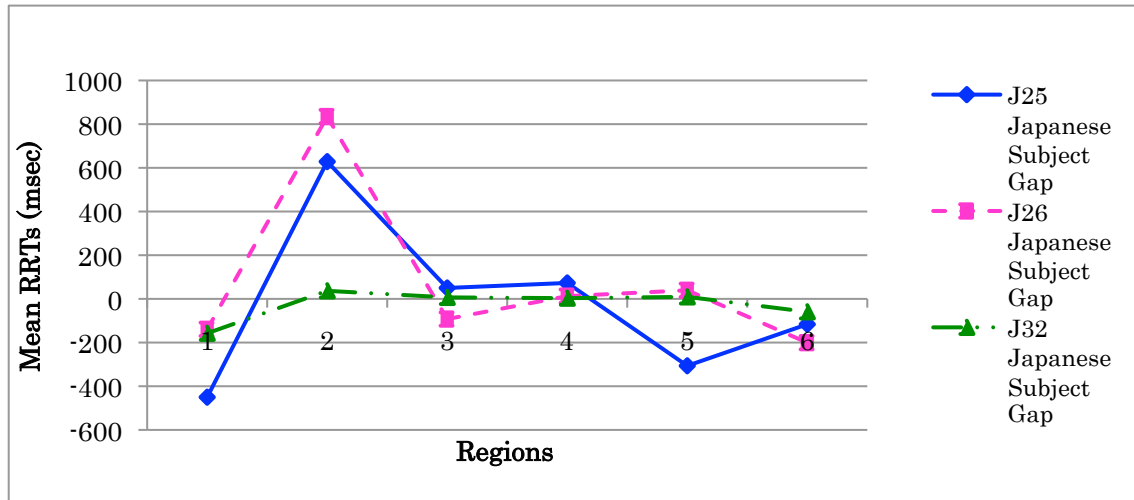


Figure 4.25: Japanese subject-gap by three Japanese native speakers (A)

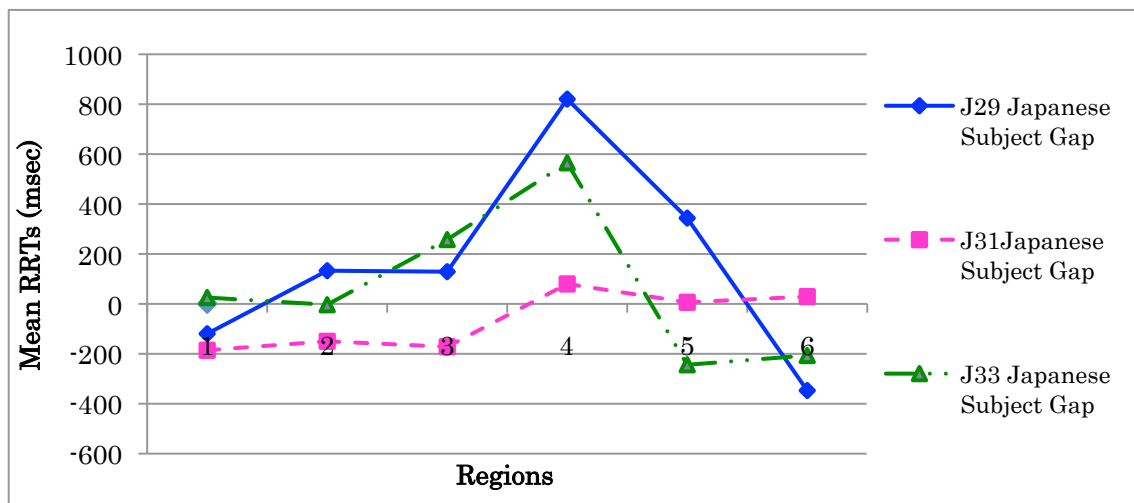


Figure 4.26: Japanese subject-gap by three Japanese native speakers (B)

Patterns (A) and (B) demonstrated peaks in Region 2 and Region 4, respectively. The participant data shows that four of the six participants demonstrated low L1 Japanese RST span scores. The two participants who demonstrated high L1 Japanese RST span

scores (J25 and J31) showed mixed results in the Japanese subject-gap comprehension accuracy. Participant J25, who showed relatively high comprehension accuracy in all Japanese sentences including the fillers and the Japanese subject-gap sentences, showed Type A reading pattern with a peak in Region 2. Participant J31, who showed low comprehension accuracy in all Japanese sentences including the fillers and the Japanese subject-gap sentences showed Type B reading pattern with a peak in Region 4. Participant J31 shows relatively fast and steady reading times in Regions 1, 2 and 3. Regions 4, 5, and 6, on the other hand, are slower than the previous three regions. The comprehension accuracy rates of these participants are not necessarily low. It can be inferred that their reading patterns may be affected by WM capacity, but the manner in which the native speakers read as demonstrated in the reading patterns may not affect the comprehension accuracy of the subject-gap and object-gap RC sentences, at least for the native speakers.

We will now look at the Japanese subject-gap reading patterns of the English-speaking learners of Japanese. Only three of the fourteen L2 learners showed a reading pattern with peaks in Region 2 and slightly higher or similar reading times in Region 4. The similarity among these three L2 learners is that they demonstrated relatively high L2 Japanese RST scores and high L2 Japanese proficiency test scores.

Participant#	Jpn all sentence comprehension (%)	Jpn subject-gap accuracy (%)	Jpn object-gap accuracy (%)	L2 Jpn prof test	L2 Jpn RST score (Group)	L1 Eng RST score (Group)
E09	80	70	100	95	43 (High)	44 (Low)
E12	80	80	100	100	54 (High)	54 (High)
E14	86.67	50	90	92.5	41 (High)	57 (High)

Table 4.8: Scores of three L2 learners of Japanese

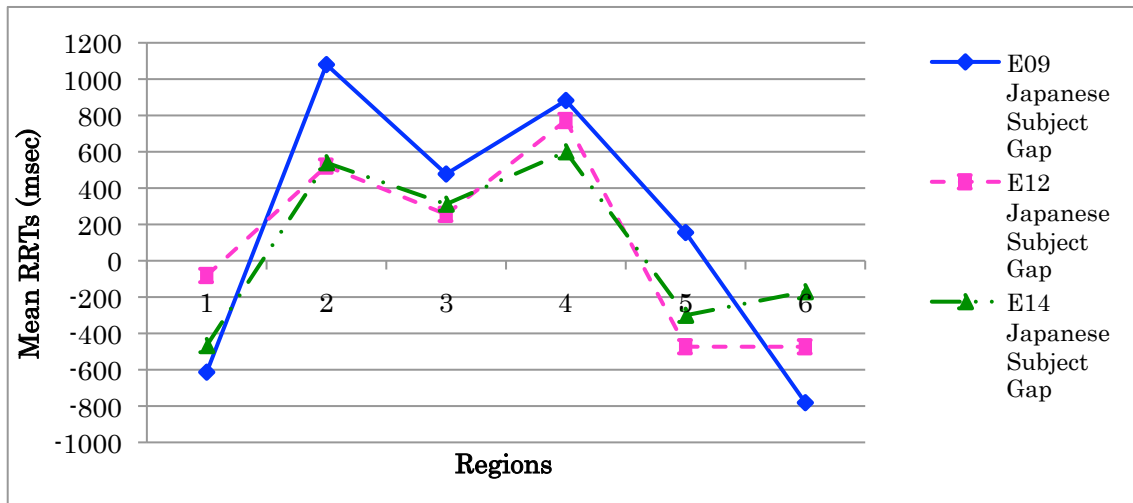


Figure 4.27: Japanese subject-gap by three L2 learners of Japanese

As Figure 4.27 above shows, these three L2 learners' reading patterns are similar to the reading pattern demonstrated by five Japanese native speakers. It can be assumed that these three L2 learners' parsers are processing the sentences incrementally using case marker information as well as appropriately processing a gap-filler dependency in Japanese subject-gap sentences, however, not necessarily achieving accurate sentence comprehension all the time.

Five English-speaking learners of Japanese have shown reading patterns with the highest peak in Region 2 in the Japanese subject-gap sentences, which was also seen among three Japanese native speakers discussed previously (Figure 4.25). The participant data shows that these L2 learners had low L2 Japanese RST scores other than one learner (E02), who showed high L2 RST score. Learner E02 showed low L2 Japanese proficiency test scores and relatively low comprehension for all Japanese sentences including the fillers and the Japanese subject-gap sentences. Since the other four participants have low L2 Japanese RST scores and their Japanese subject-gap comprehension accuracy rates are not high, it can be said that WM capacity affected their reading patterns and comprehension of the Japanese subject-gap sentences.

Participant#	Jpn all sentence comprehension (%)	Jpn subject-gap accuracy (%)	Jpn object-gap accuracy (%)	L2 Jpn prof test	L2 Jpn RST score (Group)	L1 Eng RST score (Group)
E02	83.33	50	50	82.5	47 (High)	64 (High)
E03	91.67	70	80	92.5	36 (Low)	44 (Low)
E05	91.67	70	90	90	38 (Low)	57 (High)
E07	73.33	60	30	95	34 (Low)	44 (Low)
E11	66.67	70	100	87.5	34 (Low)	53 (Low)

Table 4.9: Scores of five L2 learners of Japanese

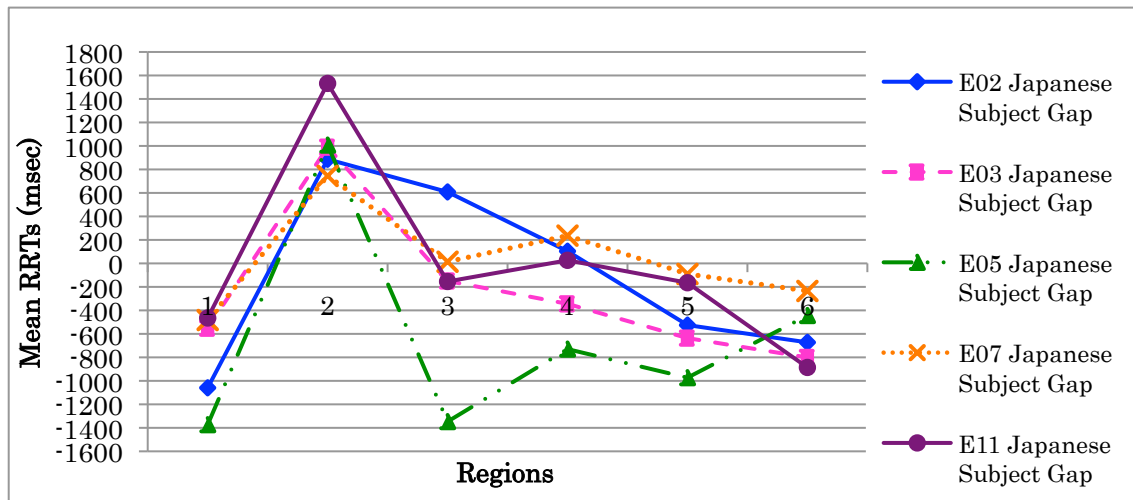


Figure 4.28: Japanese subject-gap by five L2 learners of Japanese

One L2 learner (E06) demonstrated a quite unique and dissimilar reading pattern from the others. The following figure shows that E06's reading pattern has two peaks in Regions 3 and 5. This individual has low scores in L2 Japanese and L1 English RSTs, and relatively low scores in L2 Japanese proficiency test and the Japanese subject-gap comprehension accuracy. However, the comprehension accuracy of all Japanese sentences including the fillers was quite high. What is unique about E06's reading pattern is that this individual showed a slow reading time in Region 5 (matrix verb), which may indicate the use of verb information and a wrap-up effect at the end of the sentences as this individual did with parsing the English gap type sentences.

Participant#	Jpn all sentence comprehension (%)	Jpn subject-gap accuracy (%)	Jpn object-gap accuracy (%)	L2 Jpn prof test	L2 Jpn RST score (Group)	L1 Eng RST score (Group)
E06	91.67	70	100	85	40 (Low)	41 (Low)

Table 4.10: Scores of one L2 learners of Japanese

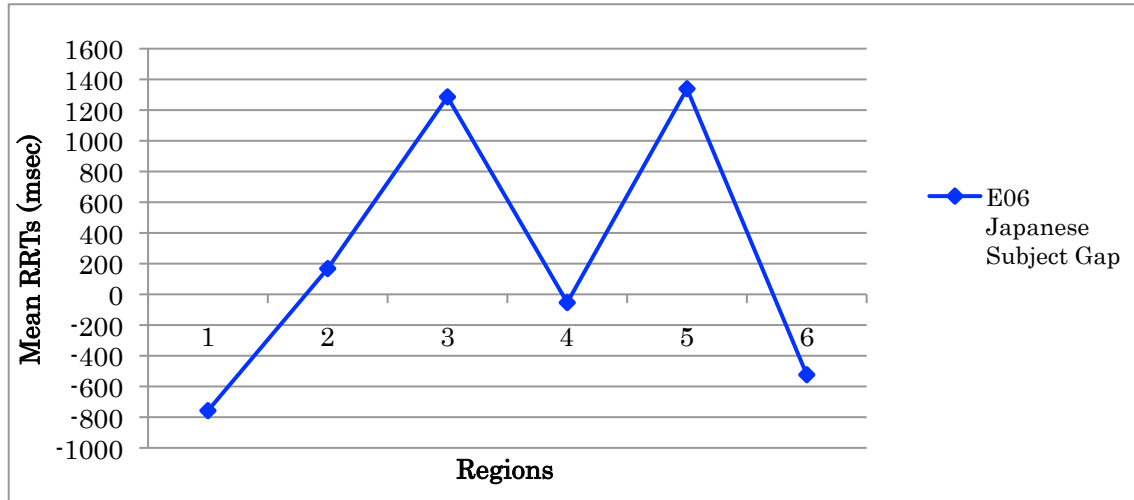


Figure 4.29: Japanese subject-gap by one L2 learner of Japanese

The remaining five English-speaking learners of Japanese also showed quite interesting reading patterns, which could be divided into two types: (A) constant high RRTs from Regions 2, 3 and on, and (B) faster reading times from Region 3 and after.

Group	Participant #	Jpn all sentence comprehension (%)	Jpn subject-gap accuracy (%)	Jpn object-gap accuracy (%)	L2 Jpn prof test	L2 Jpn RST score (Group)	L1 Eng RST score (Group)
A	E01	90	60	90	82.5	42 (High)	56 (High)
	E04	80	60	80	95	34 (Low)	54 (High)
	E08	78.33	50	50	72.5	45 (High)	51 (High)
	E13	93.33	80	100	70	33 (Low)	42 (Low)
B	E10	76.67	40	80	92.5	44 (High)	60 (High)

Table 4.11: Scores of five L2 learners of Japanese

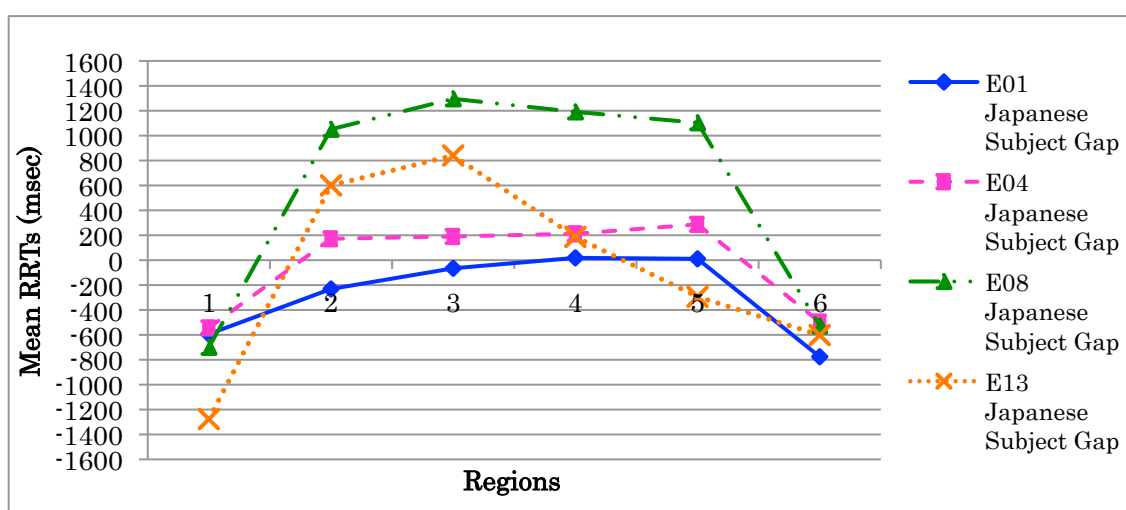


Figure 4.30: Japanese subject-gap by four L2 learners of Japanese (A)

Figure 4.30 shows Type (A) reading pattern of the Japanese subject-gap sentences. The three L2 learners showed relatively steady reading times in consecutive regions, making a plateau. There was one learner who showed a slightly different reading pattern from the others. Learner E13, who has low scores in L1 English and L2 Japanese RSTs demonstrated slower reading times only in Regions 2 and 3, and showed relatively high comprehension in the Japanese subject-gap sentences. On the other hand, the other three learners (E01, E04 and E08) who had high L1 English RST scores, but not necessarily

high in L2 Japanese RST scores or L2 proficiency test scores showed low comprehension in Japanese subject-gap sentences. Unfortunately, the question whether these plateau reading times originated from L2 WM capacity cannot be answered because of the mixed L2 RST span scores of both high and low. However, it can be suggested that with this reading pattern, these L2 learners could not achieve high comprehension accuracy in the Japanese subject-gap sentences like E13. Perhaps, the Japanese subject-gap sentences were too difficult to comprehend for these L2 learners that they could not process the regions appropriately and thus they read these regions constantly slow.

Figure 4.31 below shows the Japanese subject-gap reading pattern of Learner E10, who had high scores in L1 English RST, L2 Japanese RST, and L2 proficiency test, but showed lower comprehension in the Japanese subject-gap sentences. The figure shows fast RRTs in Regions 1 and 2 and even faster reading from Region 3 and on. Although Region 6's deep drop can be ignored because of the period and the reading speed at the period cannot always be a reliable reflection of the processing, Learner E10 reads Japanese subject-gap sentences pretty quickly through Region 4 and then gets even faster in Region 5 (Notice that the vertical major unit is 100 msec).

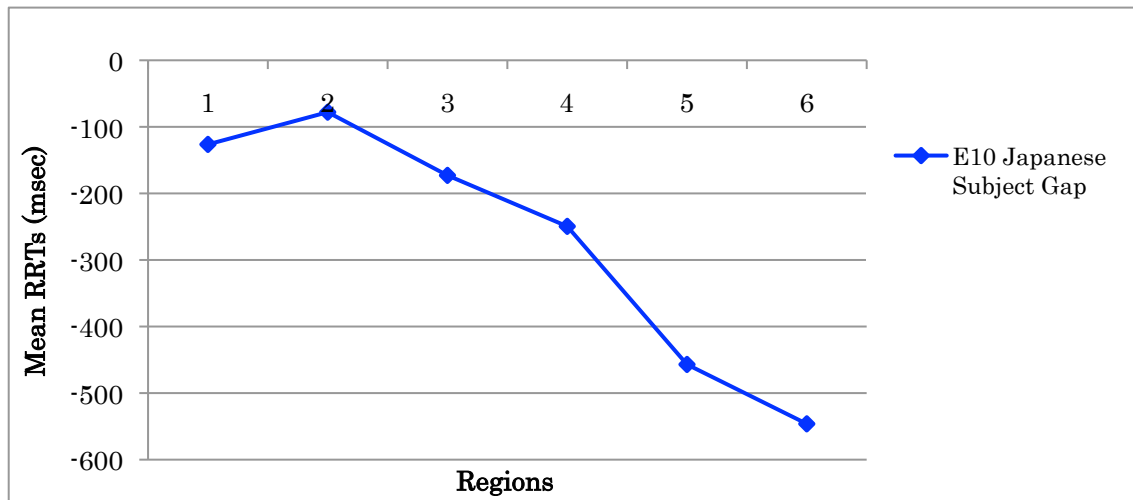


Figure 4.31: Japanese subject-gap by E10 (B)

Because E10 showed low comprehension accuracy in the Japanese subject-gap sentences despite high WM capacity and extremely fast RRTs, it is likely that E10 did not always process the Japanese subject-gap sentences successfully.²⁸ Since this is the only participant who showed such a reading pattern, further discussion is not provided.

4.3.4. Individual Differences in Japanese Object-Gap Reading Patterns

Eleven out of the fourteen Japanese native speakers read the Japanese object-gap sentences with a reading pattern with slower RRT peaks in Regions 2 and 4. Only three native speakers diverted from this reading pattern. A reading pattern with two peaks in Regions 2 and 4 in the Japanese object-gap sentences is a similar pattern, if not exactly the same, to the reading pattern shown by the six native speakers in Japanese subject-gap

²⁸ S. Speer (personal communication, February 25, 2011) mentioned that an individual with high working memory capacity, like Learner E10, may show a task-induced ‘button-press rhythm’ effect in a self-paced reading task.

sentences. Since the only difference between the Japanese subject-gap and object-gap sentences lies in case markers in Region 1, this reading pattern with two peaks in Regions 2 and 4 is within our expectation. The participants with both high and low L1 Japanese RST scores demonstrated this reading pattern. To provide a representative example that demonstrates the reading pattern of the 11 Japanese native speakers, the Japanese object-gap reading patterns by one L1 Japanese RST High and one L1 Japanese RST Low participant is shown in the figure below.

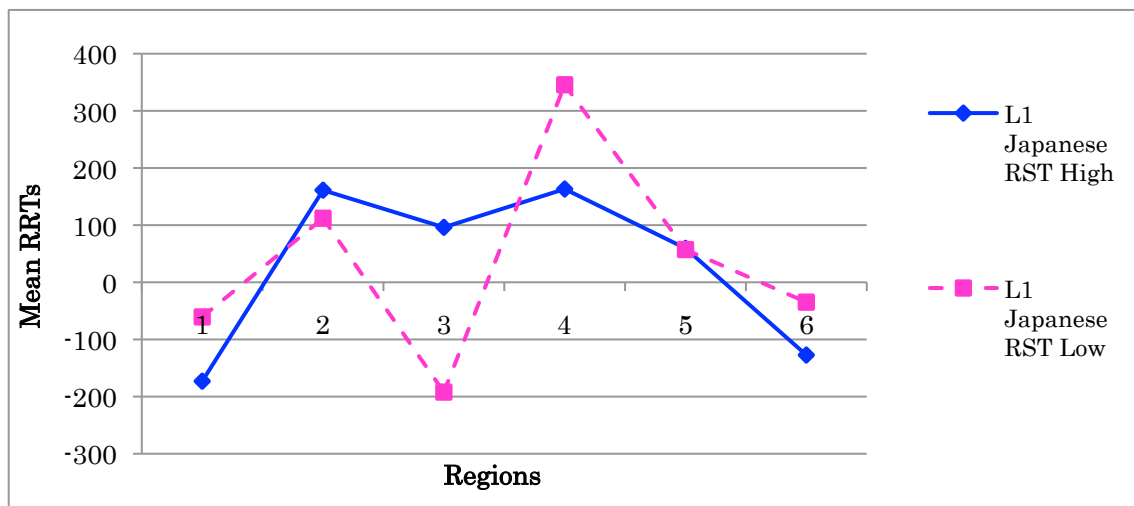


Figure 4.32: Japanese object-gap by one L1 RST High and one L1 RST Low participant

Next, Figure 4.33 shows the reading pattern of the Japanese object-gap sentences by three Japanese native speakers. Two out of three Japanese native speakers showed the slowest peak in Region 4 and one Japanese native speaker showed the slowest peak in Region 5.

Participant#	Jpn all sentence comprehension (%)	Jpn subject-gap accuracy (%)	Jpn object-gap accuracy (%)	L1 Jpn RST score (Group)
J21	88.33	40	90	41 (Low)
J29	90	70	100	32 (Low)
J31	68.33	60	100	49 (High)

Table 4.12: Scores of three Japanese native speakers

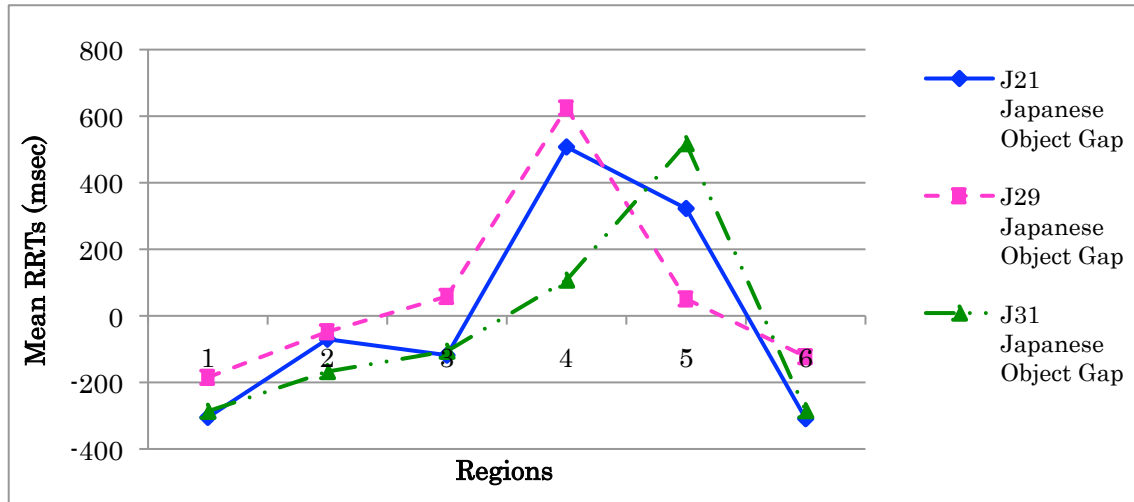


Figure 4.33: Japanese object-gap by three Japanese native speakers

All three participants had high comprehension accuracy in the Japanese object-gap sentences. Their L1 Japanese RST span score shows both low and high span scores as well as both low and high comprehension accuracy in all Japanese sentences. This seems to suggest that their WM capacity may not have been influencing the reading patterns and comprehension accuracy of the Japanese object-gap sentences.

Let us now look at the Japanese object-gap reading patterns by the English-speaking L2 learners of Japanese. There were variations in the reading patterns of the Japanese object-gap sentences demonstrated by the L2 learners. Five L2 learners showed

similar reading patterns to eleven Japanese native speakers' reading pattern with peaks in Regions 2 and 4 (Figure 4.34).

Participant #	Jpn all sentence comprehension (%)	Jpn subject-gap accuracy (%)	Jpn object-gap accuracy (%)	L2 Jpn prof test	L2 Jpn RST score (Group)	L1 Eng RST score (Group)
E02	83.33	70	80	82.5	47 (High)	64 (High)
E04	80	60	80	95	34 (Low)	54 (High)
E11	66.67	50	50	87.5	34 (Low)	53 (Low)
E12	80	20	90	100	54 (High)	54 (High)
E14	86.67	50	90	92.5	41 (High)	57 (High)

Table 4.13: Scores of five L2 learners of Japanese

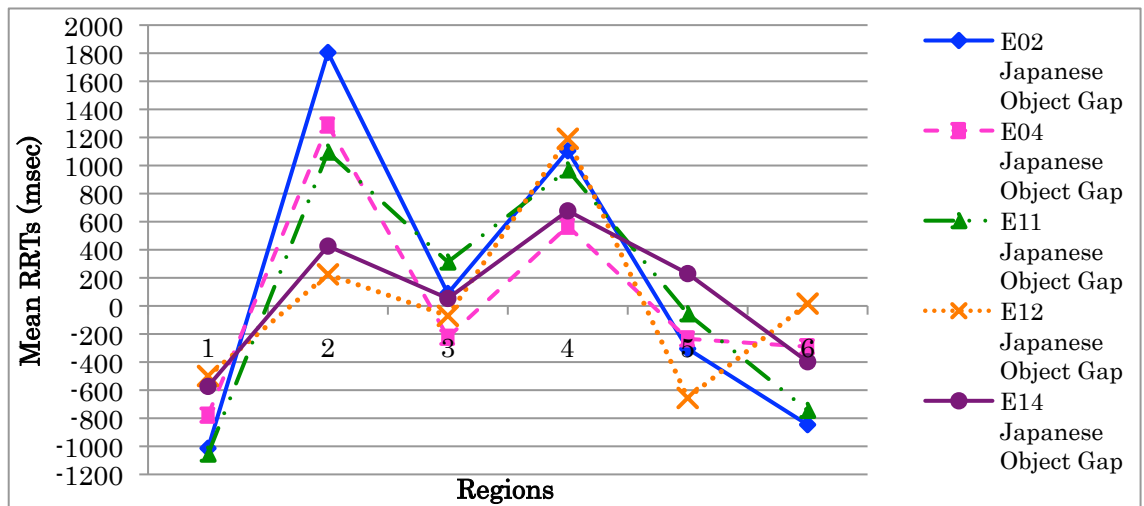


Figure 4.34: Japanese object-gap by five L2 learners of Japanese

These five L2 learners all had relatively high L1 English RST scores, but not necessarily high in L2 Japanese RST scores.²⁹ Both Learners E04 and E11 have low L2 Japanese RST scores; however, their L2 Japanese proficiency test scores show and all Japanese sentence comprehension including the fillers show that Learner E04 scored higher than Learner E11. Also, the other three L2 learners showed that they have high L2 Japanese RST scores and L2 Japanese proficiency test scores as well as relatively high comprehension accuracy in all Japanese sentences and the Japanese object-gap sentences. It seems that this reading pattern with peaks in Regions 2 and 4 was exhibited by the L2 learners with high L2 WM capacity and L2 proficiency level. It also seems that this way of processing the Japanese object-gap sentences has helped to achieve an accurate comprehension.

Next, we will look at the Japanese object-gap reading pattern with one peak in Region 2. This reading pattern was not exhibited by any of the Japanese native speakers. Two L2 learners have shown this reading pattern (Figure 4.35).

Participant #	Jpn all sentence comprehension (%)	Jpn subject-gap accuracy (%)	Jpn object-gap accuracy (%)	L2 Jpn prof test	L2 Jpn RST score (Group)	L1 Eng RST score (Group)
E07	73.33	60	30	95	34 (Low)	44 (Low)
E08	78.33	50	50	72.5	45 (High)	51 (Low)

Table 4.14: Scores of two L2 learners of Japanese

²⁹ Learner E11 is categorized in the low span L1 English RST group, but the median cut-off score to divide the participants into two L1 English RST groups was 53.5. Thus, it can be said that this learner is on the borderline between the L1 English RST High and Low groups. Again, High and Low groups are only based on this participant group and not absolute.

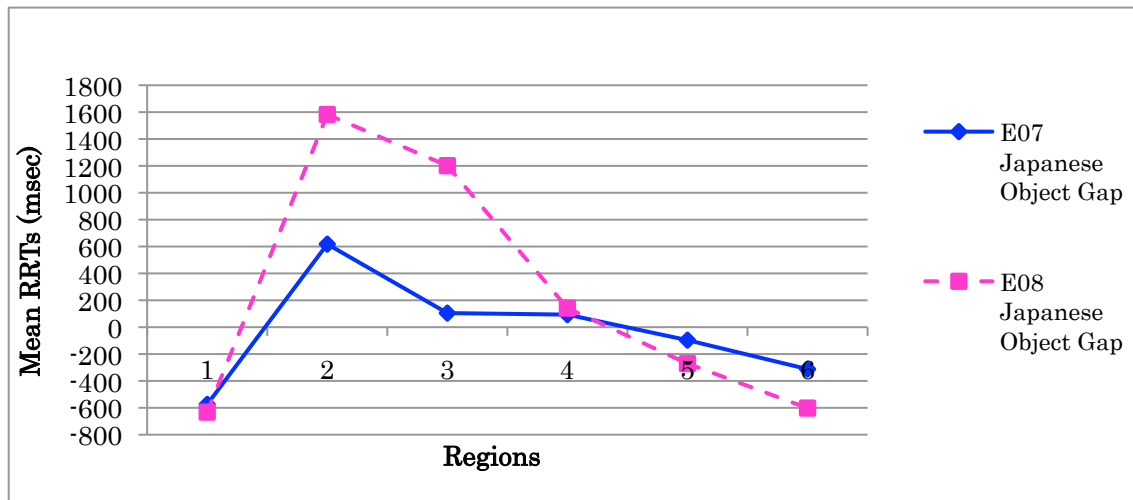


Figure 4.35: Japanese object-gap by two L2 learners of Japanese

As we discussed earlier, the Japanese object-gap sentences were easier to comprehend than the Japanese subject-gap sentences. However, both of these L2 learners showed the same or better comprehension in the Japanese subject-gap sentences. The similarities between these two participants are the fact that they had a low L1 English RST score and low comprehension accuracy for all Japanese sentences including the fillers. The fact that they showed a rise in their reading pattern in Region 2 indicates that they processed the RC regions of the sentence, integrating the first two regions (NP-*ga* and verb) together and possibly anticipating a relative head noun and upcoming elements. However, because their Japanese object-gap comprehension was quite low, it is questionable whether these two L2 learners had processed the rest of the sentences appropriately.

Next, we will discuss the Japanese object-gap reading patterns with two or more consecutive regions of relatively same slow reading times. This reading pattern can be further divided into two types: (A) relatively slow reading times only in two regions and

(B) unique reading patterns with slow reading times in more than three regions, but not necessarily in consecutive regions.

Group	Participant #	Jpn all sentence comprehension (%)	Jpn subject-gap accuracy (%)	Jpn object-gap accuracy (%)	L2 Jpn prof test	L2 Jpn RST score (Group)	L1 Eng RST score (Group)
A	E01	90	60	90	82.5	42 (High)	56 (High)
	E03	91.67	70	100	92.5	36 (Low)	44 (Low)
	E05	91.67	70	100	90	38 (Low)	57 (High)
	E13	93.33	80	100	70	33 (Low)	42 (Low)
B	E06	91.67	70	100	85	40 (Low)	41 (Low)
	E09	80	50	90	95	43 (Low)	44 (Low)
	E10	76.67	40	80	92.5	44 (High)	60 (High)

Table 4.15: Scores of seven L2 learners of Japanese

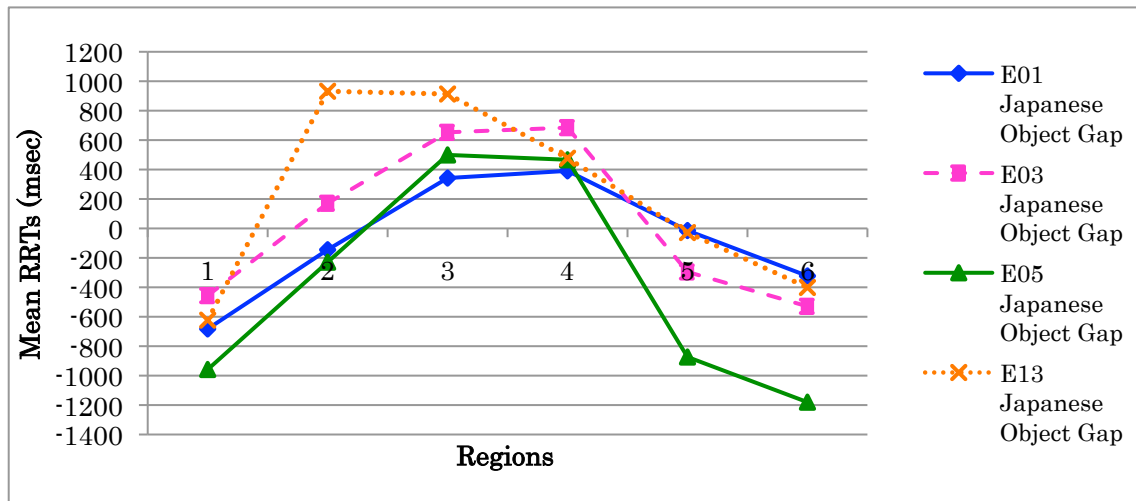


Figure 4.36: Japanese object-gap by four L2 learners of Japanese (A)

Figure 4.36 shows Type (A) reading pattern by four L2 learners. Especially, Learner E13 showed exactly the same slow reading times in Regions 2 and 3 as the Japanese subject-

gap sentences (cf. Figure 4.30), making a plateau. This means this individual processed the two types of Japanese gap sentences similarly. Learner E13's higher comprehension accuracy in the Japanese object-gap sentences than the Japanese subject-gap sentences indicates that with an easier sentence structure, the reading pattern of a sentence may not have much of an effect on comprehension. Learners E01, E03 and E05 all showed a similar reading pattern with slower RRTs in Regions 3 and 4. These three L2 learners have both high and low L1 English RST and L2 Japanese RST scores as well as relatively high comprehension in all Japanese sentences and L2 Japanese proficiency test scores. Considering the participant data of all four L2 learners who demonstrated Type (A) reading pattern, it can be said that WM capacity may have an effect on their reading patterns and the comprehension of their Japanese object-gap sentences.

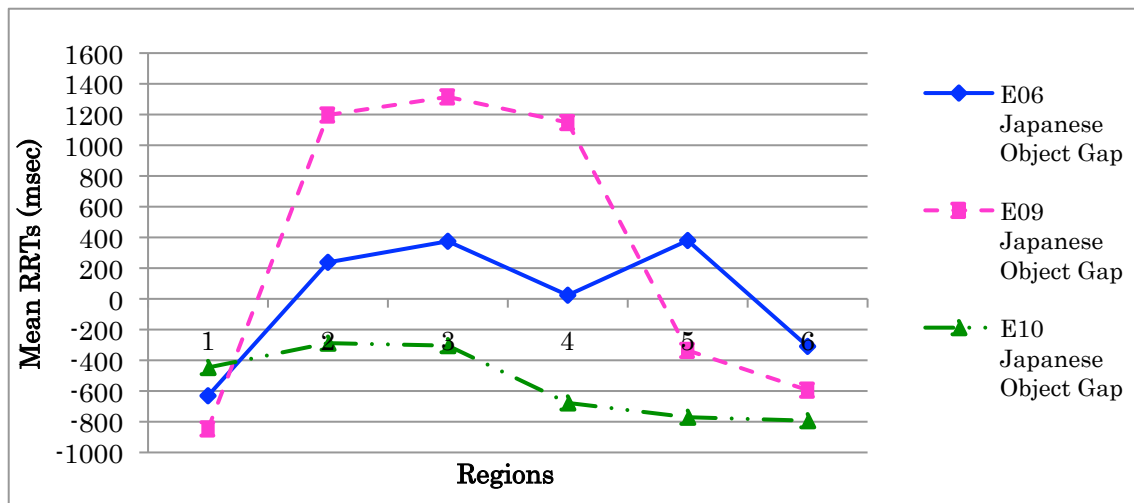


Figure 4.37: Japanese object-gap by three L2 learners of Japanese (B)

Three L2 learners demonstrated a reading pattern Type (B). Their reading patterns were all uniquely different (Figure 4.37). For example, Learner E06 shows slow reading times in Regions 2 and 3 followed by a faster reading time in Region 4 and then a slow reading time in Region 5. The reading pattern seems as if there were two peaks in Regions 3 and 5 and the reading pattern of Learner E06 seems to be showing a wrap up effect in Region 5. Learner E09 has slow RRTs from Regions 2 to 4 followed by a sudden drop in Region 5 and the reading pattern of Learner E09 seems to be showing a ceiling effect by having slow reading times in Regions 2, 3, and 4. One thing to note is these two L2 learners' comprehension accuracy of the Japanese object-gap sentences. Their Japanese object-gap sentence comprehension was better than their Japanese subject-gap sentence comprehension. Their performances indicate that low WM capacity in both L1 and L2 may not hinder achieving correct comprehension, particularly the Japanese object-gap sentences that were easier to comprehend.

Learner E10 was another L2 learner who exhibited a unique reading pattern in the Japanese object-gap sentences (Figure 4.37). This participant showed a similar reading pattern in the Japanese subject-gap sentences as in the Japanese object-gap sentences (cf. Figure 4.31 in the previous section). That is, the reading times got faster after Region 4 and on. This reading pattern of fast RRTs is particular to this individual. The difference between the two reading patterns of the two Japanese gap type sentences within this individual is that in the Japanese object-gap sentences, the RRT gets faster from Region 4 whereas in the Japanese subject-gap sentences, the RRT gets faster from Region 3. Thus, it can be speculated that the difference in the processing of two Japanese gap type sentences occurred at Region 3 where the parser encountered a RC head noun. Also, the

comprehension accuracy of Japanese object-gap sentences suggest that even when the sentences were read quickly, this individual was able to achieve reasonably high comprehension accuracy in Japanese. This was not the case with the comprehension accuracy of Japanese subject-gap sentences. The performances of Learner E10 in the two Japanese gap type sentences suggest that the fast speed in reading did not hinder achieving correct comprehension as much in the Japanese object-gap sentences as it did in the Japanese subject-gap sentences.

4.4. Discussion

In this chapter, we uncovered L1 native speakers' and L2 learners' sentence processing by comparing the two language groups directly. We also looked at individual reading patterns of English and Japanese gap sentences to find out whether L2 learners' reading patterns were consistent or not consistent with those of the native speakers. Five questions were addressed in this chapter and we will discuss the results of each question one at a time.

(3) Do the performances of the L1 native speakers and L2 learners differ in subject-gap/object-gap sentence comprehension accuracy rates in English and in Japanese?

As for question (3), the answer depended on the language. In English, the comprehension accuracy rates of the English native and L2 learner groups were different due to L2 Japanese RST Low group's performance. On the other hand, in Japanese, there was no difference between the Japanese native and L2 learner groups in the comprehension accuracy rates of the Japanese gap sentences. Provided that the native

speakers did their best in their L1 processing task, there are two possible reasons to account for these mixed results. The one is that the English-speaking L2 learners of Japanese in this study had high L2 Japanese proficiency level and the test sentences were too easy. The second is that the Japanese-speaking L2 learners of English in this study had poor L2 English proficiency level. These accounts are supported by the accuracy rates for overall sentence comprehension including the fillers. Consider the table below for the mean comprehension accuracy rates for English and Japanese sentences including the fillers.

	English sentence comprehension accuracy rates (SD)	Japanese sentence comprehension accuracy rates (SD)
English native speakers	91.19 (5.97)	83.10 (8.05)
Japanese native speakers	76.07 (8.51)	82.74 (7.26)

Table 4.16: Mean comprehension accuracy rates of English and Japanese sentences

The table above shows that the mean Japanese sentence comprehension accuracy rate by the English native speakers is slightly better than the Japanese native speakers'. On the other hand, Japanese native speakers performed poorly in English sentence comprehension. The academic backgrounds of the English and Japanese native speakers were similar. They were either enrolled in undergraduate/graduate schools in universities in the U.S. or Japan at the time of data collection, or were graduates of a university. Therefore, it can be assumed that at least their L1 reading comprehension skill should be at the level of a well-educated native speaker. Their respective L2 proficiency test scores suggest that English native speakers and Japanese natives speakers are comparable (L2

Japanese proficiency test: average=88.95%; L2 English proficiency test: average=83.61%). Combining these facts, it seems that the participants' L2 proficiency level may have affected the comprehension accuracy rates of gap type sentences, which lead to the current mixed results.

(4) Do the performances of the L1 native speakers and L2 learners differ in subject-gap/object-gap sentence processing in English and in Japanese?

The question (4) could be answered as yes, but only supported with the findings from the analyses of the 10 participants' data per language group. In the English subject-gap sentences, L1 English RST High and L1 English RST Low groups showed slow reading times at the end of the sentences whereas L2 English RST High and Low groups did not. This difference in RRTs produced a statistical significance between the English native groups and the L2 learner groups. In the English object-gap sentences, the difference was found among the L1 English RST groups and the L2 English RST groups in Region 5 (matrix verb) where both the L1 English RST groups showed fast reading times whereas both the L2 English RST groups showed slow reading times. In the Japanese subject-gap sentences, the difference was found among the L1 Japanese RST High group vs. the L1 Japanese RST Low, L2 Japanese RST High, and L2 Japanese RST Low groups because of the fast RRTs in Region 3 (relative head noun) by the L1 Japanese RST High group. In the Japanese object-gap sentences, no significance was found among the four RST groups.

In sum, the RRT analyses of the English gap sentences indicate that there is a difference between the native speaker groups and the L2 learner groups. On the other

hand, the RRT analyses of the Japanese gap sentences indicate that there is a difference even between the L1 Japanese RST High and the Low groups. The difference was also found between the L1 Japanese RST High group and the two L2 RST groups. What these results show is that the native speakers and the L2 learners can be different or similar in sentence processing. Moreover, these results and the sentence reading patterns of the native speaker and the L2 learner groups illustrated which part(s) of the sentence need more time to process and how one's WM capacity affects the sentence processing.

(5) Is the tendency in individual sentence reading patterns of the L2 learners similar to that of L1 native speakers?

The question (5) can be answered as both “similar” and “dissimilar”. What we have seen in the current study is that there seems to be a commonly-preferred way of processing English and Japanese gap sentences among the native speakers. For example, the L1 English native speakers showed a similar reading pattern in the English subject-gap sentences. Among the 14 L1 English native speakers, 13 participants showed peaks in Regions 4 and 6 (i.e. slower RRTs). Since all participants except one showed this tendency in their reading patterns of the English subject-gap sentences, it can be said that this reading pattern with slower reading times in Regions 4 and 6 is the most commonly-preferred way demonstrated by many of the English native speakers in this study. Furthermore, it is quite likely, the most efficient and effective way of parsing the English subject-gap sentences for the English native speakers.

It is also possible to have a derived reading pattern from the commonly-preferred one. A good example can be found in the Japanese subject-gap sentences, which were

more difficult for the native speakers to comprehend than the Japanese object-gap sentences. Only five Japanese native speakers exhibited peaks in Regions 2 and 4. Five native speakers demonstrated a peak in either Region 2 or Region 4 and one participant with extremely low Japanese gap comprehension accuracy rate showed a completely diverged reading pattern from the aforementioned two reading patterns in the Japanese subject-gap sentences. The different reading patterns with peak(s) in either Region 2 or Region 4 can be explained. In Japanese, one can use case marker information to build and predict the upcoming elements in a sentence structure. The verb information that is crucial for determining the structure would not be available until the end of a clause or a sentence. Having peaks in Region 2 and/or Region 4 means that one was processing verb information (Region 2) and/or used case marker information to integrate elements into an appropriate sentence structure (Region 4) and made a prediction of an upcoming final matrix verb. The RRT rise in Region 2 (RC verb) can be from the clausal wrap-up effect and the parser making a prediction as well as building a possible sentence structure since the task, the moving-window paradigm, allows one to see the sentence-length dashes on a computer screen so the participants would know that the verb in Region 2 is not the end of the sentence. Not having a slower reading time in Region 5 (matrix final verb) shows that the sentence structure had been already built and by the time the parser reached the final verb region, the only step the parser needs to take is to process the final verb and attach it to the structure. Therefore, many factors such as case markers, canonical word order, and verb information are helping one to parse L1 Japanese sentences incrementally, and the commonly-preferred reading pattern with some derivations by the Japanese

native speakers seems to reflect the effective and efficient use of information in their WM to appropriately comprehend the sentences.

The results of this study have also shown that even among the native speakers, there was not only the “one” commonly-preferred reading pattern. Nevertheless, most of the time, a variance in the native speakers’ reading patterns can be explained easily. This does not hold for L2 learners’ reading patterns. For example, the English-speaking L2 learners of Japanese showed variations of reading patterns in both the Japanese subject-gap and object-gap sentences. Although some L2 learners had shown similar reading patterns to those of the Japanese native speakers, some unique reading patterns were also seen. These unique reading patterns were only exhibited by the L2 learners and not by the Japanese native speakers. This finding provides the evidence for the conclusion that their utilization of WM may be different from that of native speakers.

(6) Is the tendency in the individual sentence reading patterns of L1 native speakers and L2 learners influenced by their WM capacity?

(7) Do the individual sentence reading patterns of L1 native speakers and L2 learners affect comprehension accuracy?

The questions (6) and (7) are related to each other so we will discuss them together. The answers for the two questions are “yes”. The results of the current study suggest that if one has lower WM capacity in L2, then that individual is likely to have a reading pattern that is not commonly preferred by the native speakers in L2 sentence processing. Furthermore, regardless of the WM capacity, not having the commonly-preferred reading pattern seems to affect the comprehension of L2 sentences in a negative

manner. This seems to be more so in the comprehension of more difficult to comprehend L2 sentences (i.e. English object-gap and Japanese subject-gap sentences). This is understandable if we assume the most efficient and effective way of using (any) one's WM is represented by the commonly-preferred reading pattern demonstrated by many of the native speakers. Therefore, not being able to process in the efficient and effective native-like manner would add a much greater load on L2 learner's WM in addition to dealing with other factors accompanied with reading L2 sentences.

In summary, it can be concluded that in L1, whether one has high or low WM capacity did not seem to affect the reading patterns exhibited by the native speakers. Moreover, whether or not one processes a L1 sentence in a commonly-preferred way did not seem to affect the comprehension accuracy of the gap type sentences by the native speakers.³⁰ On the other hand, in L2, having a higher WM capacity seems to help to process a sentence in the "native-like" way. By being able to process L2 sentences in the native-like way, one seems to achieve higher comprehension accuracy in the gap type sentences, especially in the English object-gap and Japanese subject-gap sentences that were more difficult to comprehend.

³⁰ This conclusion may not apply beyond this study because the test sentences in this study may have been too easy to challenge the native speakers' working memory. Thus, the true difference in L1 WM capacity size and reading patterns may not have explicitly appeared in the current study for the native speakers. Additionally, a commonly-preferred reading pattern may not apply to the participants outside of this study because this reading pattern was observed as a tendency among the 14 English native speakers and the 14 Japanese native speakers who participated in the study. Further investigation is necessary to determine whether the reading patterns observed in this study is actually commonly preferred by the general population of English and Japanese native speakers.

CHAPTER 5

GENERAL DISCUSSION

This study investigated L1 and L2 relative clause (RC) sentence processing with a particular focus on the potential effect of WM capacity. The experiments with self-paced sentence reading tasks as well as L1 and L2 Reading Span Tests (RSTs) in English and Japanese were conducted on English native speakers who were also L2 learners of Japanese, and Japanese native speakers who were also L2 learners of English. In this chapter, the major findings from the previous chapters are summarized. Then, the role of WM in sentence processing, especially in L2 sentence processing, will be discussed. Finally, the limitation of this study and implication for future research will be addressed with the concluding remarks of this dissertation.

5.1. Summary of Major Findings from Chapters 3 and 4

In this section, we will discuss the findings from the English and Japanese self-paced reading experiments (Chapter 3) and the comparisons of L1 native speakers and L2 learners' performances as well as examinations of individual reading patterns of English and Japanese gap sentences (Chapter 4) based on the research questions addressed in Chapter 1 of this study.

(1a) Is there a difference the comprehension accuracy rates of subject-gap and object-gap sentences in English and in Japanese respectively?

(1b) Is there a difference in the comprehension accuracy rates of subject-gap and object-gap sentences by different WM capacity groups in English and in Japanese respectively?

As for questions (1a) and (1b) in L1 English, the results from the self-paced moving window reading experiments confirmed the previous findings that English object-gap sentences were more difficult to comprehend than English subject-gap sentences. Further analysis revealed that the comprehension accuracy rates of English subject-gap and object-gap sentences were not different within the same L1 English RST group. However, it was shown that the comprehension accuracy rates were different between the L1 English RST High and Low groups only in the English subject-gap sentences.

In L2 English, the Japanese-speaking learners of English also showed that the English object-gap sentences were more difficult to comprehend than the English subject-gap sentences. Further analyses showed that the comprehension accuracy rates of the English subject-gap and object-gap sentences were different within the L2 English RST High group, but not within the L2 English RST Low group. Additionally, it was shown that the comprehension accuracy rates between the L2 English RST High and Low groups were different in the English subject-gap sentences, and in the English object-gap sentences.

In L1 Japanese, the results from the sentence reading experiments showed that the Japanese subject-gap sentences were more difficult to comprehend than the object-gap sentences. From this result, it was argued that a linear distance between the gap and the

filler (Gibson's Dependency Locality Theory (DLT)) rather than the depth of the gap (O'Grady's Structural Distance Hypothesis (SDH)) is at work when processing the Japanese gap type sentences. When L1 Japanese RST span sizes were taken into account, both the L1 Japanese RST High and Low groups showed differences in the comprehension accuracy rates between the Japanese subject-gap and object-gap sentences. However, no differences were found between the L1 Japanese RST High and Low groups in the Japanese subject-gap sentences and in the object-gap sentences.

In L2 Japanese, the English-speaking learners of Japanese showed the same results as the Japanese native speakers in sentence comprehension. They showed lower comprehension accuracy in the Japanese subject-gap sentences than the object-gap sentences. Furthermore, the L2 Japanese RST High and Low groups showed the same results as Japanese native speakers. That is, differences were found between the Japanese subject-gap and object-gap sentences within each L2 Japanese RST group, but no difference was found between the L2 Japanese RST High and Low groups in the Japanese subject-gap and in the object-gap sentences.

(2a) Is there a difference between reading times of subject-gap and object-gap sentences per region in English and in Japanese respectively?

(2b) Is there a difference between reading times of subject-gap and object-gap sentences per region by different WM capacity groups in English and in Japanese respectively?

As for questions (2a) and (2b) in L1 English, the regional analyses of Residual Reading Time (RRT) data showed a significant difference in the embedded verb regions of the English subject-gap and object-gap sentences. Further analysis showed that this

difference was only seen in the L1 English RST High group and not in the Low group. Another analysis comparing the regions from the two English gap type sentences by the L1 English High RST group showed a difference in the embedded verb region (Region 3) of English subject-gap sentences and the RC subject position region (Region 3) of the English object-gap sentences. The same result was obtained in the L1 English RST Low group. This result did not follow Gibson's integration cost part of the DLT, but coincided with his expectation-based hypothesis. From these results, it was suggested that the L1 parser is keen to the expectation of new syntactic heads in English.

In L2 English, the RRT regional analyses of the Japanese-speaking learners of English also revealed a difference between the embedded verb regions of the two gap sentence types. Further analysis showed that only the L2 English RST High group was able to show this difference. Comparing each region of the English gap sentences, neither the L2 English RST High group nor the Low group showed any differences among the regions. Unlike the English native speakers, the results of L2 English learners follow the predictions of neither the DLT's integration cost part nor the expectation-based hypothesis. This means that the L2 English learners' parser may not be as keen as the L1 English native speakers' in expecting and predicting upcoming syntactic structures. This finding, in addition to the unique reading patterns of the L2 learners especially in the English object-gap sentences, which are more difficult to comprehend, points to a different utilization of resources to comprehend the English gap type sentences by the L2 English learners.

In L1 Japanese, the RRT regional analyses of the Japanese native speakers showed a difference between the Japanese subject-gap and object-gap sentences in the

RC verb region (Region 2). This seems to coincide with the integration cost part of Gibson's DLT. Moreover, the L1 Japanese RST High and Low groups showed a difference in the object region of the matrix sentence (Region 4) in the Japanese subject-gap sentences. Also, the L1 Japanese RST Low group showed differences between the Japanese subject-gap and object-gap sentences in the RC verb region (Region 2), relative head noun region (Region 3), as well as in the object region of the matrix sentence (Region 4). The L1 Japanese RST High group did not show such differences. From these results, it was suggested that in general, Japanese native speakers follow the integration cost of Gibson's DLT, but it was also indicated that one's WM capacity might affect the reading times of Japanese gap type sentences.

In L2 Japanese, the regional RRT analyses of the English-speaking learners of Japanese showed a difference in the object region of the matrix sentence between the Japanese subject-gap and object-gap sentences. Further analyses revealed that only the L2 Japanese RST Low group showed the difference in this region. No difference was found between the L2 Japanese RST High and Low groups in the other regions of the Japanese subject-gap and object-gap sentences. From this, it was suggested that the L2 Japanese learners' processing seems to coincide with the predictions of neither the DLT's integration cost nor expectation-based theory. Again, this finding also points to the different utilization of WM between the L2 learners and Japanese native speakers in reading Japanese gap type sentences.

(3a) Do the performances of the L1 native speakers and L2 learners differ in subject-gap/object-gap sentence comprehension accuracy rates in English and in Japanese?

As for question (3a) in English, the comparisons between the L1 English native speakers and the Japanese-speaking L2 learners' English gap sentence comprehension accuracy rates showed that their comprehension accuracy rates are different. Further analysis revealed that this difference came from Japanese-speaking L2 learners of English RST Low group's low comprehension accuracy rates in the English subject-gap sentences, and the object-gap sentences.

In Japanese, the comparisons between the L1 Japanese native speakers' and English-speaking L2 learners' Japanese gap sentence comprehension accuracy rates, on the other hand, showed no difference among them. This finding was unanticipated because one would normally expect to see a better performance by L1 native speakers than L2 learners. Therefore, an additional analysis was conducted with 10 participants each in each language group (5 participants per RST group). Comparing the L1 Japanese RST High, L1 Japanese RST Low, L2 Japanese RST High, and L2 Japanese RST Low groups, a difference was found among the L2 Japanese RST Low group and each of the other three groups in the Japanese object-gap sentence comprehension accuracy rates. This result was obtained by eliminating four participants around the median of the 14 participants, which made each group more distinct such that the statistically significant difference was found. However, this difference was only found in the comprehension accuracy rates of the Japanese object-gap sentences. This result may indicate that the effect of WM capacity can be more explicitly demonstrated in the sentences that are easier to comprehend than the sentences that are more difficult to comprehend.

(3b) Do the performances of the L1 native speakers and L2 learners differ in subject-gap/object-gap sentence processing in English and in Japanese?

As for question (3b) in English, the RRT regional comparisons of L1 English native speakers and Japanese-speaking L2 learners of English showed meaningful significances only when the number of participants was cut down to 10. The differences were found in different regions of the English subject-gap and object-gap sentences, and those differences were obtained among the L1 English RST High, and the L1 English RST Low groups vs. the L2 English RST High, and the L2 English RST Low groups.

In Japanese, the RRT regional comparisons of the L1 Japanese native speakers and English-speaking L2 learners of Japanese also showed meaningful significances only when the number of participants was cut down to 10. Those differences were obtained only in the Japanese subject-gap sentences among the L1 Japanese RST High group vs. the L1 Japanese RST Low, L2 Japanese RST High, and L2 Japanese RST Low groups. From these results, it was suggested that the parsing by the native speakers and by the L2 learners is not always dissimilar, but not always similar, either.

(4a) Is the tendency in individual sentence reading patterns of the L2 learners similar to that of L1 native speakers?

(4b) Is the tendency in the individual sentence reading patterns of L1 native speakers and L2 learners influenced by their WM capacity?

(4c) Do the individual sentence reading patterns of L1 native speakers and L2 learners affect comprehension accuracy?

As for questions (4a), (4b) and (4c), the current study provided a tendency of a commonly-preferred reading pattern demonstrated by many of the L1 native speakers

regardless of their WM capacity size. However, some varieties were seen in the reading patterns of the L1 native speakers and this seemed to be more abundant in the sentence structures that are more difficult to comprehend. Moreover, there was a larger variety of reading patterns in Japanese, probably due to the SOV word order in Japanese language.

The L2 learners in this study showed both similar reading patterns as the L1 native speakers as well as independent, unique reading patterns dissimilar to those of the native speakers. Additionally, the findings showed the tendency that a lower WM capacity in L2 affects L2 processing. More explicitly, an individual is likely to show a reading pattern that is not commonly preferred by the native speakers, if one has a lower WM capacity. It also seems that this “non-preferred” reading pattern especially affects the comprehension of the L2 sentences that are more difficult to comprehend.

In sum, the above findings indicated, generally speaking, if one has a higher WM capacity, then one would generally do better in comprehension in L2. The findings also indicated that the native speakers by and large utilize appropriate and important information that is available in the process to predict an upcoming element of the sentences whereas the L2 learners do not always do so. Particularly, the unique reading patterns demonstrated by the L2 learners indicated that the inefficient and ineffective utilization of WM may hinder successful comprehension of the L2 sentences.

5.2. Effect of Working Memory in L2 Sentence Processing

The L2 learners of this study showed a native-like discrepancy in comprehension between the two gap sentence types. That is, what was more difficult to comprehend for the native speakers was more difficult for the L2 learners as well. Additionally, the

current study showed the effect of WM capacity on L2 sentence comprehension by the L2 learners. For example, in English, a difference was found among the L2 English RST Low group and the L1 English RST High, L1 English RST Low, and L2 English RST High groups in the comprehension accuracy rates of the English subject-gap sentences and a difference was found among the two groups – L2 English RST Low and L1 English RST High groups – in the comprehension accuracy rates of the English object-gap sentences. In Japanese, a difference was found only in the comprehension accuracy rates of the Japanese object-gap sentences among the L2 Japanese RST Low group and the L1 Japanese RST High, L1 Japanese RST Low and L2 Japanese RST High groups. These results showed that the L2 RST Low groups in English and Japanese were different from the other three groups. This implies that the L2 English and Japanese RST High groups' performance may be, if not the same, quite similar to the native speaker groups' performance.

Having stated the above, there were exceptions. One exception is the English object-gap sentences, in which only the L2 English RST Low and L1 English RST High groups were significantly different. No difference was found between any other groups. The reason for this outcome could be due to the English object-gap sentences being inherently difficult for everyone. More strictly, with the limitation of WM capacity, the L1 English RST Low group might not have been able to comprehend English object-gap sentences as successfully as the L1 English RST High group. Likewise, the L2 English RST High group with their detriment of being non-native speakers might have been hindered from comprehending the English object-gap sentences as successfully as the L1 English RST High group. The L2 English RST Low group's English proficiency is lower

than the other three RST groups as the post-hoc Tukey's HSD test of overall English sentence comprehension accuracy rates shows ($F(3,16) = 12.489, p < .000$). Consequently, only the L2 English RST Low and L1 English RST High groups were found to be significantly different in the comprehension of the English object-gap sentences. The other exception is Japanese subject-gap sentences, in which no difference was found among any of the L1 and L2 RST groups. This result can be explained as the following. Either the English-speaking learners of Japanese in this study had higher L2 Japanese proficiency or the Japanese native speakers had lower Japanese comprehension ability. In detail, even after removing four participants from each language group to make the RST groups more distinct, no difference was found in the overall Japanese sentence comprehension accuracy rates among the L1 Japanese RST High, L1 Japanese RST Low, L2 Japanese RST High, and L2 Japanese RST Low groups ($F(3,16) = 1.601, p < .228$). This indicates that the overall comprehension performances of Japanese native speakers and English-speaking learners of Japanese were not distinguishable. For the Japanese native speakers and English-speaking learners of Japanese, the Japanese subject-gap sentences seem to have been equally or similarly difficult to comprehend.

Finding such a native-like performance in the comprehension of different structures in L2 performance is not unusual. In fact, some previous studies show that L2 learners' performance may be equivalent to that of L1 speakers (Chipere, 2003; Dabrowka, 1997; Dussias and Piner, 2008). For example, Chipere (2003) examined complex NP comprehension of English native speakers who were highly educated graduate students, English native speakers who were low-educated with only a high school degree, and highly educated L2 English graduate students. Chipere found that

highly educated L1 and highly educated L2 speakers behaved similarly while low-educated English native speakers had an error rate close to 90% in comprehension accuracy. Dussias and Piner (2008) examined the processing of long-distance *wh*-questions by English native speakers and Chinese-speaking learners of English. In their study, they examined the long-distance *wh*-questions with plausible and implausible information like *Who_i did the police declare t_i killed the pedestrian?* (subject extraction-implausible) and *Who_i did the police know t_i killed the pedestrian?* (subject extraction-plausible). They also measured the participants' WM capacity using RST. The results showed that plausibility did not prevent initial misparses, but implausible information facilitated the speed of recovery from misanalysis. The interesting finding from this study was that only L2 learners with the higher span size resembled the English native speakers in using the plausibility information in such a way. These findings from the previous studies and the current study indicate that L2 learners may show a native-like performance in L2 processing.

Obtaining a difference in L2 sentence comprehension between different L2 WM capacity groups is not common. For example, Omaki (2005) examined the relationship between the WM capacity of Japanese-speaking learners of English and their RC attachment preference. In his study, no effect of WM capacity size was found in Japanese-speaking L2 English learners' sentence comprehension accuracy rates. Equally, Ren (2009) examined the relationship between the WM capacity of Chinese-speaking learners of English and the sentence comprehension of different English embedded sentences. Her result also showed that only a little difference was found in comprehension accuracy rates between L2 high and L2 low WM capacity groups.

Consequently, following Juffs (2004, 2005), Ren interpreted this result as WM effects being not observable in L2 sentence comprehension.

Despite these previous findings of L2 sentence comprehension and L2 RST span size, the current study has found the effect of WM on L2 sentence comprehension. The difference between the findings of the previous studies and the current study may come from the difference in L2 exposure and L2 proficiency level of the L2 learners. In the previous studies, the L2 exposure of the participants was similar to one another within the study. For instance, Omaki's participants were mostly graduate students (21 out of 24 participants) from an American university who were studying English. Being a graduate student at an American university, their L2 English proficiency level can be assumed as high and needless to say, their exposure to English must have been high. Ren's L2 participants were also graduate students in China, whose exposure to English was only through formal classroom instruction with no record of staying in English-speaking countries. On the other hand, although the participants were recruited in the U.S., the L2 experiences of the participants in this study were more diverse: some had only less than one month of experience living in the U.S. or Japan while others had studied and/or worked in the L2 speaking country for more than 5 years. If L2 WM is influenced by the overall language skills and if the utilization of WM changes from more experience and exposure to L2 (Service, Simola, Metsanheimo, and Maury, 2002; Van den Noort, Bosch, and Hugdahl, 2006), then it can be assumed that the L2 proficiency level of the participants in this study may have been more discrete to begin with. If so, seeing an effect of WM capacity in L2 sentence comprehension between two RST span size groups is not surprising.

Collectively from the above discussions, it can be inferred that WM capacity of the L2 learners is an important factor in determining the extent to which sentence processing might be similar or different to that of native speakers. More specifically, the effect of WM capacity appears in L2 sentence comprehension, but it appears more explicitly in the sentences that are easier to comprehend. The reason for this may be due to the utilization of WM within an individual. A capacity-constrained theory by Just and Carpenter (1992) proposes that memory and computational operations necessary for sentence processing are shared by a single WM system. Assuming that this is true, the parsing of sentences that are more difficult to comprehend requires much more computational operations and leaves less capacity to be used for storage and other processes regardless of one's WM capacity. In the case of the L2 learners in the current study, the sentences which are more difficult to comprehend, i.e. English object-gap sentences and Japanese subject-gap sentences, might have been so difficult even for the L2 learners with a high WM capacity that they used much of their WM for computational operations. On the other hand, the parsing of the sentences that are easier to comprehend would require fewer computational operations and leave much more capacity for storage and other processes. Therefore, the sentences that are easier to comprehend, i.e. English subject-gap sentences and Japanese object-gap sentences, might have been very easy to parse for the L2 learners with a high WM capacity, but not so much for the L2 learners with a low WM capacity who might have struggled to parse those sentences. Hence, those differences in ability may have created a larger gap between the performances of the two L2 RST groups and led to a statistically significant difference. Consequently, the effect of the WM capacity was seen more robustly in the sentences that are easier to

comprehend in this study. This is probably because with difficult sentence structures, it takes longer for L2 learners to overcome the stage of just concentrating on using L2 specific knowledge in sentence comprehension. It can be speculated that as the exposure to L2 increases and when the sentence structures that are difficult to comprehend become easy to comprehend, the effect of general cognitive factors like WM capacity in L2 comprehension may become more robust (Hulstijn and Bossers, 1992; Schoonen, Hulstijn and Bossers, 1998; Van Gelderen, Schoonen, Stoel, De Glopper, and Hulstijn, 2007).

Although there was an effect of WM capacity in L2 comprehension, in general this study showed no effect of having high or low WM capacity on L2 learners' sentence reading times, which is somewhat in accordance with the findings from the previous studies. That is, no regions produced significant differences between the RRTs of the high and low L2 WM capacity groups. Regardless, the L2 learner groups' general reading patterns and the regions where they read slowly suggest at least an influence of WM on L2 reading. Additionally, it was shown that L2 learner groups take both similar and also dissimilar parsing strategies to the native speakers in L2 RC sentence processing.

Demonstrating similar and dissimilar parsing patterns to the native speakers' raises some questions about Shallow Structure Hypothesis proposed by Clahsen and Felser (2006). Shallow Structure Hypothesis hypothesizes that the syntactic representations computed by L2 learners during comprehension are shallower and less detailed than those computed by native speakers and involve more direct form-function mappings. More specifically, shallow parsing by L2 learners is hypothesized to involve: (1) identifying parts of speech, (2) segmenting the input string into meaningful chunks

(i.e. phrasal or clausal units), and (3) determining what relations these chunks bear to the main verb (e.g. subject, object, etc.). Taking the integrated processing model proposed by Townsend and Bever (2001) into account, Clahsen and Felser further argued that the difference between L1 processing and L2 processing is that L2 processing takes the shallow processing route. According to Clahsen and Felser, the shallow processing route is guided by lexical-semantic and pragmatic information and in L2 processing, it predominates the full parsing route, which is fed by the grammar.³¹ Clahsen and Felser deny the effect of individual WM differences on L2 parsing performance because they assume that L2 learners rely on the shallow processing route, which reflects inadequacies of the L2 grammar. However, as demonstrated in this study, the L2 learners, especially those L2 learners with high WM capacity, can take a similar parsing strategy to that of the native speakers, and more or less obtain successful sentence comprehension in L2. The fact that we can explain the results by the difference in WM capacity of L2 learners makes it difficult to completely deny the effect of WM on L2 performance. Additionally, numerous previous studies have provided evidence of the effect of WM on L1 performance. In this study, the exact same participants participated in both L1 and L2 tasks. Since these participants have shown the effective and efficient use of WM and demonstrated that they are capable of using it in their L1 parsing, how can we fully refute the effect of WM in their L2 parsing?³²

³¹ Integrated processing model (Townsend and Bever, 2001) assumes two parallel working routes for sentence processing in which one involves the application of semantically based comprehension heuristic and the other involves syntactic analysis.

³² Negative transfer from L1 parsing strategies is also a possibility, although it was not the focus of this study. What can be inferred from this study is that there was little or no transfer of the parsing strategies from L1, since for instance, English-speaking learners of Japanese showed some evidence of using case marker information to incrementally process and not solely depending on, or waiting for verb information to parse the Japanese gap type sentences. Another example is the slower RRTs in the regions following the

In this study, some L2 learners showed similar reading patterns to those of the native speakers and some showed unique reading patterns dissimilar to those of the native speakers. The reading patterns that were exhibited by the L2 learners can be assumed as the reflection of the parsing strategies employed with their WM capacity constraints. Accordingly, the question of whether there is a parsing strategy that accounts for both native-like and non-native-like L2 reading patterns arises.

We know that sentences are processed incrementally not only in L1, but also in L2. Thus, it can be said that the L2 learners with both native-like and non-native-like L2 reading patterns processed L2 sentences incrementally. We also know that L1 processing strategies are available for all L2 learners, especially adult L2 learners, to process L2 sentences. These L1 processing strategies may be used for parsing L2 sentences, but if these L1 parsing strategies are not suited for parsing L2, i.e. do not accomplish accurate comprehension, they may not be used. In fact, the L1 transfer of processing strategies changes as the learner becomes more proficient in the L2. For example, Su (2001) tested English-speaking learners of Chinese and Chinese-speaking learners of English. Su found that the former participants with low proficiency level used English word order strategies most of the time in processing Chinese sentences. However, the higher proficiency level learners used animacy cue in Chinese sentence processing like the native speakers did. Likewise, low proficiency Chinese-speaking learners of English used their L1 animacy cue when reading English. The higher proficiency level learners, on the other hand,

relative head noun in the English object-gap sentences by Japanese-speaking learners of English. Their performance seems to be showing the maxing out or the ceiling effect of one's working memory capacity, rather than L1 transfer. It is also possible to apply incomplete acquisition of the target grammar as the explanation of their deficiency. However, it is extremely difficult to determine whether L2 learners have fully and completely 'acquired' the target grammar. Thus, it is difficult to deny its effect on L2 performance as well.

employed the word order cue when reading English sentences like the native speakers did. The results of Su's study clearly show that L2 learners, especially those with high L2 proficiency, do not use L1 processing strategies if they were not suited for processing L2. In the case of the current study, we can assume that the L1 parsing strategies that the participants possessed could not have been straightforwardly applied to L2 parsing due to the typological differences between English and Japanese. Even if they did, it is likely that the L2 learners had to alter the L1 processing strategy to fit to the target language. Otherwise, they would be unable to achieve the accurate comprehension. From this, we can eliminate the direct transfer of L1 processing strategies to L2 parsing in this study.

Several studies have demonstrated that L2 learners with high proficiency level are guided by information about the L2 argument structure during sentence processing and parse L2 sentences in accordance with the lexical constraints of that language and thus their performances were native-like (Frenck-Mestre and Pynte, 1997; Juffs, 1998). Similarly, in the current study, the L2 learners who exhibited the commonly-preferred reading patterns by the native speakers are assumed to be strongly guided by L2 linguistic information, taking a similar parsing strategy as the native speakers. Those L2 learners who did not exhibit the reading patterns that were commonly preferred by the native speakers are likely to be guided by their developing interlanguage system, taking a dissimilar parsing strategy to the native speakers.

An interlanguage system is a linguistic system that has been developed by a L2 learner who has not fully become proficient in the target language. The interlanguage system is neither L1 nor L2, but rather an independent system of its own approximating the target language system (Selinker, 1972). Thus, if the parsing strategy is guided by the

linguistic system that the learner has, then the parsing strategy that the learner takes to parse L2 sentences would be accordingly independent from L1, but approximating that of L2, i.e. the parsing strategy based on one's interlanguage system. This would explain the unique reading patterns demonstrated by the L2 learners, which are not completely different from those of the native speakers, but not necessarily in accordance with the native speakers' commonly-preferred ones. That is, these L2 learners attempted to use the information available, like case marker information and verb-subcategorization information, to parse the incoming L2 sentence elements. Despite the attempt, due to factors such as still developing L2 grammatical knowledge, overall L2 language proficiency, and WM capacity, they failed to take the native-like parsing strategy. Thus, their reading patterns exhibited dissimilar patterns from the native speakers' commonly-preferred ones. Here, we would like to emphasize the fact that the reading patterns that are not the native speakers' commonly-preferred ones do not necessarily lead to inaccurate comprehension. As we will discuss below, a good enough representation may be sufficient to achieve an accurate comprehension in L2. This may be the reason why we saw the reading patterns that are different from the native speakers' commonly-preferred ones taken by the L2 learners who still achieved high comprehension accuracy.

In Sawasaki (2007), it was speculated that the L2 learners might not have to perform exactly native-like unless it causes a problem, and the unique L2 learners' reading patterns may not disappear even when the learners became highly proficient in L2. It is true that even L1 native speakers sometimes do not compute syntactic representation fully and just build a 'good enough representation' for the purpose of getting the meaning of sentences (Ferreira, Bailey, and Ferraro, 2002). With the close

examination of each participant's reading patterns of L1 and L2 sentences, this study also demonstrated that some of the dissimilar reading patterns lead to the accurate comprehension, which could be taken as an indication of 'good enough representation' for processing the sentences demonstrated not only by the L1 native speakers, but also by the L2 learners as well. Hence, the findings of this study provide evidence for Sawasaki's speculation that L2 learners, as well as L1 learners, do not have to have exactly the same commonly-preferred reading patterns in order to successfully comprehend a sentence in L1 or L2.

Nevertheless, the results of the current study also suggest that one would be better off in their comprehension accuracy if one processed the sentence in the most efficient native-like way to avoid the delay in processing and WM overload. Of course, overall L2 proficiency cannot be neglected, but effective utilization of WM capacity seems to certainly lead to the successful L2 sentence comprehension. That is, if one already has a reading pattern similar to the native speakers' commonly-preferred one, then the capacity size of WM does not matter as much to achieve a successful L2 comprehension. This is probably because the overall load of sentence processing on WM would not be overwhelming by parsing a sentence in the most effective and efficient way. If one does not have the reading pattern that is commonly preferred by the native speakers, then having a higher WM capacity helps to accomplish a successful L2 comprehension because WM will not be overloaded from dealing with ineffective and inefficient processing. In other words, the results of this study indicated that having a larger or smaller capacity facilitates or impedes the successful comprehension in L2.

The question arises whether or not L2 learners become less affected by L2 linguistic restrictions as their proficiency improves, and consequently come to parse like native speakers. Sawasaki (2007) also speculated that L2 learners might not become exactly native-like based on the research findings he conducted with Japanese as second/foreign language learners. In his study, even advanced L2 Japanese learners showed different reading patterns from the Japanese native speakers in the reading of Japanese simplex sentences. However, in the current study, there were L2 learners who showed similar reading patterns to those of the native speakers. In the field of L2 research, it has been widely acknowledged that L2 learners tend to rely on declarative memory rather than procedural memory for the representation and their L2 processing (Ellis, 2004). However, recently, there are some studies that showed L2 learners, especially high proficiency L2 level learners, using procedural memory in L2 processing as native speakers do (Doughty and Long, 2003; Paradis, 2004; Ullman, 2001, 2005). If so, there is at least a potential of becoming native-like in L2 sentence processing. Whether that change will happen eventually to every L2 learner for all L2 sentences is still undetermined and needs further investigation.

5.3. Limitation of the Current Study and Implication for Future Research

The effect of the WM capacity was explored in the current study as a potential variable that underlies individual differences in sentence processing. There are limitations that need to be recognized in this study. One of the weakest points of the study is the small number of participants because the findings may be limited only to the participants of this study and not applicable to others. Second, the L2 proficiency levels of English

native and Japanese native L2 learners may not have been exactly the same as their comprehension accuracy in L2 indicated. Thus, for example, when L2 groups were compared in discussion, their WM capacity in L2 RST High and Low groupings between two languages may not have been the exactly same. Third, the experiments of this study were conducted under the assumption that the L2 learners have already acquired the vocabulary and grammatical structures used in the tasks. In order to ensure their acquisition, other measurements such as familiarity rating and grammatical judgment tasks could have been conducted. Along this line, the limited number of vocabulary in English and Japanese L2 learners restricted the creation of test sentences. Since these issues may always exist in any L2 research, further studies with a larger number of participants with different sentence structures and languages need to be conducted. Fourth, this dissertation study only examined WM. However, factors other than WM may also have an influence, especially on L2 learners' performance. For example, the reading of *kanji* by English-speaking learners of Japanese may affect their L2 performance. Additionally, vocabulary size, length of study, experiences, and L2 exposure may have also affected how L2 learners read sentences. Different L2 proficiency levels as well as the proximity of the native language to the target L2 language may also influence L2 sentence reading. These factors were not investigated in the current study and still need to be investigated.

To conclude, the present study addressed the issue of individual differences in sentence processing and discussed it from the points of view of WM capacity and individual general reading patterns. It revealed that WM capacity has an effect on L1 and L2 sentence comprehension and processing in some way. Although there are many more

issues to be investigated and more studies on various aspects are necessary from a variety of perspectives, I hope this study added another stepping stone to deepen our understanding of how we comprehend a sentence.

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APPENDIX A

SENTENCES USED IN ENGLISH READING TASK

English test sentences:

- (1a) The client who irritated the businessman paid the monthly bill.
- (1b) The client who the businessman irritated paid the monthly bill.
- (2a) The children who chased the grandmother threw the yellow ball.
- (2b) The children who the grandmother chased threw the yellow ball.
- (3a) The pilot who complimented the stewardess asked a thoughtful question.
- (3b) The pilot who the stewardess complimented asked a thoughtful question.
- (4a) The singer who married the scientist played an exciting game.
- (4b) The singer who the scientist married played an exciting game.
- (5a) The writer who ignored the editor entered the lengthy article.
- (5b) The writer who the editor ignored entered the lengthy article.
- (6a) The runner who helped the policeman lost the leather wallet.
- (6b) The runner who the policeman helped lost the leather wallet.
- (7a) The student who criticized the professor missed a boring meeting.
- (7b) The student who the professor criticized missed a boring meeting.
- (8a) The burglar who killed the officer broke the important promise.
- (8b) The burglar who the officer killed broke the important promise.
- (9a) The actor who visited the director kicked the big wall.
- (9b) The actor who the director visited kicked the big wall.
- (10a) The mailman who hated the employer ate a tasty muffin.
- (10b) The mailman who the employer hated ate a tasty muffin.
- (11a) The lawyer who liked the assistant wrote an official letter.
- (11b) The lawyer who the assistant liked wrote an official letter.
- (12a) The partner who assisted the detective bought the brown jacket.
- (12b) The partner who the detective assisted bought the brown jacket.
- (13a) The victim who attacked the prisoner expressed his strong anger.
- (13b) The victim who the prisoner attacked expressed his strong anger.
- (14a) The mayor who passed the governor drove an expensive car.
- (14b) The mayor who the governor passed drove an expensive car.
- (15a) The landlord who fought the resident phoned the emergency room.
- (15b) The landlord who the resident fought phoned the emergency room.
- (16a) The fireman who saved the journalist took the beautiful picture.
- (16b) The fireman who the journalist saved took the beautiful picture.
- (17a) The salesman who excited the customer sold an American truck.
- (17b) The salesman who the customer excited sold an American truck.
- (18a) The doctor who pleased the caretaker covered the small bed.
- (18b) The doctor who the caretaker pleased covered the small bed.
- (19a) The drummer who observed the conductor practiced the shinny instrument.
- (19b) The drummer who the conductor observed practiced the shinny instrument.
- (20a) The parent who bothered the advisor heard the school event.
- (20b) The parent who the advisor bothered heard the school event.

English filler sentences:

- (1) The boy who was mowing the lawn hit the woman.
- (2) The informer recorded by the emergency call could not be understood.
- (3) The gardener spoke to the master that he did not have time to plant the field.
- (4) The soldier who was serving in the army comforted the friend.
- (5) The husband knew the thief to whom the cop issued a ticket.
- (6) The leader supported by the followers started a new religion.
- (7) The instructor answered to the class that they came up with thoughtful ideas.
- (8) The diplomat warned the spy that he should not blackmail anyone.
- (9) The pianist followed the patron to whom the violinist revealed the secret.
- (10) The supervisor respected by the staff taught him a lot.
- (11) The author who was in Japan met the photographer.
- (12) The receptionist watched the advisor to whom the banker gave the nice present.
- (13) The coach advised the football player that he should not go out to party.
- (14) The criminal notified the attorney that the pistol was stolen from the drawer.
- (15) The driver fed the accountant to whom the CEO explained the difficult situation.
- (16) The babysitter who was lying on the floor saw the niece.
- (17) The speaker proposed by the group would work perfectly for the program.
- (18) The waiter fooled the owner to whom the waitress sent a card.
- (19) The prince responded to the king that he did not do anything at all.
- (20) The farmer called the store manager that the vegetables were all damaged.
- (21) The sheriff who was patrolling arrested the gunman.
- (22) The poet studied by the historian was not known until late 1920s.
- (23) The specialist requested by the hospital finally got there.
- (24) The nurse who was resting on the sofa contacted the patient.
- (25) The executive member protected by the bodyguards smiled proudly.
- (26) The board member inspected by the expert looked strange and suspicious.
- (27) The mother who was in pain blamed the father.
- (28) The secretary cherished the model to whom the bartender offered the cocktail.
- (29) The young guy announced to the family that he got engaged with his girlfriend.
- (30) The fisherman told the dealer that he did not catch enough fish.
- (31) The sister who was drinking beer filmed the lover.
- (32) The scholar hired the lecturer to whom the office personnel presented flowers.
- (33) The swimmer reported to the lifeguard that he did not swim in the pool.
- (34) The actress who was on the balcony shot the dancer.
- (35) The wife admired the athlete to whom the daughter showed affection.
- (36) The son who was at the beach cheered the man.
- (37) The security guard examined the fan to whom the comedian acted out the story.
- (38) The president sketched by the artist was very diligent.
- (39) The old lady loved the gentleman to whom the neighbor provided the cake.
- (40) The guests expected by the host arrived too late to eat a decent dinner.

APPENDIX B

SENTENCES USED IN JAPANESE READING TASK

Japanese subject-gap and object-gap RC examples:

(1a) Japanese subject-gap

Ueno-san-o	miokutta	ojisan-ga	omocha-o	hirotta.
Ueno-acc	saw off	man-nom	toy-acc	picked up.

‘The man who Ueno saw off picked up the toy.’

(1b) Japanese object-gap

Ueno-san-ga	miokutta	ojisan-ga	omocha-o	hirotta.
Ueno-nom	saw off	man-nom	toy-acc	picked up.

‘The man who Ueno saw off picked up the toy.’

Japanese test sentences:

- (1a) 上野さんを見送ったおじさんがおもちゃをひろった。
- (1b) 上野さんが見送ったおじさんがおもちゃをひろった。
- (2a) 横山さんを手伝った学生がビデオをけした。
- (2b) 横山さんが手伝った学生がビデオをけした。
- (3a) 野口さんをなぐさめたかんごふがたばこをすった。
- (3b) 野口さんがなぐさめたかんごふがたばこをすった。
- (4a) 大西さんを見つけた妹が新聞を読んだ。
- (4b) 大西さんが見つけた妹が新聞を読んだ。
- (5a) 和田さんをいじめた友だちが電話をかけた。
- (5b) 和田さんがいじめた友だちが電話をかけた。
- (6a) 小林さんをつかまえた父親がバイクを直した。
- (6b) 小林さんがつかまえた父親がバイクを直した。
- (7a) 上田さんを助けた弟がジュースをこぼした。
- (7b) 上田さんが助けた弟がジュースをこぼした。
- (8a) 川村さんを起こしたお婆さんがさいふをなくした。
- (8b) 川村さんが起こしたお婆さんがさいふをなくした。
- (9a) 森田さんをおいかけた受付がニュースを知った。
- (9b) 森田さんがおいかけた受付がニュースを知った。
- (10a) 山下さんをころしたどろぼうがテレビをつけた。
- (10b) 山下さんがころしたどろぼうがテレビをつけた。
- (11a) 石田さんを出むかえた母親が肉を料理した。
- (11b) 石田さんが出むかえた母親が肉を料理した。
- (12a) 小川さんをさした先生が写真をとった。
- (12b) 小川さんがさした先生が写真をとった。
- (13a) 高橋さんをやとった男性がスーツをえらんだ。
- (13b) 高橋さんがやとった男性がスーツをえらんだ。

- (14a) 村上さんを見かけたべんごしがタオルを落とした。
- (14b) 村上さんが見かけたべんごしがタオルを落とした。
- (15a) 原田さんをほめた店員がバッグをぬすんだ。
- (15b) 原田さんがほめた店員がバッグをぬすんだ。
- (16b) 中野さんを育てた院長がテープを作った。
- (16b) 中野さんが育てた院長がテープを作った。
- (17a) 広田さんをせめた長男がおかしを買った。
- (17b) 広田さんがせめた長男がおかしを買った。
- (18a) 北村さんをけったお客がお酒を飲んだ。
- (18b) 北村さんがけったお客がお酒を飲んだ。
- (19a) 大田さんをなぐった学長が手紙を書いた。
- (19b) 大田さんがなぐった学長が手紙を書いた。
- (20a) 田中さんと呼び出した兄がルールを説明した。
- (20b) 田中さんが呼び出した兄がルールを説明した。

Japanese filler sentences:

- (1) まさる君がひしよに借りたジャケットをよごした。
- (2) みのりさんが料金をはらったのこりをしまった。
- (3) りなさんが子どもが学校でだれに宿題を出したか教えた。
- (4) たかし君が助手に持っていったレポートをやぶった。
- (5) 西村さんが笑っている運転手を大声でおこった。
- (6) たろう君が窓をわった部屋をそうじした。
- (7) みち子さんが兄弟にもらったかさをこわした。
- (8) しゅんすけ君がお父さんが家でだれに一万円をやったか思いついた。
- (9) かずき君がパーティーをする予定をたてた。
- (10) きょうへい君がおじいさんにさし上げた辞書を使った。
- (11) こうた君はだれが医者に部屋で花を送ったか伝えた。
- (12) けんご君が社長にたしかめた予約を取りけした。
- (13) しゅんぺい君がスチュワーデスが空港でだれにかばんをわたしたか忘れた。
- (14) 本田さんが泣いているボーイフレンドをかなしそうに見た。
- (15) のぼる君がせんぱいにあげたサンドイッチをつぶした。
- (16) 田村さんががんばって勉強しているまごをつれ出した。
- (17) けい君がドライバーが車で住所をだれに知らせたか覚えていた。
- (18) 山本さんがのんびり歩くサラリーマンをおいぬいた。
- (19) まゆさんがテーブルを動かしたところをふいた。
- (20) 中川さんが出かける彼女を笑顔で送り出した。
- (21) みゆきさんが事務員からいただいた果物をすてた。
- (22) みほさんが仕事をやめた場合を考えた。

- (23) ゆいさんが交番でけいさつかんがだれに自転車を返したか気づいた。
- (24) 山田さんがよっぱらって寝ているエンジニアをふんだ。
- (25) たつやさんが会社でだれが課長におべんとうを届けたか思い出した。
- (26) よしひろ君がしけんをうけているようすをしつもんした。
- (27) ゆうなさんが台所でだれがおばあさんにお茶を入れたかわかった。
- (28) あきらさんが女の人に注文したケーキを食べた。
- (29) 大森さんがとび出すおまわりさんをあわててひき止めた。
- (30) はな子さんがピアノを習う日を決めた。
- (31) 池田さんが座っている主人をぼんやりながめた。
- (32) みおさんが部長がだれにかいぎ室でかぎを預けたか言った。
- (33) あき子さんが男の子に売ったコートを受け取った。
- (34) 橋本さんがゆっくり走っている夫を呼び止めた。
- (35) さとる君がけがをしたじこを調べなおした。
- (36) ひかるさんがだれが図書室で彼に雑誌をかしたか気になった。
- (37) 中田さんが立っているつまをうれしそうにささえた。
- (38) つよし君が時間をまちがえたわけを話した。
- (39) よう子さんが少女に着せた洋服を洗った。
- (40) だいが君が手を洗う場所を聞いた。

APPENDIX C

MEAN RESIDUAL READING TIMES BY INDIVIDUAL PARTICIPANTS

Mean RRTs per region of English RC sentences by English native speakers
(L1 English)

Region	1	2	3	4	5	6	7
E01 SG	-45.41	-162.88	-78.97	55.21	-6.59	603.98	-270.36
E01 OG	-31.83	-166.58	10.06	-96.11	-85.06	656.22	-253.80
E02 SG	217.30	-661.64	-385.65	132.08	-678.44	1378.83	-818.48
E02 OG	-88.90	-351.59	169.61	202.30	-610.32	1104.55	-805.19
E03 SG	107.42	-234.80	-49.63	336.24	-52.37	782.03	-403.16
E03 OG	-65.59	-317.95	-3.85	-77.39	-165.94	865.31	-395.72
E04 SG	-66.10	-77.32	-85.25	-20.30	-54.89	369.81	-55.72
E04 OG	-45.27	-67.29	-27.01	-40.64	-52.31	202.33	-94.78
E05 SG	-524.74	-1040.08	-418.97	276.24	-430.28	1732.92	-929.16
E05 OG	-459.29	-1006.06	524.99	-335.28	-112.15	1669.05	-499.36
E06 SG	-107.39	-238.08	-33.31	365.10	-86.11	267.27	-392.36
E06 OG	-107.42	-239.97	253.24	-57.85	-70.74	157.58	-502.13
E07 SG	90.49	-150.24	-67.42	76.87	-10.42	599.42	-66.34
E07 OG	173.58	-141.24	56.44	-14.33	-95.69	356.44	-226.71
E08 SG	-198.28	-494.94	-369.33	40.84	-301.62	1128.10	-657.54
E08 OG	-321.22	-514.74	58.32	-60.91	-202.82	524.57	-649.82
E09 SG	-556.14	-1337.61	-312.61	726.39	-69.52	1003.55	-925.19
E09 OG	-625.89	-1338.32	693.13	1302.92	-1024.96	1521.39	-852.86
E10 SG	23.09	-78.84	-67.52	-3.65	-83.92	107.13	-66.34
E10 OG	-13.98	-126.90	-41.84	24.18	23.42	155.71	-7.59
E11 SG	-157.72	-392.30	-168.07	60.80	-254.17	669.22	-394.76
E11 OG	-175.90	-389.10	38.30	-113.91	26.50	817.84	-315.98
E12 SG	-280.01	-617.60	-380.74	47.22	-520.44	924.90	-713.30
E12 OG	-300.46	-561.00	25.20	989.72	-524.45	629.79	-743.72
E13 SG	11.12	-78.69	272.59	170.94	-297.67	421.05	-257.78
E13 OG	-46.93	-343.64	413.24	-190.85	-301.94	1111.57	-141.03
E14 SG	-146.68	-374.01	-398.49	148.37	-240.60	619.94	-85.71
E14 OG	-115.49	-257.89	-87.96	-20.10	294.77	542.04	-56.36

SG=subject-gap; OG=object-gap

Mean RRTs per region of English RC sentences by Japanese native speakers
(L2 English)

Region	1	2	3	4	5	6	7
J21 SG	-275.25	-574.32	406.42	1179.76	98.67	84.50	-820.65
J21 OG	-129.06	-225.28	627.83	190.91	248.22	209.25	-794.92
J22 SG	-153.66	-103.43	-37.39	120.40	4.41	233.36	-238.06
J22 OG	-50.88	-135.73	208.53	-49.02	43.40	136.51	-259.92
J23 SG	-537.56	-721.24	-1313.80	33.91	-1415.95	-200.98	-729.79
J23 OG	-647.34	-874.70	-753.30	454.93	345.75	654.59	-852.41
J24 SG	-566.02	-964.33	-454.67	113.28	-576.07	449.76	-907.01
J24 OG	-221.46	-810.30	259.09	73.43	252.43	434.53	-998.47
J25 SG	-203.05	-466.98	-66.96	837.37	83.46	-299.92	-1087.70
J25 OG	-348.46	-526.96	589.89	-30.63	1105.92	9.70	-998.42
J26 SG	-614.59	-845.71	-92.38	443.63	-722.64	-64.82	-815.88
J26 OG	-345.53	-865.93	851.22	1260.37	-510.58	-8.99	-823.44
J27 SG	-491.16	-1002.49	-372.52	1136.46	539.48	367.79	-799.18
J27 OG	-485.32	-537.21	307.67	1297.07	2631.89	2234.41	-822.75
J28 SG	-116.36	-249.05	-205.29	3.42	-122.24	139.01	-300.06
J28 OG	-182.99	-348.90	26.72	-6.09	-223.69	80.15	-264.86
J29 SG	-206.88	-192.41	160.11	553.45	-89.42	646.95	-833.91
J29 OG	-319.11	-243.29	433.66	-302.93	450.06	465.88	-821.42
J30 SG	-380.50	-705.93	-174.39	265.25	-86.27	317.57	-736.41
J30 OG	-373.45	-475.97	66.28	216.48	789.32	586.95	-856.09
J31 SG	-531.64	-529.15	-226.85	1074.37	-115.00	35.47	-931.75
J31 OG	-428.52	-389.59	1232.36	254.09	103.96	106.68	-903.80
J32 SG	100.21	-377.02	-247.24	-249.40	104.93	-243.17	-813.57
J32 OG	25.41	-406.63	10.18	574.99	317.54	-21.57	-936.77
J33 SG	-104.82	-68.59	345.80	224.04	38.29	567.96	-896.39
J33 OG	-98.70	-40.39	375.76	283.23	186.82	505.73	-809.63
J34 SG	-272.82	-767.79	-177.18	1032.06	262.49	-158.90	-702.12
J34 OG	-429.88	-484.80	361.78	1040.13	208.34	-65.78	-1076.23

SG=subject-gap; OG=object-gap

Mean RRTs per region of Japanese RC sentences by Japanese native speakers
(L1 Japanese)

Regions	1	2	3	4	5	6
J21 SG	-329.31	434.15	196.51	551.53	162.03	-250.73
J21 OG	-305.12	-70.24	-118.18	507.45	322.55	-309.11
J22 SG	-325.94	76.63	34.62	147.52	-39.74	-221.41
J22 OG	-273.04	161.14	96.19	163.20	59.44	-127.26
J23 SG	-745.18	649.43	-105.78	212.03	-466.37	-547.56
J23 OG	-657.68	509.83	229.82	726.73	-718.67	-416.46
J24 SG	-22.85	-94.89	781.79	1074.79	-513.57	-767.61
J24 OG	21.47	127.98	19.02	390.44	-564.37	-184.11
J25 SG	-450.15	628.45	50.00	72.93	-306.34	-116.32
J25 OG	-461.04	375.92	319.83	445.32	164.41	-136.61
J26 SG	-139.31	834.80	-92.38	12.57	39.33	-200.57
J26 OG	67.38	251.55	-2.40	152.55	-234.65	-290.48
J27 SG	-149.57	417.02	-135.69	814.47	-466.81	-282.64
J27 OG	-60.60	112.08	-392.09	345.65	57.31	-34.74
J28 SG	-81.32	147.15	8.53	451.87	-0.19	8.27
J28 OG	-289.76	272.21	76.27	150.17	64.12	-170.16
J29 SG	-119.58	132.91	128.98	820.43	343.79	-347.10
J29 OG	-184.81	-47.74	58.36	624.69	50.91	-122.64
J30 SG	-304.86	613.13	-311.69	559.84	316.95	-229.82
J30 OG	-89.93	162.99	-72.28	-132.69	-162.36	112.43
J31 SG	-185.74	-149.90	-171.74	79.85	6.45	129.14
J31 OG	-286.72	-167.39	-106.28	107.35	517.39	-284.86
J32 SG	-157.48	36.80	6.82	3.28	9.21	-59.26
J32 OG	-141.83	64.36	76.31	19.36	6.35	-35.31
J33 SG	25.43	-3.33	257.67	565.33	-243.97	106.79
J33 OG	-249.94	88.95	60.83	168.04	-154.35	-74.90
J34 SG	-190.20	86.38	232.20	-98.89	-48.41	-150.71
J34 OG	-174.19	267.19	-0.86	118.59	-31.44	-75.96

SG=subject-gap; OG=object-gap

Mean RRTs per region of Japanese RC sentences by English native speakers
(L2 Japanese)

Regions	1	2	3	4	5	6
E01 SG	-593.73	-231.42	-65.38	18.43	10.70	-775.87
E01 OG	-682.77	-144.79	342.26	391.09	-14.40	-322.76
E02 SG	-1059.25	886.31	608.33	103.90	-525.21	-672.29
E02 OG	-1013.43	2205.08	88.82	1104.91	-304.91	-845.89
E03 SG	-551.85	989.62	-149.71	-344.43	-636.01	-800.72
E03 OG	-456.24	170.99	652.97	684.73	-295.45	-529.20
E04 SG	-543.84	171.86	190.47	211.75	287.60	-497.00
E04 OG	-778.09	1288.27	-223.22	567.78	-234.37	-290.46
E05 SG	-1373.16	1007.28	-1347.00	-729.67	-972.96	-2243.76
E05 OG	-958.18	-229.07	499.34	466.55	-873.35	-1180.19
E06 SG	-757.48	167.71	1285.91	-53.88	1339.12	-523.65
E06 OG	-730.97	237.70	374.82	23.71	379.86	-309.40
E07 SG	-482.28	744.78	14.06	236.34	-89.94	-234.97
E07 OG	-574.46	617.77	104.80	93.40	-96.53	-312.05
E08 SG	-1999.80	1051.09	1295.93	1191.03	1103.61	-527.59
E08 OG	-1232.07	1782.64	1201.69	142.16	-270.90	-801.99
E09 SG	-613.38	1080.01	477.53	882.51	155.41	-1181.47
E09 OG	-1346.80	1196.92	1314.92	1147.96	-535.61	-894.31
E10 SG	-326.38	-277.94	-372.91	-449.50	-756.97	-946.21
E10 OG	-446.97	-288.30	-304.47	-637.42	-970.56	-993.21
E11 SG	-464.82	1532.30	-154.07	26.28	-164.68	-885.84
E11 OG	-1055.39	1095.62	312.77	968.98	-56.00	-743.87
E12 SG	-81.15	521.21	255.52	772.08	-473.19	-473.50
E12 OG	-499.08	224.73	-70.85	1190.85	-655.47	216.62
E13 SG	-1276.71	600.37	840.24	187.04	-294.16	-601.91
E13 OG	-1023.33	931.85	913.10	477.01	-28.14	-401.08
E14 SG	-466.96	539.74	311.49	599.97	-300.23	-170.38
E14 OG	-572.90	426.19	53.38	677.19	230.33	-397.53

SG=subject-gap; OG=object-gap

APPENDIX D
L2 READING SPAN TESTS

L2 English Reading Span Test

- 2.1.1 He played baseball all day at the park and got a sore arm.
- 2.1.2 The clerk in the department store put the presents in a bag.

- 2.2.1 I saw a child and her father near the river playing ball.
- 2.2.2 His younger brother played guitar in a rock and roll band.

- 2.3.1 Suddenly the taxi opened its door in front of the bank.
- 2.3.2 The last thing he did was to take a nice hot bath.

- 2.4.1 Her best memory of England was the Tower of London bell.
- 2.4.2 At the very top of the tall tree sat a small bird.

- 2.5.1 She took a deep breath and reached into the rusty box.
- 2.5.2 The state of Wisconsin is famous for its butter and cheese.

- 3.1.1 He overslept and missed all of the morning economics class.
- 3.1.2 The first thing he does every morning is swing a golf club.
- 3.1.3 Popular foods in the summer are watermelon and sweet corn.

- 3.2.1 The boy was surprised to learn that milk came from a cow.
- 3.2.2 The only thing left in the kitchen cupboard was a broken cup.
- 3.2.3 The birthday party began in the morning and lasted all day.

- 3.3.1 The young woman and her boyfriend thought they saw a dog.
- 3.3.2 There was nothing left to do except leave and lock the door.
- 3.3.3 In order to attend the dinner she needed to buy a dress.

- 3.4.1 The woman screamed and slapped the old man in the face.
- 3.4.2 She leaned over the candle and her hair caught on fire.
- 3.4.3 The drinks were all gone and all that remained was the food.

- 3.5.1 He quickly drank some of the milk and then washed the glass.
- 3.5.2 He looked across the room and saw a person holding a gun.
- 3.5.3 The hunting knife was so sharp that it cut his right hand.

- 4.1.1 She soon realized that the man forgot to leave the room key.
- 4.1.2 The saw that he brought was not strong enough for the lock.
- 4.1.3 The first driver out in the morning always picks up the mail.
- 4.1.4 All that remained in the lunch box was one salted nut.

- 4.2.1 The boat engine would not run because it was out of oil.
4.2.2 The letter said to come to the market to claim the prize.
4.2.3 It was a very simple meal of salted fish and boiled rice.
4.2.4 They decided to take an afternoon break by the large rock.
4.3.1 He wanted to leave his bags and jacket in the hotel room.
4.3.2 There were so many people that I couldn't find a seat.
4.3.3 He opened the bottom drawer and pulled out a shirt.
4.3.4 The skiing was so wonderful that he didn't mind the snow.
- 4.4.1 They knew that it was impolite to eat spaghetti with a spoon.
4.4.2 The season that people often associate with love is spring.
4.4.3 The letter was lost because it did not have a postage stamp.
4.4.4 The people in northern Europe always like to travel by train.
- 4.5.1 All morning the two children sat and talked under a tree.
4.5.2 At night the prisoners escaped through a hole in the wall.
4.5.3 The machine, which I have for many years, is still working perfectly.
4.5.4 He changed his mind again, which made me very angry.
- 5.1.1 We were so worried not having heard from you for so long.
5.1.2 She did not know the way and asked him if he did.
5.1.3 There is a maple tree near the fence and it is very beautiful.
5.1.4 When I opened the box of eggs, I found that several were broken.
5.1.5 I came across him in the very same place as before.
- 5.2.1 He left the town in 1965 and I haven't seen him since.
5.2.2 I do not enjoy tennis and I do not much like swimming either.
5.2.3 He wants to do it all the more because it is difficult.
5.2.4 By this time next month, all the roses will have died.
5.2.5 If you do not work, you can not get the guitar you want.
- 5.3.1 If he heard of her marriage, he would be shocked.
5.3.2 If there were any alternative, it would certainly be adopted.
5.3.3 I wish I had not wasted my time when I was young.
5.3.4 As I had a slight headache, I went to bed early.
5.3.5 The car made a big noise, so I stopped to check.
- 5.4.1 He said with a sigh that he was terribly unlucky.
5.4.2 He told me to leave the house until I was called.
5.4.3 No sooner had she entered the room than she began to cry.
5.4.4 We will not survive unless the problem is solved.
5.4.5 If you eat so much ice cream, you will get sick.

- 5.5.1 It was Mary who bought the perfume at the department store yesterday.
- 5.5.2 Whatever business you engage in, work at it as hard as you can.
- 5.5.3 I warned the boys not to swim out too far.
- 5.5.4 She suggested to him that they should start at once.
- 5.5.5 The doctor advised me not to smoke until I was completely recovered.

L2 Japanese Reading Span Test

- 2.1.1 プールのとなりのビルで待つ。
2.1.2 きょう持っているのはたぶん千円だ。
- 2.2.1 プレゼントは別に何でもいい。
2.2.2. なくしたのは黒いスーツケースのかぎだ。
- 2.3.1 サンドイッチを作るのにかかるのは七分だ。
2.3.2 ひどく高くてつまらない本だ。
- 2.4.1 そこがぼくの知っている病院だ。
2.4.2 ボールペンとお金はオーバーのポケットだ。
- 2.5.1 アルバイトはこのごろすばらしくまじめだ。
2.5.2 フィルムは買ったカメラの中だ。
- 3.1.1. ずいぶん古くて重いかばんだ。
3.1.2 ルールのむずかしいゲームをやる。
3.1.3 あんな楽しいパーティーはひさしぶりだ。
- 3.2.1 たいていちょうど十二時にご飯だ。
3.2.2 パンにつけたのはこんなジャムだ。
3.2.3 もうすぐ来る台風は強い。
- 3.3.1 お肉のまずい料理はいやだ。
3.3.2 あちらが弟にもらったナイフだ。
3.3.3 今の子どもは足が長い。
- 3.4.1 少し朝が早い仕事だ。
3.4.2 お姉さんがいらっしゃるホテルの名前だ。
3.3.3 駅の入りはたいへんぎやかだ。
- 3.5.1 一週間に三度電話をかける。
3.5.2 兄が使うのと同じスプーンだ。
3.5.3 学校を休んだのはこれがはじめてだ。

- 4.1.1 きのういただいたセーターはあたたかい。
4.1.2 そちらの方はこの医者だ。
4.1.3 教室はそのエレベーターの左だ。
4.1.4 おばさんはうすいお茶はきらいだ。
- 4.2.1 父はワイシャツとネクタイで会社だ。
4.2.2 赤ちゃんがいることを考える。
4.2.3 どれも秋にできた銀行だ。
4.2.4 アメリカに住んだのはだいたい五か月だ。
- 4.3.1 うちは大い建物のむこうだ。
4.3.2 夜おそく歩くのはだめだ。
- 4.3.3 あの犬は体が小さい。
4.3.4 どんなスポーツもほとんどできる。
- 4.4.1 おとといおじさんが読んだ新聞だ。
4.4.2 あそこはジュースを売っているタバコ屋だ。
4.4.3 しばらくフランスの映画を見る。
4.4.4 あれはピクニックにはくズボンだ。
- 4.5.1 店が開くのはつぎの土曜だ。
4.5.2 こっちがあなたに貸した洋服だ。
4.5.3 南の海は魚がきれいだ。
4.5.4 ステレオの安いところが多い。
- 5.1.1 きっとみんながほしがるペンだ。
5.1.2 東京はもうすっかり夏だ。
5.1.3 デパートがある道はまっすぐだ。
5.1.4 花にたくさん水をあげる。
5.1.5 それは私が書いた英語だ。
- 5.2.1 レストランで食べるケーキはおいしい。
5.2.2 友達の家はスーパーの後ろだ。
5.2.3 おくれてもかまわない日に起きる。
5.2.4 男のトイレはそっちのドアだ。
5.2.5 このあいだおいでになったおばあさんは元気だ。

- 5.3.1 なかなかすぐにはやまない雨だ。
5.3.2 バスやトラックの運転がこわい。
5.3.3 山はどこもごみでいっぱいだ。
5.3.4 先生が冬になさるのはスキーだ。
5.3.5 みなさんのおっしやったようにする。
- 5.4.1 あさってはまた漢字のテストだ。
5.4.2 いつも帰るときは車だ。
5.4.3 おまわりさんはゴルフがかなりうまい。
5.4.4 母に送ったスカートは白だ。
5.4.5 テニスをやめた妹はひまだ。
- 5.5.1 こちらがうるさくなるのは春だ。
5.5.2 おじいさんはとてもやさしい人だ。
5.5.3 あしたは借りたコートを着る。
5.5.4 そんなミルクを飲むのはおかしい。
5.5.5 テレビやラジオは研究のじゃまだ。