An investigation of the automaticity in parsing for Japanese EFL learners: Examining from psycholinguistic and neurophysiological perspectives

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An investigation of the automaticity in parsing for Japanese EFL learners: Examining from psycholinguistic and neurophysiological perspectives

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Abstract

The purpose of this dissertation is to investigate and reveal the mechanism of sentence processing for Japanese EFL (English as a Foreign Language) learners, especially focusing on the use of the explicit linguistic information, and the effects of proficiency on the automaticity in syntactic parsing.

Japanese EFL learners tend to be not good at reading English sentences. Although the difficulties of Japanese EFL learners in comprehending sentences are often discussed in pedagogical forums, they are rarely targeted in the psycholinguistic literature so far. Particularly in English, it is crucial to parse and understand the syntactic structure of the sentences correctly. During syntactic parsing, readers need to use the linguistic information of the sentence such as morphological, syntactic, semantic, and discourse information as the cue to construct the structure. But it is not clear what is easy or what is difficult for Japanese EFL learners to construct sentence structures and what becomes easier when their proficiency improves.

In the previous research, psycholinguistic experiments were conducted on native speakers of English from the perspective of their use of syntactic and semantic information in processing temporarily ambiguous sentences. Ferreira and Clifton (1986) insisted that native speakers of English use only syntactic information on parsing. Trueswell, Tanenhaus, and Garnsey (1994), on the other hand, concluded that native speakers of English use not only syntactic information but also semantic and other information on parsing. In addition, Just and Carpenter (1992) investigated the relation between linguistic information processing and individual difference of working memory capacity in sentence processing and revealed that the use of the linguistic information differed depending on readers' working memory capacity. In contrast, it is said that L2 learners including Japanese EFL learners rely more on lexical, semantic and pragmatic information and that the syntactic information is absent in their sentence processing (Shallow Structure Hypothesis: Clahsen & Felser, 2006). Moreover, in recent studies, neurophysiological methods that focus on brain activation gradually become more used for investigating the mechanism of language processing and the sensitivity to the linguistic information on syntactic parsing in both L1 and L2 speakers.

But little is known about how Japanese EFL learners build syntactic representations during sentence processing and how learners acquire and develop their methods of sentence processing

including syntactic parsing. In this dissertation, the mechanism of syntactic parsing for Japanese EFL learners, especially focusing on the use and the process of linguistic information, and the effects of proficiency on the automaticity in syntactic parsing are investigated from both psycholinguistic and neurophysiological perspectives.

In Chapter 3, an eye-tracking experiment was conducted to investigate how Japanese EFL learners with intermediate proficiency process temporarily ambiguous sentences from the perspective of their use of semantic and morphosyntactic information. In Experiment 1, participants read sentences containing reduced relative clauses for which initial noun phrases were controlled by the information of animacy. In Experiment 2, participants read sentences containing main clause or reduced relative constructions for which initial verbs were morphologically controlled. The effects of the improvement of proficiency within the intermediate group and the increase of working memory capacity were also considered using the linear mixed-effects model. The results revealed that Japanese EFL learners can use the information of animacy to facilitate sentence processing as their proficiency improves. However, they do not always use the morphosyntactic information effectively for sentence processing and there were few effects of proficiency and working memory capacity for reading sentences containing reduced relative clauses. These results indicate that Japanese EFL learners rely on the semantic and other information for sentence processing and that the use of the syntactic information is absent, which is consistent with the Shallow Structure Hypothesis of L2 speakers (Clahsen & Felser, 2006).

In Chapter 4, the event-related potentials (ERP) experiment was conducted to investigate Japanese EFL learners' sensitivity to linguistic information, including (a) morphosyntactic information (regular/irregular verbs), (b) semantic information, and (c) phrase structural rules, during sentence processing. Learners with intermediate and lower proficiency participated in the experiment and the effects of proficiency on the sensitivity to the information were also examined. Participants read sentences including correct or incongruent information and judged whether the sentences were grammatically/semantically correct. The results revealed that the P600 magnitude for the morphosyntactic incongruent condition of the regular verbs was positively correlated with proficiency level, indicating that proficient learners became more sensitive to the morphosyntactic rules of regular verbs in later processing stages. However, learners were not sensitive to the morphosyntactic information of the irregular verbs and the phrase structural rules regardless of their proficiency; the ERP components that L1 speakers typically have were not detected. On the other hand, N400 was detected in the semantic incongruent condition even if learners' proficiency were relatively low. These results indicate that, in terms of automaticity, Japanese low-proficiency EFL learners are sensitive to semantic information but not morphosyntactic information or phrase structural rules.

In Chapter 5, the changes of the sensitivity to the syntactic information after the exposure to the correct information were investigated. Recent studies revealed that the exposure to the linguistic information including sentence structure is effective to promote the sentence processing and language learning. The exposure tasks focusing on (a) morphosyntactic information (regular/irregular verbs) and (b) phrase structural rules were conducted to Japanese EFL learners with low proficiency. The effects of task type on exposure are also investigated, (1) silent reading task and (2) repetition task without looking. Then the ERP experiment was conducted in the same manner as Chapter 4. The experiment showed that P600 components were elicited against the morphosyntactic violations of the regular verbs and the phrase structural violations after participants completed the silent reading task. In contrast, P600 components were detected in the incongruent condition of the irregular verbs after participants completed the repetition task without looking. The results revealed that the learnability of the linguistic information is different between the morphosyntactic information of the verbs and the phrase structural rules for Japanese low-proficiency EFL learners.

Chapter 6 presents the general discussion about the results obtained from the experiments. Lastly, Chapter 7 concludes this dissertation with reviewing the residual problems and improvements for further studies.

Contents

Tables

Figures

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1. Introduction

1.1 Problems

Understanding the knowledge and information of the world is crucial to communicate with people in the global society. Reading is one of the important activities to learn about the foreign language and culture, leading to the correct understanding of the world and the better communication with the people. English education in Japan traditionally puts great emphasis on textbooks and on reading tasks. Students are required to read a great amount of English, and the curriculum is full of grammar and vocabulary tasks. Nevertheless, very few Japanese EFL (English as a Foreign Language) learners can read English sentences fluently and accurately. Some of the most recent educational movements in Japan aim to bring students to a higher level of reading comprehension so that they can understand the thoughts or opinions of the writers through reading the foreign language sentences. But recent English education in Japan does not arrive at that level and Japanese EFL learners tend to be not used to understand the contents of the sentences.

Although the difficulties of Japanese EFL learners in comprehending sentences are often discussed in pedagogical forums, they are rarely targeted in the psycholinguistic literature so far. Particularly in English, it is crucial to process and understand the syntactic structure of the sentences correctly. For example, the sentences “The man sees the woman.” and “The woman sees the man.” (van Gompel & Pickering, 2007) are constructed with the same words, but the meanings are not the same since the agents and objectives of the sentences are different due to the word order, in other words, the syntactic structure. In addition, the sentence like “The hunter killed the poacher with the rifle.” (van Gompel & Pickering, 2007) has two different interpretations since the prepositional phrase “with the rifle” can modify both the agent “The hunter” and the objective “the poacher”. This means that there are two possible syntactic structures in one sentence. Humans need to process and construct the complex structures of the sentences in their minds immediately and correctly to understand the contents of the sentences. This processing is called syntactic parsing (van Gompel & Pickering, 2007). During syntactic parsing, readers need to use the linguistic information of the sentence such as morphological, syntactic, semantic, and discourse information as the cue to construct the structure.

There are a lot of psycholinguistic studies focusing on how L1 speakers parse and comprehend written text and the parsing models for L1 speakers are proposed in previous literature. It is said that L1 speakers' syntactic parsing is operated rapidly and automatically, but little is known about how Japanese EFL learners build syntactic representations during sentence processing and what kind of processes are difficult for them to perform. In addition, it is not clear how Japanese EFL learners acquire and develop their methods of sentence processing including syntactic parsing. Since the English proficiency of Japanese EFL learners spread in various range, it is essential to reveal what is easy or what is difficult for Japanese EFL learners to process during syntactic parsing and what becomes easier when their proficiency improves.

It is possible that Japanese EFL learners face some extra difficulties which native speakers of English do not when they read sentences. In order to reveal the reasons behind the difficulties that Japanese EFL learners face in reading tasks, differences between native and EFL reading process need to be carefully investigated from a psycholinguistic perspective.

1.2 Purpose of the Study

The purpose of this dissertation is to investigate and reveal the mechanism of syntactic parsing for Japanese EFL learners, especially focusing on the use and the process of linguistic information including morphological, syntactic and semantic information, and the effects of proficiency on the automaticity in syntactic parsing.

One of the possible ways to investigate the mechanism of syntactic parsing is offered by a special grammatical structure called the garden-path sentence. Garden-path structure traditionally refers to a special phrasing of words in which the reader is encouraged to incrementally build up a structure for the sentence which turns out to be invalid at a later point. When the next word cannot be incorporated into the current structure, the reader has to parse the whole sentence again. So the garden-path sentences are described as syntactically ambiguous. The example of garden-path sentences is the following one.

(1) The horse raced past the barn fell.

(Bever, 1970)

This sentence can be parsed as the main clause sentence structure until the word "barn", but when the reader encounters the word “fell”, it turns out that the sentence cannot be parsed as the main clause sentence structure and has to be parsed again as the reduced relative clause sentence structure. This reanalysis of the sentence structure is called garden-path phenomenon (Frazier, 1983). Garden-path sentences can reveal and visualize the process of syntactic parsing.

According to Inoue (1998), readers sometimes build wrong structure while parsing syntactically ambiguous sentences like garden-path sentences since one structure is more preferred than another. Inoue mentions three important issues concerning the garden-path phenomenon.

(2)

a. What type of information can affect our sentence comprehension?

b. How can we describe the preference of the sentence structure on sentence processing?

c. How can sentence processing understood as part of the cognitive system?

(Inoue, 1998, p.73)

The first two issues (2a-b) are frequently addressed in ongoing debates about models of syntactic parsing. Especially, the issue (2a) is very important to investigate the process of syntactic parsing. Garden-path sentences have structural ambiguity that is temporal in nature, and the ambiguity is resolved at a later point in the sentence. But if there is some explicit information which is useful to parse the structure, the ambiguity of the sentence becomes invalid before the disambiguating point. The present study explores whether Japanese EFL learners use those explicit information on syntactic parsing. In order to prove that, the study conducted the experiments to examine the way Japanese EFL learners process syntactically ambiguous sentences from the perspective of their use of the linguistic information to avoid the ambiguity. If they have some problems to use the information and fail to comprehend the sentences, there would be some clues to find their difficulty on sentence processing.

In addition, it is gradually revealed that the sentence processing of Japanese EFL learners tend to vary depending on their proficiency (Hashimoto, 2011; Nagai, 2011). It is said that language processing of the learners becomes automatic and is done unconsciously as their learning progresses. This improvement is defined as “automatization” process and is gradually researched from a neurophysiological perspective in these days (Oishi, 2006; Yoshida, Yokokawa, Murase, Tanabe, Makita and Sadato, 2009). The effects of proficiency cannot be ignored to reveal Japanese EFL learners' mechanism of syntactic parsing and its developmental process, but it is still remain unresolved so far. It is required to reveal the relationship between proficiency and language learning of Japanese EFL learners to advance the research of their syntactic parsing. In this dissertation, the effects of learner's proficiency on their syntactic parsing are examined from both psycholinguistic and neurophysiological perspectives. In order to promote educational achievements in the domain of reading comprehension of Japanese EFL learners, their acquiring and developing mechanism of syntactic parsing need to be investigated and possible directions for improvements be pointed out.

1.3 Overview

Chapter 2 gives an overview of previous research in the topic of the parsing sentences among native speakers of English and among Japanese EFL learners from both psycholinguistic and neurophysiological perspective. Then, Chapter 3 presents the details of the experiment that was implemented in order to examine how Japanese EFL learners process syntactically ambiguous sentences from eye-tracking study. Chapter 4 presents the design and results of the experiment that was implemented in order to examine the neurophysiological processing of syntactic and semantic information in sentence processing for Japanese EFL learners from event-related potentials study. Chapter 5 reviews the previous studies that investigated the effects of repetition and the task when readers comprehend the sentences and presents the results of the experiment which investigated the effects of exposure to the linguistic information on syntactic parsing. Chapter 6 presents the general discussion on the results from the experiments in the previous chapters. Lastly, Chapter 7 presents conclusions of this dissertation and implications for further studies.

2. Literature Review

In this chapter, the previous studies on sentence processing are reviewed, especially from the perspective of processing linguistic information on parsing for native speakers of English and non-native English speakers including Japanese EFL learners. Then, the neurophysiologic studies of processing linguistic information on sentence processing for native speakers of English and non-native English speakers including Japanese EFL learners are presented. Finally, previous researches on the changes of the activation of learners' brain when they learn some second languages are reviewed.

2.1 Constructing Syntactic Representations with Linguistic Information

2.1.1 Modular Model

In traditional discussions of sentence processing by native speakers of English, most of sentence processing models assumed that readers can process the syntactic information correctly and automatically and considered whether they can process the semantic information simultaneously, focusing on ambiguity resolution of temporarily ambiguous sentences containing reduced relative (RR) clauses. Ferreira and Clifton (1986) monitored readers' eye movements when they read RR sentences or unreduced relative clauses sentences with animate/inanimate initial noun phrases (NPs). The examples of the target sentences are as follows.

(2) The defendant examined by the lawyer turned out to be unreliable. (animate, reduced)

(3) The evidence examined by the lawyer turned out to be unreliable. (inanimate, reduced)

(4) The defendant that was examined by the lawyer turned out to be unreliable. (animate, unreduced)

(5) The evidence that was examined by the lawyer turned out to be unreliable. (inanimate, unreduced)

(Ferreira & Clifton, 1986, p.352)

As for RR sentence beginning with animate NP (2), the NP "*The defendant*" is parsed as the subject of the main clause (MC) sentence structure until the following verb "*examined*" since the structure is simpler and more frequent than others. But when readers encounter the prepositional phrase "*by the lawyer*" and the following main verb "*turned*", MC sentence structure turns out to be the wrong construction. They need to parse the sentence again to build RR sentence structure. So sentences like (2) are determined as temporarily ambiguous between MC sentence and RR sentence owing to the semantic information of animacy. On the other hand, RR sentence beginning with inanimate noun phrase (3) never be parsed as MC sentence since the inanimate noun phrase never be the subject of MC sentence. So the sentence is immediately determined as RR sentence and there is no need to reconstruct the structure. Therefore, sentences like (3) is not determined as temporarily ambiguous and parsed faster than the sentence like (2). With regards to the unreduced relative clause sentences (4, 5), the relative "that" appears after the noun phrase, so it is obvious that the sentences are the unreduced relative clause constructions and that information promotes parsing.

The experiment revealed that participants read the unreduced relative clause sentences significantly faster than RR sentences, but that the animacy of initial NPs did not eliminate the ambiguity. They concluded that only the syntactic information affected initial parsing. This sentence processing model is called Modular Model, which claims that parsing relies solely on syntactic information and that semantic content has no relevance to the initial parsing process. In this theory, the independent syntactic processor (or parser) computes the sentence structure using syntactic information. After that, two principles of sentence processing, which are "minimal-attachment principle" and "late-closure principle," are used to determine the structure (Frazier and Rayner, 1982). The semantic and other information affects sentence processing after the construction of the syntactic structure of the sentence.

2.1.2 Constraint-Based Model

Trueswell, Tanenhaus, and Garnsey (1994) improved the method of Ferreira and Clifton (1986). They defined the morphological ambiguity of the relative verbs as the baseline condition of the ambiguity and controlled the relative verbs of the sentences morphologically. The examples of the target sentences are as follows.

Verb type - ambiguous

(6) The defendant examined by the lawyer turned out to be unreliable. (animate, reduced)

(7) The defendant that was examined by the lawyer turned out to be unreliable. (animate, unreduced)

(8) The evidence examined by the lawyer turned out to be unreliable. (inanimate, reduced)

(9) The evidence that was examined by the lawyer turned out to be unreliable. (inanimate, unreduced)

Verb type - unambiguous

(10) The poster drawn by the illustrator was used for a magazine cover. (inanimate, reduced)

(11) The poster that was drawn by the illustrator was used for a magazine cover. (inanimate, unreduced)

(Trueswell et al., 1994, p.291)

If the relative verbs are morphologically ambiguous (regular verbs), the syntactic structures of the sentences at this point are ambiguous between MC sentence and RR sentence since the past tense and the past participle forms of the verbs are identical. So the sentences become temporarily ambiguous when the readers see the verbs for the first time. However, if the relative verbs are morphologically unambiguous (irregular verbs), the verbs have different forms for its past tense and its past participle form, so there is no ambiguity with respect to the structures of the sentences, there is only one valid parse. This information is called morphosyntactic information, which can determine the syntactic structures of the sentences.

Trueswell et al. found that RR sentences with animate initial NPs and morphologically ambiguous relative verbs took longer to read compared to RR sentences with inanimate initial NPs. They concluded that the results showed clear evidence that the semantic information of animacy had immediate effects on disambiguation. This sentence processing model is called Constraint-Based Model. The Model insists that not only syntactic but also semantic and other information is used on parsing and one sentence structure are selected from some of the possible structures by using the linguistic information.

2.1.3 The Effects of Working Memory on Syntactic Parsing

Some previous studies take memory capacity of readers, especially working memory (WM) capacity, into account on syntactic parsing. Daneman and Carpenter (1980) first proposed the idea that WM is an important factor in processing information and WM capacity differs across individuals. WM is assumed to be a limited capacity system of the brain that can process and store the information simultaneously. There is a trade-off between the processing and storage function, so if one of the functions spends a lot of WM capacity, the other function cannot use a lot of capacity and that makes the overall function of WM inefficient (Just and Carpenter, 1992). Daneman and Carpenter (1980) constructed a test that measures individual WM capacity that correlates with reading comprehension performance called "the reading span test". They gave the reading comprehension tasks to native speakers of English after measuring their WM capacity. They found a high correlation between the scores of the test and the tasks. If WM capacity is large, WM can process and store more information simultaneously, allowing the reader to comprehend the sentence more efficiently and accurately.

Just and Carpenter (1992) replicated the study of Ferreira and Clifton (1986) in terms of the individual differences of WM capacity. They divided the participants into high (large) and low (small) span groups and revealed that the information of the inanimate NPs eliminated ambiguity only for the high span group, indicating that high span readers can use syntactic and semantic information simultaneously, but low span readers can use only the syntactic information for initial parsing. In recent research, Clifton, Traxler, Mohamed, Williams, Morris, and Rayner (2003) found no effect of the animacy information or WM capacity for parsing by replicating the study of Trueswell et al. (1994), whereas Traxler, Williams, Blozis, and Morris (2005) argued that helpful semantic cues reduced or eliminated the effects of syntactic complexity, especially in high span readers.

Not only the semantic information, but also the use of the morphosyntactic information for ambiguity resolution has been discussed. MacDonald, Just, and Carpenter (1992) proposed "The Capacity Constrained Parsing Model" which insists that the strategy of parsing is different from the individual differences of WM capacity. When the reader encounters the syntactically ambiguous sentences, high span readers can maintain multiple possible constructions (MC and RR constructions) when they encounter morphologically ambiguous verbs (regular verbs) and use them for sentence processing. On the other hand, low span readers can maintain only one possible construction that is more frequent than others (MC construction), so if it does not fit the structure, they fail to comprehend the sentence.

They made the group of MC sentences, RR and unreduced relative clause sentences that only the first verbs after the first NP are morphologically controlled and conducted a self-paced reading experiment. The examples of the target sentences are as follows.

MC sentence - unambiguous

(12) The experienced soldiers spoke about the dangers before the midnight raid.

MC sentence - temporarily ambiguous

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

RR sentence - unambiguous

(14) The experienced soldiers who were told about the dangers conducted the midnight raid.

RR sentence - temporarily ambiguous

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

(MacDonald et al., 1992, p.61)

If the first verbs are morphologically ambiguous (13, 15), it is difficult to judge whether the verbs are the main verb or the relative verb only by itself. So readers cannot decide the structure until the disambiguating points of the sentences. In parsing those sentences, high span readers can maintain two possible structures and use that information to decide the one certain structure at the disambiguating point. MacDonald et al. insisted that this process increases the reading time. On the other hand, low span readers can only maintain more frequent structure, so they insisted that if the sentence structure was more frequent one, the reading time get faster than high span readers, but if the structure was not frequent one, they fail to comprehend the sentences and the error rates of the comprehension questions increase.

With regards to the main verb sentence condition, high span group took relatively more time in reading the ambiguous sentences than the low span group. The results are consistent with the model. As for the relative clause sentence condition, low span group made more errors than high span group, but the reading time did not increased owing to the WM capacity. MacDonald et al. discussed that high span readers postponed the process of the sentence when they encounter the rare structure.

2.2 The Use of Linguistic Information by L2 Learners

2.2.1 Semantic Information

It is said that L2 learners including Japanese EFL learners rely more on lexical, semantic and pragmatic information and that the syntactic information is absent in their sentence processing (Shallow Structure Hypothesis: Clahsen & Felser, 2006).

With regards to Japanese EFL learners, Kadota, Hase, Yokokawa, Yoshida, Kuramoto, Tsurii, Yamashina, and Yoshida (2007) conducted an experiment on reading garden-path sentences with Japanese EFL learners and recorded their eye movements and overall reading times. The kind of ambiguity of the garden-path sentences are as follows (Pritchett, 1992): (a) Main Clause - Relative NP Ambiguity, (b) Complement Clause - Relative Clause Ambiguity, (c) Object - Subject Ambiguity, (d) Double Object Ambiguity, and (e) Lexical Ambiguity. The results showed that Japanese EFL learners also have difficulty processing garden-path sentences and that the reading times of the sentences were significantly affected by manipulating the semantic information. This means that Japanese EFL learners use the semantic information when they read garden-path sentences. Other research also concluded that Japanese EFL learners tend to use the semantic information when they parse sentences (Satoi, Yabuuchi & Yokokawa, 2002; Yabuuchi, Satoi & Yokokawa, 2001). However, Kadota et al. found that learners took longer to read unambiguous sentences containing unreduced relative clauses compared to RR sentences, which revealed their difficulty of processing syntactically complex sentences.

In addition, Nakanishi (2007) examined the use of syntactic and semantic information on processing RR sentences in terms of WM capacity. Participants read garden-path sentences which improved upon Ferreira and Clifton's (1986) target sentences and answered comprehension questions. Participants were divided into high and low span groups based on the results of Nakanishi's original reading span test for Japanese EFL learners. The study concluded that garden-path sentences were more difficult for Japanese EFL learners to process regardless of their WM capacity and both high and low span groups could make use of the semantic information to avoid ambiguity. Low span group could process the sentences as well as the high span group. The examples of the target sentences are as follows.

(16) The woman paid after the end of the month had worried the man.

(17) The woman that was paid after the end of the month had worried the man.

(18) The bill paid after the end of the month had worried the man.

(19) The bill that was paid after the end of the month had worried the man.

(Nakanishi, 2007, p.195)

2.2.2 Morphosyntactic Information

With regard to the morphosyntactic information, Juffs (1998) examined L2 learners' use of the information when they read RR sentences conducting the self-paced reading study. Morphosyntactic information of the verbs were manipulated with (a) irregular verbs which are unambiguous (Unambiguous), (b) regular verbs which are ambiguous between the transitive verb and the relative verb (Transitive), (c) regular verbs which are ambiguous among the transitive verb, the relative verb, and the transitive verb which does not take the direct object (Optional object). Optional object verb is the most ambiguous among the three. In addition, the cues that can resolve the ambiguity at the beginning of them (good cue) or the cues that cannot resolve the ambiguity unless readers read all of them (bad cue) are controlled after the morphosyntactic information (post-ambiguity cues). The examples of the target sentences are as follows.

Unambiguous

(20) The bad boys seen during the morning were playing in the park. (good cue)

(21) The bad boys seen almost every day were playing in the park. (bad cue)

Transitive

(22) The bad boys criticized during the morning were playing in the park. (good cue)

(23) The bad boys criticized almost every day were playing in the park. (bad cue)

Optional object

(24) The bad boys watched during the morning were playing in the park. (good cue)

(25) The bad boys watched almost every day were playing in the park. (bad cue)

(Juffs, 1998, p.122)

Juffs revealed that L2 learners including Japanese EFL learners can use the morphosyntactic information and the post-ambiguity cues for the ambiguity resolution. Moreover, some L2 learners failed to comprehend the sentences when there were the bad cues after the morphosyntactic information. He concluded that L1 parsing strategies affected to the L2 processing of the learners. He replicated the study in terms of WM capacity (Juffs, 2006), but few reliable effects of WM capacity for sentence processing were found. In this experiment, Japanese L2 learners showed a unique tendency for reading sentences. When the post-ambiguity cues were the good cues, they read the sentence slower if the morphosyntactic information is more ambiguous, but on the other hand, when the post-ambiguity cues were the bad cues, they read the sentence faster if the morphosyntactic information is more ambiguous. He argued that since learners' L1 (Japanese) was the head-final language, so the L1 parsing strategies affected the results. Juffs and Harrington (2011) insist that L1 overwhelms the individual differences of WM capacity from the results of their previous research.

But Nakanishi and Yokokawa (2011) found the extra cost for syntactic processing task on Japanese EFL learners' WM capacity. They included semantic judgment task, syntactic judgment task, and comprehension tasks in the reading span test and the score of the test was significantly decreased when there was the syntactic judgment task in the test. The results indicate that Japanese EFL learners' syntactic processing requires high processing costs in their WM and their syntactic processing is not as automatic. There is the possibility that they do not process the syntactic information unless they are required to.

2.3 Processing of Linguistic Information from Neurophysiological Perspective

It is difficult to investigate whether readers use the linguistic information immediately and accurately for syntactic parsing only by the psycholinguistic experiments. Recently, some neurophysiological methods that focus on brain activation in processing linguistic information gradually become more used to reveal language processing system. One of the methods is called event-related potentials (ERP), which records electrical signals (brain waves) in the brain. This method can detect several distinctive ERP components that relates to linguistic information processing when human encounter the violations in the sentences. Since this method can detect temporal change in the brain quite accurately, it might be effective to investigate the on-line language processing of the brain.

Some of the potentials are already defined as signals which indicate reader's detection of the violations in the sentences by examining native speakers of English. One of them called "N400" indicates the semantic violations, which is the negative potentials peaking 400 milliseconds (msec.) after the reader encounter semantically incongruent point in the sentence (Kutas and Hillyard, 1980a; 1980b). The examples of the target sentences are as follows.

(26) It was his first day at work. (Small / Congruous)

(27) He spread the warm bread with *socks*. (Small / Incongruous)

(28) Please get the file from the cabinet. (Large / Congruous)

(29) I take coffee with cream and engine. (Large / Incongruous)

(Kutas & Hillyard, 1980b, p.102)

In Small / Incongruous condition (27), the negative potential was detected 400 msec. after readers saw semantically inappropriate word (*socks*). In contrast, in Large / Congruous condition (28), the positive potential was detected 560 msec. after readers saw large words (cabinet). So the negative potential thought to reflect the detection of the semantic violations in the sentences. Kutas and Hillyard (1983) examined and compared ERP components when readers saw semantic and grammatical violations in the sentences. The examples of the target sentences are as follows.

(30) The leopard is a very good *napkin*. (Sentence Terminal Semantic Anomalies)

(31) A low often brings *kitten* or snow. (Sentence Intermediate Semantic Anomalies)

(32) Some storms have *thunders* and lightning. (Grammatical Error-Noun Number)

(33) Then she *dig* a hole with her rear feet. (Grammatical Error-Verb Number)

(34) Air does not always *had* the same humidity. (Grammatical Error-Verb Tense)

(Kutas & Hillyard, 1983, p.550)

In sentence (30) and (31), the negative potentials peaking 400 msec. after readers saw semantic inappropriate words were detected (N400). On the other hand, in sentence (32), (33), and

(34), negative potentials were not detected and the positive potentials were detected 300 msec. after readers saw grammatical errors. The results also indicate that N400 reflects semantic violations rather than grammatical violations in the sentences.

The potential “LAN” (left anterior negativity) indicates the syntactic violations including phrase structural violations (Neville, Nicol, Barss, Forster, and Garrett, 1991). LAN is the negative potentials peaking 300-500 msec. after readers encounter syntactically incongruent point in the sentence, especially in the left hemisphere of the brain. The potential “ELAN” (early left anterior negativity) reflects faster syntactic processing than LAN, which peaks 100-200 msec. after readers saw syntactic violations. The examples of the target sentences are as follows.

(35) The man admired Don’s sketch of the landscape.

(36) *The man admired Don’s *of* sketch the landscape.

(Neville et al., 1991, p.153)

In syntactic violation condition (36), the negative potentials peaking 125 msec. after readers encounter the violations (N125) were detected in anterior regions of the left hemisphere. After that, the negative potentials peaking 300-500 msec. after readers encounter the violations (N300-N500) were detected in temporal and parietal regions of the left hemisphere. These ERP components are thought to indicate the response to the syntactic violations.

Moreover, the potential “P600” reflects the process of syntactic information, including syntactic violations and syntactic ambiguity. It is also said that P600 components reflect syntactic complexity and syntactic reanalysis when readers encounter complex sentences. P600 is the positive potentials peaking about 600 msec. after readers encounter syntactically incongruent or ambiguous point in the sentence (Hagoort, Brown, & Groothusen, 1993; Osterhout & Holcomb, 1992). Hahne and Friederici insist that LAN (ELAN) reflects initial syntactic parsing of the sentence processing and P600 reflects the reanalysis and repair of the sentence processing using the syntactic and semantic information (Friederici, 2002; Hahne & Friederici, 1999).

Recently, L1 speakers’ responses to morphological violations of the verbs were measured through the ERP method (Newman, Ullman, Pancheva, Waligura, and Neville, 2007). Newman et al. investigated whether the responses to morphological violations of regular verbs and irregular verbs were different or not and tried to reveal the neural processing system of the morphological information. They also observed the response to phrase structural violations and semantic violations based on Neville et al. (1991) to compare the response to morphological violations. The examples of the target sentences are as follows.

morphological violations (regular verbs)
(37) Yesterday I frowned (**frown*) at Billy.
morphological violations (irregular verbs)
(38) Yesterday I ground (**grind*) up coffee.
phrase structural violations
(39) Yesterday I drank Lisa's brandy by the fire. / *Yesterday I drank Lisa's *by* brandy the fire.
semantic violations
(40) Yesterday Daniel sipped his tonic (**sarcasm*) for hours.

(Newman et al., 2007, pp.438-439)

In morphological violation condition, LAN and P600 were detected in regular verbs, but only P600 was detected in irregular verbs. In phrase structural violation condition, LAN and P600 were detected and N400 was detected in semantic violation condition. These results indicate that L1 speakers' processing of the morphological information is different between regular verbs and irregular verbs. Newman et al. insisted that the processing of regular verbs is more rule-governed and compositional, but the processing of irregular verbs depends more on lexical memory.

2.4 Neurophysiological Processing of L2 Reading

In the L2 field, Ojima, Nakata and Kakigi (2005) compare ERP components among native speakers of English, advanced Japanese L2 learners and intermediate Japanese L2 learners. Ojima et al. presented semantically or syntactically (S-V number agreement) correct and incongruent sentences to the participants and recorded ERP when they read the target sentences. The examples of the target sentences are as follows.

semantic violations

(41) The house has ten rooms (**cities*) in total.

S-V number agreement violations

(42) Turtles move (**moves*) slowly.

(Ojima et al., 2005, p.1224)

In semantic violation condition (41), N400 was detected in all 3 groups and only the time course of the brain activation was different among the groups. In addition, P600 was detected only in L1 group. On the other hand, in S-V number agreement violation condition (42), the potentials like LAN were detected only in L1 and advanced L2 groups and not in intermediate L2 group. P600 was also detected only in L1 group. Ojima et al. concluded that semantic processing is robust from early levels of L2 learning, but the development of syntactic processing is more dependent on proficiency. Wakabayashi, Fukuda, Bannai and Asaoka (2007) also concluded that there were no ERP responses to the S-V number agreement violations for Japanese EFL learners, although there was P600 response to the S-V personal agreement violations.

In other research, Tomita, Fukuda, and Tatsuta (2003) also conclude that the appearances of N400 for Japanese EFL learners are affected by their proficiency, but there are no differences between high and low proficiency groups in the time course of the components, which is inconsistent to Ojima et al. (2005). In addition, Kubota and his colleagues (2003, 2004, 2005) investigated the response to the grammatical violations for advanced Japanese EFL learners using the Magnetoencephalography (MEG) and found the ERP components which is similar to ELAN (SF-M150), but that components appeared in both hemispheres of the brain, not only in the left hemisphere. These results indicate that Japanese EFL learners might process the grammatical information in early stage of processing like L1 speakers as their proficiency improves.

But Pakulak and Neville (2011) investigated and compared the brain activation to phrase structural violations for the English L1 speakers and German L2 speakers which were the same proficiency and revealed that the responses to the violations are quite different between L1 and L2 speakers. The examples of the target sentences are as follows.

(43) Timmy can ride the horse at his farm.

(44) *Timmy can ride the horse at my *his* farm.

(Pakulak and Neville, 2011, p.2756)

In L1 speakers, anterior negativity (AN), which is the same negativity as LAN but appears in both hemispheres of the brain, was detected 100 msec. after readers saw phrase structural violations (44). After that, P600 was also detected in L1 speakers' brain. On the other hand, in L2 speakers, AN was not detected and P600 was detected in the broader extent of the brain for longer period of time than L1 speakers. These results indicate that neural processing of the linguistic information is different between L1 and L2 speakers and L2 learners' processing does not become the same as that of L1 speakers even though their proficiency improves. Moreover, Newman, Tremblay, Nichols, Neville and Ullman (2012) investigate the effects of proficiency for the appearance of N400 in both L1 and L2 speakers. They conclude that the amplitude (the strength of the electrical signals) of N400 is affected by proficiency, but the latency (the time from the encounter of violations until the appearance of ERP components) and the ERP components after N400 are affected by the difference of L1 and L2 speakers.

In the L2 field, the relationship between the appearance of ERP components and proficiency is gradually becoming more discussed and L2 speakers' automaticity of language processing is gradually revealed in these days. But only a few studies are conducted so far and the effects of proficiency on ERP components still remain incompletely understood in many aspects.

2.5 Changes of the L2 Processing Mechanism by Learning

Recently, L2 learning experiments, which measures the changes of the brain activation and ERP components after language processing tasks, are gradually conducted. The ERP method is used to investigate whether learners acquire and learn sentence processing through the tasks or not. For example, Ojima, Nakamura, Matsuba-Kurita, Hoshino, and Hagiwara (2011) conducted three-year longitudinal study for Japanese elementary school students and measured their ERP components when they performed English word-picture matching task. Ojima et al. found that Japanese elementary school students improved their language processing and get close to L1 speakers' processing with increasing age.

In addition, Osterhout, Poliakov, Inoue, McLaughlin, Valentine, Pitkanen, Frenck-Mestre, and Hirschensohn (2008) investigated how L2 learners' brain activation change in classroom-based instruction and found that learners' brain activation changed in the aspect of ERP components, the sources of ERP components and the brain structure. These results indicate that classroom-based instruction might affect L2 learners' brain and L2 processing. Osterhout et al. insist that these changes can occur during the early stage of L2 acquisition. Moreover, the changes of the brain occur even human learn the artificial language. Morgan-short, Steinhauer, Sanz, and Ullman (2012) conducted implicit and explicit training of the artificial language to monolingual English speakers longitudinally and found that participants who received implicit training elicited native-like ERP components when they process the artificial language. This means adult foreign language learners' brain can improve native-like language brain mechanisms, depending on how they learn target language. In this experiment, behavioral performance did not differ between implicit and explicit training, so the ERP method is one of the effective way to investigate the changes of L2 learners through language learning.

In addition, recent studies examine L2 learners' language processing from neuroimaging technique like functional MRI (fMRI) or optical topography and investigate the brain activation through the blood flow and the amount of oxygen while they process sentences. For example, Nauchi and Sakai (2009) observed the activated region of the brain when L2 learners process L2 sentences using fMRI and found that left inferior frontal gyrus especially manages syntactic knowledge of the L2. Oishi (2006) used optical topography and investigated the activation of the brain when Japanese EFL learners listen or read English sentences.

With regards to L2 learning experiments using neuroimaging technique, Yusa, Koizumi, Kim, Kimura, Uchida, Yokoyama, Miura, Kawashima, and Hagiwara (2011) conducted fMRI experiment to Japanese EFL learners to examine how their brain activation changes when they learn new grammatical rules intensively. They found that learners' activation of the brain changed even when they process "uninstructed" complex sentences and they insist that adult learners' linguistic knowledge can be developed even after the critical period.

L2 learners' changes and improvements of the sentence processing are still remain unresolved so far, but neurophysiological methods seem to be effective and useful to investigate how learners learn and acquire linguistic knowledge and mechanism of sentence processing.

2.6 Residual Problems

From the previous studies mentioned in this chapter, L2 learners including Japanese EFL learners seem to rely more on semantic information and their syntactic processing seems to be different or absent comparing to L1 speakers (Shallow Structure Hypothesis). This means that there are some possibilities that they cannot use the syntactic information and cannot build the sentence structure correctly through parsing. But only a few studies which investigated Japanese EFL learners' sentence processing have been found so far.

Japanese EFL learners' syntactic representations are not developed enough, so it is impossible to assume that they can process the syntactic information automatically like native speakers of English. In addition, since learners' English proficiency vary greatly from person to person, it is important to investigate what kind of information is used (or not used) in their ambiguity resolution and sentence processing depending on their proficiency. Moreover, the effects of individual differences of learners' WM capacity also need to be investigated based on their proficiency.

In the next chapter, an eye-tracking experiment was conducted to explore when and how the explicit linguistic information (semantic and morphosyntactic information) affects learners' sentence processing to avoid ambiguity and construct syntactic representations and how the effects of information differ depending on the development of proficiency and the increase of WM capacity.

3. The Use of Animacy and Morphosyntactic Information in Comprehending Temporarily Ambiguous Sentences: An Eye-Tracking Study

In order to determine how Japanese EFL learners use semantic and morphosyntactic information, the present study conducted eye-tracking experiment to examine the way Japanese EFL learners with intermediate proficiency process temporarily ambiguous sentences from the perspective of their use of explicit information, taking account of individual differences of learners' proficiency and WM capacity. Based on Trueswell et al. (1994), in Experiment 1, the use of animacy (the semantic information) is examined when Japanese EFL learners process temporarily ambiguous and unambiguous RR sentences. In Experiment 2, the use of the morphosyntactic information is examined when Japanese EFL learners process temporarily ambiguous and unambiguous MC and RR sentences based on MacDonald et al. (1992). Learners' proficiency was restricted to intermediate level to investigate how they process temporarily ambiguous sentences during the middle stage of acquisition of English.

3.1 Method

3.1.1 Participants

A total of 29 Japanese undergraduate and graduate EFL learners participated in the experiment in return for a small fee. All of them had normal or corrected-to-normal vision.

3.1.1.1 Proficiency

Participants were measured for their proficiency using a short test, Oxford quick placement test (Oxford University Press, 2004) and classified into groups in compliance with standards of Common European Framework of Reference for Languages (CEFR). The test took 30 minutes and included 60 questions. Based on the results, the upper intermediate group with eleven participants (B2 in CEFR; score range: 40-47) and the lower intermediate group with fourteen participants (B1 in CEFR; score range: 30-39) were defined as the intermediate group consisting of 25 participants.

3.1.1.2 WM Capacity

Participants were also required to take the reading span test which is the revised version of

Nakanishi (2007) in order to determine their WM capacity. In this test, they read aloud the target sentences on the computer monitor and remember the final word of the sentences simultaneously for several times in a row. The sentences were presented with the Cedrus' "SuperLab Pro," the stimulus presentation software.

The target sentences were presented to participants under the condition of two, three, four, and five sentences. Each condition comprised three sessions. Participants were asked to read the sentences aloud increasingly longer sets of sentences until they finished reading three sets of five sentences in the five-sentence condition. They were required to read aloud the sentence clearly at their own pace and some mistakes or ambiguity on the pronunciation was permitted. There were two sessions of the two-sentence condition for practice before starting the test. All of the target sentences were semantically unrelated.

The procedure of the RST was as follows. First, the sentence condition of the session was presented on the monitor and participants required to press the spacebar when they are ready for the session. When they pressed the spacebar, after the mark "++++++++" was presented on the center of the computer monitor for one second, a target sentence appeared on a center of the monitor in one line. Participants were required to press the spacebar immediately after they had read aloud the sentence and remember the final word of the sentence. Then, the next sentence appeared on the monitor following the "++++++++" mark. Participants were asked to read the sentence aloud and remember the final word of the sentence while remembering the last word of the previous sentence. This procedure was repeated until they arrived at presenting the green screen on the monitor, indicating that the end of the session. Then on the answer sheet, participants were required to write down the final words of the sentences that had been presented in the session while the green screen was presented on the monitor. For example, under the four-sentence condition, after participants had read the four sentences aloud, they encountered the green screen indicating the end of the session. Then, they were required to write the four final words of the sentences on the answer paper. The test took approximately fifteen minutes including the instruction of the test. The example of the "++++++++" mark and the target sentence on the screen are showed in Figure 1.

There was a time limit of the presentation of the green screen; 10 seconds for the two-sentence condition and 5 seconds were added when the sentence condition advanced by one sentence. Thus, participants were given 25 seconds for recalling final words of the sentences in the five-sentence condition. They were required to move on to the next session immediately after the end of the presentation of the green screen. Writing the final word of the last sentence of the session on the answer sheet first was prohibited in order to avoid the ceiling effect. The method of scoring the test was to count the total number of words that were correctly recalled.

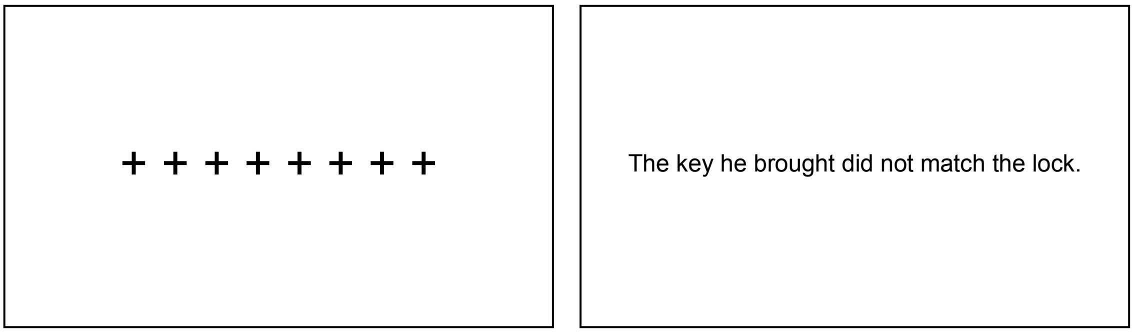

Figure 1. The example of the mark (Left) and the target sentence (Right) on the screen

Table 1. Descriptive statistics of the test (intermediate group) (*n*=25)

	Range	Number	Maximum	Minimum	Mean	SD
Proficiency	60-0	25	46	36	39.44	2.65
WM	42-0	25	37	19	27.96	5.00

3.1.2 Materials

3.1.2.1 Experiment 1: The Use of Animacy

This experiment examined the use of the semantic information (the animacy information) for Japanese EFL learners. Sixteen pairs of RR sentences with animate/inanimate initial NPs (total 32 sentences) were made. The materials contained the *NP* in two words (R1), the *relative verb* (R2), the “*by*” *phrase* in three words (R3), the first two words of the *main verb phrase* (R4), the *ending* (the rest of the target sentence) up to three words (R5). All of the animate initial NPs had nouns related to people. All of the relative verbs used morphologically ambiguous transitive verbs (e.g., *graded*). Pronouns were excluded in the materials in order to avoid anaphora. The familiarity rate of words for Japanese EFL learners was over 5.00 on a seven point scale (seven = highly familiar; Yokokawa (Ed.), 2006), except the word “describe,” which was measured 4.98.

RR sentences with animate initial NPs were initially ambiguous between MC and RR constructions and they were disambiguated in R3 (the “by” *phrase*) (Trueswell et al., 1994).

The true/false comprehension question sentences were made by using the words of the target sentences. Each of the target sentences had a comprehension question and the numbers of the "true" and "false" answers among the materials were made equal. Examples of the target sentences and comprehension questions are as follows. All of the target sentences appear in Appendix A.

(45) The student / graded / by the teacher / got a / low mark. (animate)

Q: The student was graded by the teacher. (A: True)

(46) The paper / graded / by the teacher / got a / low mark. (inanimate)

Q: The paper was graded by the teacher. (A: True)

3.1.2.2 Experiment 2: The Use of Morphosyntactic Information

This experiment examined the use of the morphosyntactic information for Japanese EFL learners. Four pairs of morphologically ambiguous and unambiguous initial verbs were selected (push/drive, supply/give, teach/show, send/write). Twelve pairs of ambiguous/unambiguous MC sentences (total 24 sentences) and also twelve pairs of ambiguous/unambiguous RR sentences (total 24 sentences) were made based on the verb pairs. All of the sentences contained the *NP* in three words (R1), the *main/relative verb* (R2), and the *prepositional phrase* (PP) or the *object phrase* (OP) in three words (R3). MC sentences contained the first three words of the *PP* (R4) and the *final word* of the sentence (R5) after R3. RR sentences contained the first two words of the *main verb phrase* (R4) and the *ending* (the rest of the target sentence) in two words (R5) after R3. All of the sentences had animate initial NPs related to people. Pronouns were excluded in the materials in order to avoid anaphora. The familiarity rate of words for Japanese EFL learners was over 5.00 on a seven point scale (seven = highly familiar; Yokokawa (Ed.), 2006).

The sentences with morphologically ambiguous initial verbs were initially ambiguous between MC and RR constructions. MC sentences were disambiguated in R5 (the final word of the sentence) and RR sentences were disambiguated in R4 (the first two words of the main verb phrase) (MacDonald et al., 1992).

The true/false comprehension question sentences were the same as Experiment 1. Examples of the target sentences and comprehension questions are as follows. All of the target sentences appear in Appendix A.

MC sentence

(47) The young girl / sent / a birthday card / to the new / friend. (ambiguous)

Q: The young girl was sent a birthday card. (A: False)

(48) The young girl / wrote / a birthday card / to the new / friend. (unambiguous)

Q: The young girl wrote a birthday card. (A: True)

RR sentence

(49) The young girl / sent / a birthday card / thought about / the present. (ambiguous)

Q: The young girl sent a birthday card. (A: False)

(50) The young girl / written / a birthday card / thought about / the present. (unambiguous)

Q: The young girl thought about the present. (A: True)

3.1.3 Procedure

Experiments 1 and 2 were conducted together in one session. Four material sets were made and each set had 60 sentences including 20 target sentences (Experiment 1; four sentences each of the sentences with animate/inanimate initial NPs: Experiment 2; three sentences each of the ambiguous/unambiguous MC sentences and the ambiguous/unambiguous RR sentences) and 40 filler sentences with comprehension questions. All of the target sentences were picked only once to build the material sets avoiding the redundancy of the sentence pairs. The numbers of the "true" and "false" answers of the comprehension questions were made equal among 60 sentences. Four filler sentences were presented for practice before the experiment.

The eye movements of the participants were detected using the eye tracker "VOXER" from nac image technology with a spatial resolution of 0.3° and sampling frequency of 60 Hz and recorded to a Mini DV tape. The tracker measured only the movement of the right eye. Sentences were presented randomly on a 15-inch computer monitor with the Cedrus' "SuperLab Pro" and the answers for the comprehension questions were recorded. All the characters were printed in Tahoma font. The size of the characters was set to 22.

Participants sat 70 cm away from the monitor. Before the measurement, the calibration which adjusts and matches the participants' actual staring point and the eye position was conducted. The tracker keeps tracking the positions of their faces and fixating points on the monitor once their faces are registered, even if they slightly move their heads. Participants were required not to move their heads or relax their posture too much after the calibration. The experiment took approximately 30 minutes including the instructions of the test and calibration.

The procedure of the experiment was as follows. First, the mark “+” was presented at the center of the monitor and participants stared at the mark and pressed the spacebar when they were ready. Then, a sentence appeared at the center of the monitor in one line. Participants read the sentence silently from the beginning. They were required to read it as quickly and as accurately as possible. They pressed the spacebar immediately after they had comprehended the sentence. Then, a comprehension question was presented on the monitor. Participants pressed the “f” key for true and the “j” key for false depending on which of the answers they thought was the correct one. Then, the mark “+” was presented again and participants repeated the procedure. Participants were allowed to take a rest while the mark “+” was being shown on the monitor.

The example of the “+” mark, the target sentence, and true/false comprehension question sentence on the screen are as follows.

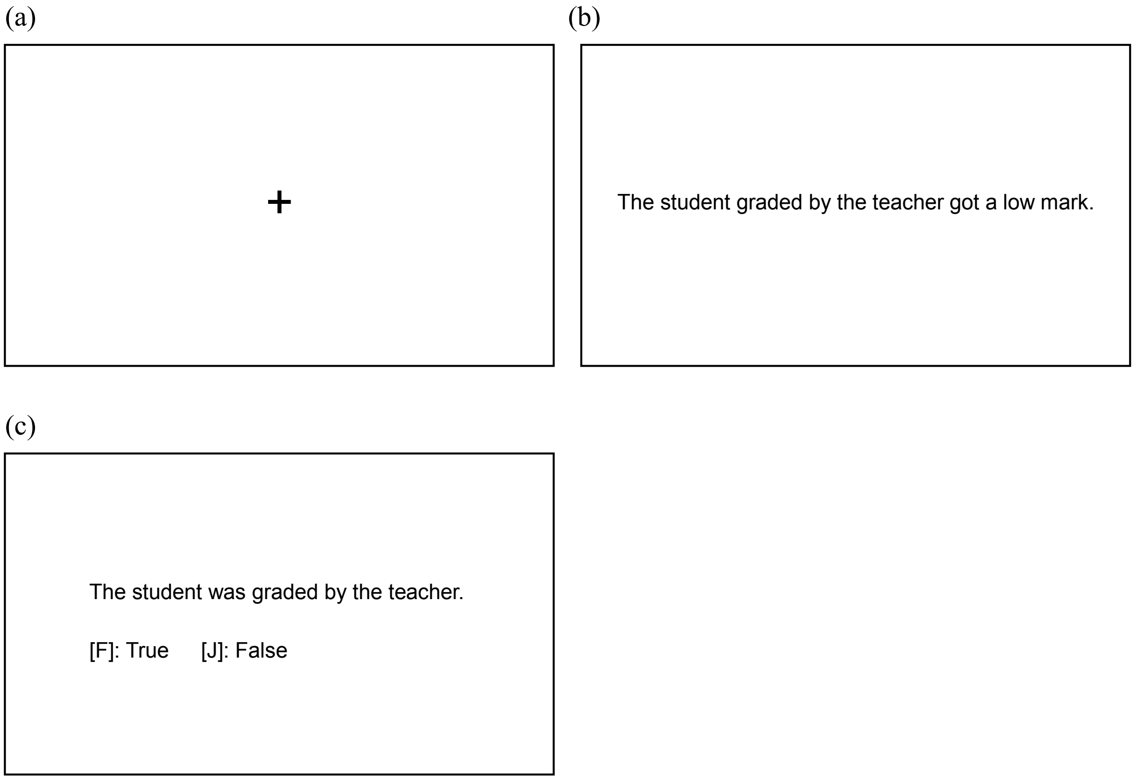

Figure 2. The example of the mark (a), the target sentence (b) and true/false comprehension question sentence (c) on the screen

3.1.4 Data Analysis

3.1.4.1 Linear Mixed-Effects Model

The answers of the comprehension questions were classified by item conditions and the error rates were calculated. Paired *t*-test was conducted to compare the mean of the error rates between the two conditions.

The eye movement data was analyzed using "EMR-dFactory" from nac image technology to calculate five standard eye-movement measures for each participant. *First-pass time* was defined from when the eye position entered into the region for the first time to when the eye position went out the region moving to other regions, left or right. *Go-past time* was the reading time from the first fixation in a region until the reader's fixation crossed the right-hand boundary of the region. This measure also included refixations of preceding regions and the target region itself. The time was calculated only in R2, R3 and R4. *Second-pass time* included the rest of the reading time in the region after the first-pass time. Zero reading time was also included in the analysis of the second-pass time. *Total time* was the sum of the reading time in a region, regardless of order. *Frequency of fixation* was the total number of times that the eye position entered into the region. The duration was defined over 100 milliseconds (msec.). Staying on any letters of the region was defined as the fixation duration of the region. Blinks or regressions within the same region were all disregarded and counted as fixation in the region.

In Experiment 1, two sentences without R5 were discarded from the analysis to avoid the wrap-up effect in the analysis of R4. In addition, participants who failed to comprehend more than half of each condition of the sentences were removed from the analysis of that condition. In Experiment 1, seven people in animate condition and two people in inanimate condition were removed. In Experiment 2, four people in ambiguous condition of MC sentences, one person in unambiguous condition of MC sentences, eleven people in ambiguous condition of RR sentences, and ten people in unambiguous condition of RR sentences were removed.

After that, the reading times were divided by the number of syllables of the regions. The data which exceeded the average plus or minus 2.5 standard deviation was removed as outliers. This procedure led to exclusion of 3.11% of the data. Then, the average was calculated again and the data which exceeded the average plus or minus 2.5 standard deviation was changed into the cutoff value, leading to the replacement of 1.94% of the remaining data.

The data analysis was conducted using the linear mixed-effects (LME) model. The model can treat participants and items as random effects. In addition, it does not require that individuals have the same number of data and it does not require aggregation across trials. Moreover, this model can treat continuum data such as test scores as covariance, so the model can analyze proficiency effects or WM capacity effects without grouping participants arbitrary.

The effects of item conditions of the sentences (animacy or ambiguity) constituted the first level of the model. At the second level, the effects of proficiency or WM capacity were tested separately. Proficiency was centered at the sample mean 39.44 and WM capacity was centered at the sample mean 27.96. In each experiment, three separate models were fitted for each dependent measure for each region. Model 1 tested only for the effects of item conditions. Model 2 tested for the effects of proficiency and Model 3 tested for the effects of WM capacity.

3.1.4.2 Further Analysis

The available data of the participants were also divided into two groups depending on their proficiency and compared the *First-pass time* and the *Second-pass time* of the regions to investigate the difference between the two groups: the upper intermediate group with 11 participants (B2 in CEFR) and the lower intermediate group with 14 participants (B1 in CEFR). In the following discussion, the upper intermediate group is referred to as the high proficiency group and the lower intermediate group as the low proficiency group. Analysis with two proficiency groups was conducted using MANOVA with (1) region, (2) proficiency and (3) animacy or ambiguity as independent variables and reading times as dependent variables. In addition, a two-way repeated measures ANOVA was conducted with region and proficiency classified by animacy or ambiguity as independent variables and reading times as dependent variables. Paired comparisons (Scheffe) were conducted for all of the independent variables. The error rates for comprehension questions were calculated in each group.

Table 2. Descriptive statistics of the proficiency test (B2 and B1 proficiency groups)

	Range	Number	Maximum	Minimum	Mean	SD
Overall	60-0	25	46	36	39.44	2.65
B2	40-47	11	46	40	41.82	2.09
B1	30-39	14	39	36	37.57	1.02

In addition, the intermediate learners were also divided into three groups depending on the WM capacity; high, middle and low. In the further analysis, the high span group and the low span group were analyzed to compare the difference of the *First-pass time* and the *Second-pass time* of the regions. The high span group was defined within the score between Mean+1/2SD[1] (30.46) to Mean+2SD (37.95) and consisted of 7 participants. The low span group was defined within the score between Mean-2SD (17.97) to Mean-1/2SD (25.46) and involved 8 participants. The data analysis was conducted using MANOVA with (1) region, (2) WM capacity and (3) animacy or ambiguity as independent variables and reading times as dependent variables. In addition, a two-way repeated measures ANOVA was conducted with region and WM capacity classified by animacy or ambiguity as independent variables and reading times as dependent variables. Paired comparisons (Scheffe) were conducted for all of the independent variables. The error rates for comprehension questions were calculated in each group.

Table 3. Descriptive statistics of the reading span test (divided by three groups)

	Range	Number	Maximum	Minimum	Mean	SD
Overall	0-42	25	37	19	27.96	5.00
High	30.46-37.95	7	37	31	34.14	2.34
Middle	25.46-30.46	10	30	26	28.10	1.29
Low	17.97-25.46	8	25	19	22.38	2.20

3.2 Results and Discussions of Experiment 1: The Use of Animacy

3.2.1 Overall

The error rates were 22.00% in the animate condition and 12.00% in the inanimate condition. Paired *t*-test (two-tailed) revealed that the difference between the two conditions was marginally significant ($t(24)=1.92$, $p=.067$, $r=.365$). It indicates that Japanese EFL learners with intermediate proficiency use the animacy information to comprehend RR sentences.

Table 4 shows the results of Model 1 for Experiment 1. It tested only for the effects of animacy (animate vs. inanimate). In R1 (NP), there were significantly longer first-pass time (246 msec. vs. 290 msec.), second-pass time (109 msec. vs. 170 msec.), and total time (379 msec. vs. 464 msec.) in the inanimate condition than in the animate condition (all $ps<.05$). Moreover, the

[1] Overall Mean (27.96) and SD (5.00) were used in this calculation.

increase of frequency of fixation in the inanimate condition was marginally significant (1.8 time vs. 2.0 time; *p*=.086). On the other hand, first-pass time (230 msec. vs. 196 msec.; *p*<.05), total time (444 msec. vs. 379 msec.; *p*<.05), and frequency of fixation (2.8 time vs. 2.2 time; *p*<.01) in R3 ("by" phrase) and go-past time in R4 (main verb phrase) (364 msec. vs. 301 msec.; *p*<.05) decreased significantly in the inanimate condition than in the animate condition. In addition, the decrease of second-pass time in the inanimate condition was marginally significant in R3 (222 msec. vs. 165 msec.; *p*=.063). These results revealed that intermediate learners pay continuous attention to the animacy information in the NPs when they read the sentences and that the information facilitates disambiguation and sentence processing of learners.

Table 4. The LME model for Experiment 1: Overall

	First-pass (msec.)	Go-past (msec.)	Second-pass (msec.)	Total (msec.)	Fixation (time)
R1 (NP)					
Intercept (Inanimate)	290.19(15.27)**		170.47(19.56)**	463.69(31.03)**	2.00(.108)**
Animate effect	-44.25(19.80)*		-61.69(25.70)*	-84.87(35.44)*	-.223(.129)***
R2 (relative verb)					
Intercept (Inanimate)	351.97(25.31)**	444.18 (31.25)**	288.81(34.99)**	667.52(50.12)**	2.34(.143)**
Animate effect	6.62(31.56)	-36.93(39.48)	60.29(51.11)	45.61(63.21)	-.039(.178)
R3 ("by" phrase)					
Intercept (Inanimate)	195.81(14.90)**	299.27(18.74)**	164.99(23.47)**	379.11(27.20)**	2.23(.168)**
Animate effect	34.64(14.45)*	-10.99(23.50)	57.22(30.55)***	64.80(32.12)*	.589(.208)**
R4 (main verb phrase)					
Intercept (Inanimate)	260.91(15.66)**	300.52(23.16)**	174.89(24.54)**	425.59(30.33)**	2.10(.127)**
Animate effect	6.17(20.47)	63.38(32.01)*	33.91(34.03)	62.84(39.46)	.241(.185)
R5 (ending)					
Intercept (Inanimate)	232.34(18.98)**		71.58(14.95)**	346.25(28.51)**	1.41(.079)**
Animate effect	1.95(25.11)		14.78(21.29)	-19.03(37.20)	.140(.108)

Note. Estimates are maximum likelihood. Standard errors are in parentheses.
* : $p < .05$ ** : $p < .01$ *** : $.05 < p < .10$

3.2.2 Proficiency

Table 5 shows the results of Model 2 which tested for cross-level interactions of proficiency and animacy. The results showed a cross-level interaction between proficiency and the magnitude of the inanimate NP effect in first-pass time in R3 (*p*<.01) and marginal cross-level interactions in first-pass time (*p*=.053) and go-past time (*p*=.070) in R2 (relative verb). The results indicate that these dependent measures decrease as learners' proficiency develops, suggesting that the use of the animacy information become automatized. In contrast, there were a cross-level interaction between proficiency and the magnitude of animate NP effect in first-pass time in R5 (ending) (*p*<.05) and a marginal cross-level interaction in first-pass time in R4 (*p*=.062). The results indicate that the first-pass time difference between animate and inanimate conditions increases with the development of proficiency in R4, while it decreases with the development of proficiency in R5. This means that proficient learners have the extra cost and take time to process temporarily ambiguous sentences right after the disambiguating regions (R3: "by" phrase).

Table 5. The LME model for Experiment 1: Proficiency

	First-pass (msec.)	Go-past (msec.)	Second-pass (msec.)	Total (msec.)	Fixation (time)
R1 (NP)					
Intercept (Inanimate)	290.10(15.58)**		170.92(19.43)**	463.53(31.69)**	2.01(.100)**
Prof. influence on intercept	.652(5.81)		10.22(7.18)	4.65(11.78)	.083(.037)*
Animate effect	-41.60(20.46)*		-66.93(26.34)*	-81.05(36.52)*	-.268(.131)*
Prof. influence on Animate effect	-3.78(7.61)		-.469(9.94)	-7.50(13.66)	.006(.048)
R2 (relative verb)					
Intercept (Inanimate)	351.92(23.83)**	442.62(30.12)**	288.95(35.27)**	667.39(50.89)**	2.34(.138)**
Prof. influence on intercept	-17.59(8.79)***	-20.82(11.21)***	1.16(13.14)	-7.22(18.76)	.099(.051)***
Animate effect	9.98(32.29)	-30.72(40.27)	51.28(52.32)	46.36(65.32)	-.065(.182)
Prof. influence on Animate effect	4.59(12.02)	7.62(15.34)	12.95(20.03)	4.43(24.45)	-.025(.068)
R3 ("by" phrase)					
Intercept (Inanimate)	195.53(13.20)**	299.28(18.73)**	165.16(23.41)**	379.32(27.45)**	2.24(.163)**
Prof. influence on intercept	-14.32(4.92)**	-7.36(6.91)	9.17(8.62)	-6.13(10.21)	.097(.060)
Animate effect	35.56(14.81)*	-10.58(24.22)	53.40(31.57)***	59.75(33.50)***	.548(.214)*
Prof. influence on Animate effect	2.95(5.51)	4.08(8.99)	-1.57(11.69)	9.55(12.33)	-.011(.079)
R4 (main verb phrase)					
Intercept (Inanimate)	260.73(15.68)**	298.81(23.09)**	175.38(24.71)**	424.89(30.70)**	2.10(.128)**
Prof. influence on intercept	-8.29(5.80)	-11.31(8.45)	7.28(9.29)	-5.61(11.60)	.036(.047)
Animate effect	.093(20.90)	59.86(32.82)***	28.76(35.16)	56.20(40.72)	.218(.190)
Prof. influence on Animate effect	14.63(7.79)***	17.03(12.28)	.256(13.30)	14.12(15.44)	-.005(.072)
R5 (ending)					
Intercept (Inanimate)	231.57(18.09)**		71.63(15.04)**	346.45(28.45)**	1.41(.080)**
Prof. influence on intercept	-.311(6.50)		.172(5.40)	5.49(10.36)	.027(.028)
Animate effect	17.65(25.23)		19.24(21.71)	-6.77(38.15)	.143(.111)
Prof. influence on Animate effect	-20.16(9.32)*		-7.69(8.20)	-21.35(14.15)	-.032(.042)

Note. Estimates are maximum likelihood. Prof. was centered at the sample mean, 39.44. Standard errors are in parentheses.
* : $p < .05$ ** : $p < .01$ *** : $.05 < p < .10$

In the further analysis, the error rates were particularly high in the low proficiency group in the animate condition. In the inanimate condition, there was only a small difference between high and low proficiency groups.

The main effect of proficiency was highly significant ($F(1, 955)=16.87$, $p<.01$) and the high proficiency group was 29 msec. shorter in First-pass time, but it was not significant in Second-pass time ($F(1, 955)=0.50$, $p>.05$). The interaction between animacy and proficiency was not significant in both First-pass time ($F(1, 955)<.01$, $p>.05$) and Second-pass time ($F(1, 955)=0.62$, $p>.05$). The low proficiency group could comprehend the target sentences correctly more often in the inanimate condition, even if it took more time to process the sentences.

In First-pass time, the interaction between proficiency and region was highly significant ($F(4, 955)=5.09$, $p<.01$). The high proficiency group was 62 msec. shorter in R2, 42 msec. shorter in R3 and 64 msec. shorter in R5. There were highly significant differences in all three regions (all *ps*<.01). On the other hand, the interaction between proficiency and region was approached significance in the Second-pass time ($F(4, 955)=2.26$, $p=0.061$). In R5, the low proficiency group was 55 msec. longer. There was a significant difference ($p=0.015$).

The interaction among animacy, proficiency and region was significant in both First-pass time ($F(4, 955)=3.07$, $p=0.016$) and Second-pass Time ($F(4, 955)=3.07$, $p=0.016$). In First-pass time, the high proficiency group was 105 msec. shorter in R5 in the animate condition. There was a highly significant difference ($p<.01$). In the inanimate condition, the high proficiency group was 84 msec. shorter in R2 and 69 msec. shorter in R3. There were significant differences in both two regions (R2: $p<.01$; R3: $p=0.025$). In Second-pass time, the high proficiency group was 160 msec. shorter in R2 in the inanimate condition. There was a highly significant difference ($p<.01$).

Clear effects of proficiency were found especially in the high proficiency group's reading times in the inanimate condition. The high proficiency group seemed to use the animacy information more effectively as indicated by the shorter reading times for R2 and R3 in the inanimate condition, and by the lower error rates in the inanimate condition. These results indicate that Japanese EFL learners can use the semantic information easily even if their proficiency is relatively low, but it was harder for the low proficiency group to process the sentences.

Table 6. Mean First-pass time and Second-pass time for animacy classified by proficiency (msec.)

			R1	R2	R3	R4	R5
First	Animate	High	190	230	153	209	157
		Low	178	269	167	211	262
	Inanimate	High	226	212	102	244	200
		Low	229	297	171	214	222
Second	Animate	High	173	443	238	225	134
		Low	216	400	234	226	206
	Inanimate	High	232	286	212	213	219
		Low	213	359	170	161	255

Table 7. Error rates for comprehension questions (%) (Experiment 1: Proficiency)

	Animate	Inanimate
B2	11.36	9.09
B1	30.36	14.29

3.2.3 WM Capacity

Table 8 shows the results of Model 3 which tested for cross-level interactions of WM capacity and animacy, and they appeared only in first-pass time and total time in R5. This suggests that WM capacity did not affect processing RR sentences with the animacy information. The effects of WM capacity on the semantic processing need to be examined together with the syntactic processing, so it is necessary to investigate intermediate learners' syntactic processing and the effects of WM capacity in Experiment 2.

Table 8. The LME model for Experiment 1: WM Capacity

	First-pass (msec.)	Go-past (msec.)	Second-pass (msec.)	Total (msec.)	Fixation (time)
R1 (NP)					
Intercept (Inanimate)	290.36(15.50)**		169.71(19.89)**	464.03(31.64)**	2.00(.110)**
WM influence on intercept	-.755(3.15)		3.15(4.05)	-1.71(6.43)	.017(.022)
Animate effect	-44.37(19.95)*		-61.07(25.84)*	-85.08(35.71)*	-.219(.130)***
WM influence on Animate effect	-.831(3.97)		-1.30(5.14)	1.81(7.10)	-.012(.025)
R2 (relative verb)					
Intercept (Inanimate)	352.49(25.75)**	443.85(31.91)**	290.00(35.76)**	671.01(50.74)**	2.34(.145)**
WM influence on intercept	-2.49(5.22)	-.080(6.47)	-2.16(7.33)	-9.07(10.29)	-.017(.030)
Animate effect	6.51(31.79)	-36.25(39.85)	58.77(51.59)	41.05(63.57)	-.044(.179)
WM influence on Animate effect	.793(6.24)	-1.45(7.93)	5.40(10.35)	12.21(12.54)	.024(.036)
R3 ("by" phrase)					
Intercept (Inanimate)	195.84(15.03)**	300.50(18.91)**	165.45(23.99)**	379.85(27.72)**	2.24(.171)**
WM influence on intercept	-2.05(3.05)	-4.45(3.87)	-.391(4.88)	-2.60(5.67)	-.032(.035)
Animate effect	34.91(14.55)*	-12.15(23.56)	56.13(30.73)***	63.88(32.35)***	.577(.209)**
WM influence on Animate effect	-1.00(2.84)	4.12(4.70)	3.68(6.02)	2.84(6.29)	.035(.041)
R4 (main verb phrase)					
Intercept (Inanimate)	261.00(15.95)**	301.49(23.52)**	175.98(25.00)**	426.79(30.74)**	2.10(.129)**
WM influence on intercept	.081(3.28)	-4.07(5.02)	-2.86(5.17)	-3.92(6.40)	-.017(.026)
Animate effect	6.21(20.62)	62.29(32.08)***	32.18(34.19)	61.20(39.63)	.233(.186)
WM influence on Animate effect	-.276(4.10)	7.48(6.54)	7.21(6.75)	7.90(7.89)	.026(.037)
R5 (ending)					
Intercept (Inanimate)	230.98(19.15)**		71.36(15.19)**	345.71(29.08)**	1.41(.080)**
WM influence on intercept	7.70(4.03)***		.912(3.18)	5.28(6.08)	.014(.017)
Animate effect	3.35(24.76)		15.01(21.46)	-19.29(36.96)	.142(.108)
WM influence on Animate effect	-11.40(5.01)*		-1.26(4.34)	-13.31(7.40)***	-.018(.022)

Note. Estimates are maximum likelihood. WM was centered at the sample mean, 27.96. Standard errors are in parentheses.
* : $p < .05$ ** : $p < .01$ *** : $.05 < p < .10$

In the further analysis, the error rates were relatively high for the low span group in the animate condition. It decreased in the inanimate condition for both high and low span groups.

The main effect of WM capacity was significant in both First-pass time ($F(1, 565)=5.11$, $p=0.024$) and Second-pass time ($F(1, 565)=4.59$, $p=0.033$). The high span group was 21 msec.

shorter in First-pass time and 27 msec. shorter in Second-pass time. The interaction between animacy and WM capacity was not significant in both First-pass time ($F(1, 565)=0.06$, $p>.05$) and Second-pass time ($F(1, 565)=0.20$, $p>.05$).

The interaction between WM capacity and region was not significant in First-pass time ($F(4, 565)=0.80$, $p>.05$), but it was highly significant in Second-pass time ($F(4, 565)=4.51$, $p<.01$). The high span group was 62 msec. shorter in R2 and 115 msec. shorter in R5. There were significant differences in both two regions (R2: $p=0.039$; R5: $p<.01$). In addition, the high span group was 60 msec. longer in R3. There was a significant difference ($p=0.047$).

The interaction among animacy, WM capacity and region was significant in First-pass time ($F(4, 565)=2.45$, $p=0.045$), but there was no significant difference in the post hoc analysis. It approached significance in Second-pass time ($F(4, 565)=1.99$, $p=0.094$). In the inanimate condition, the high span group was 168 msec. shorter in R5. There was a highly significant difference ($p<.01$).

Contrary to LME model, the high span group read the sentence faster regardless of animacy in both First-pass time and Second-pass time, except R3 in the second pass. R3 is an important region for distinguishing the structure of the sentence, so the results indicate that high span readers may have understood and gathered the important information of the sentence including the semantic and syntactic information more effectively. In addition, the low error rates in the inanimate condition indicate that high span readers could process the sentence correctly using the information of the sentence. On the other hand, the low span group took more time to read the sentences, especially R5 in the Second-pass time in the inanimate condition, but the error rates of the inanimate condition were lower than the animate condition. This means that low span readers could store and process the semantic information of animacy correctly, but their WM was overloaded due to their small WM capacity.

Table 9. Mean First-pass time and Second-pass time for animacy classified by WM capacity (msec.)

			R1	R2	R3	R4	R5
First	Animate	High	204	302	126	189	155
		Low	200	263	175	212	217
	Inanimate	High	224	259	97	215	235
		Low	269	305	149	207	215
Second	Animate	High	174	371	274	218	121
		Low	268	455	221	206	184
	Inanimate	High	258	330	225	180	114
		Low	219	371	160	193	282

Table 10. Error rates for comprehension questions (%) (Experiment 1: WM capacity)

	Animate	Inanimate
High	17.86	3.57
Low	28.13	15.63

3.3 Results and Discussions of Experiment 2: The Use of Morphosyntactic Information

3.3.1 Main Clause Sentences

3.3.1.1 Overall

The error rates were 24.00% in the ambiguous condition and 16.00% in the unambiguous condition. Paired *t*-test (two-tailed) revealed that there was no significant difference between the two conditions ($t(24)=1.36$, $p>.05$, $r=.268$), indicating that the morphosyntactic information does not affect the comprehension of MC sentences for Japanese EFL learners with intermediate proficiency.

Table 11 shows the results of Model 1 for MC sentences in Experiment 2. It tested only for the effects of ambiguity (ambiguous vs. unambiguous). The results showed that there was no significant difference between the two conditions in first-pass time for any of the regions. This suggests that the morphosyntactic information does not affect initial parsing of intermediate learners. Moreover, the increase of second-pass time in R1 (NP) (117 msec. vs. 170 msec.; $p=.060$) and go-past time in R2 (main verb) (510 msec. vs. 619 msec.; $p=.079$) in the unambiguous condition was marginally significant. The results indicate that the unambiguous morphosyntactic information does not facilitate intermediate learners' processing of MC sentences.

Table 11. The LME model for Experiment 2: MC sentences; Overall

	First-pass (msec.)	Go-past (msec.)	Second-pass (msec.)	Total (msec.)	Fixation (time)
R1 (NP)					
Intercept (Unambiguous)	245.31(12.87)**		169.67(21.32)**	402.50(26.41)**	2.02(.115)**
Ambiguous effect	5.57(15.29)		-52.78(27.80)***	-27.99(31.02)	-.103(.144)
R2 (main verb)					
Intercept (Unambiguous)	411.91(28.45)**	619.41(46.84)**	386.63(56.35)**	878.71(69.20)**	2.14(.150)**
Ambiguous effect	45.90(36.60)	-109.38(61.84)***	18.03(79.45)	-21.46(95.02)	.141(.198)
R3 (PP or OP)					
Intercept (Unambiguous)	241.34(16.27)**	331.10(25.17)**	268.28(30.56)**	524.92(37.80)**	2.60(.145)**
Ambiguous effect	8.14(22.05)	-20.08(27.42)	-47.92(41.21)	-55.30(51.62)	-.091(.212)
R4 (PP)					
Intercept (Unambiguous)	223.09(14.57)**	249.56(15.95)**	190.16(22.73)**	444.40(26.17)**	2.51(.137)**
Ambiguous effect	-14.37(16.64)	10.58(20.32)	23.94(33.18)	-23.31(38.67)	.019(.203)
R5 (final word)					
Intercept (Unambiguous)	216.32(16.06)**		108.49(19.31)**	341.43(28.53)**	1.71(.099)**
Ambiguous effect	-8.79(17.69)		42.62(28.00)	18.14(34.03)	.118(.144)

Note. Estimates are maximum likelihood. Standard errors are in parentheses.
* : *p* < .05 ** : *p* < .01 *** : .05 < *p* < .10

3.3.1.2 Proficiency

Table 12 shows the results of Model 2 which tested for cross-level interactions of proficiency and ambiguity. The results showed a cross-level interaction between proficiency and the magnitude of the unambiguous verb effect in frequency of fixation in R2 (p<.05) and marginal cross-level interactions in second-pass time (p=.070) and frequency of fixation (p=.075) in R1. The results indicate that these dependent measures increase as learners' proficiency develops. In contrast, a marginal cross-level interaction between proficiency and the magnitude of the unambiguous verb effect in first-pass time in R3 (PP or OP) (p=.087) indicates that the first-pass time in R3 decreases as learners' proficiency develops. These results suggest that proficient learners use the unambiguous morphosyntactic information to facilitate initial parsing right after the exposure to the information, but they have the extra cost in processing unambiguous MC sentences.

Table 12. The LME model for Experiment 2: MC sentences; Proficiency

	First-pass (msec.)	Go-past (msec.)	Second-pass (msec.)	Total (msec.)	Fixation (time)
R1 (NP)					
Intercept (Unambiguous)	245.20(13.06)**		168.25(20.24)**	401.92(25.79)**	2.02(.108)**
Prof. influence on intercept	.045(5.10)		14.20(7.69)***	13.22(9.96)	.075(.041)***
Ambiguous effect	6.19(15.40)		-54.15(27.87)***	-29.88(31.23)	-.120(.144)
Prof. influence on Ambiguous effect	-3.17(5.90)		-.551(10.38)	1.60(11.70)	.021(.054)
R2 (main verb)					
Intercept (Unambiguous)	411.02(28.95)**	616.31(47.42)**	385.40(56.51)**	877.70(70.22)**	2.13(.138)**
Prof. influence on intercept	4.88(11.08)	26.12(18.24)	18.53(21.57)	14.65(27.00)	.119(.052)*
Ambiguous effect	48.69(36.86)	-103.29(61.88)***	17.13(80.01)	-20.30(95.73)	.126(.198)
Prof. influence on Ambiguous effect	-11.61(13.75)	-30.11(23.06)	-6.98(29.94)	-14.05(35.88)	-.009(.074)
R3 (PP or OP)					
Intercept (Unambiguous)	243.49(15.79)**	332.09(25.49)**	268.21(30.81)**	526.47(38.31)**	2.59(.144)**
Prof. influence on intercept	-10.61(6.09)***	-8.34(9.72)	2.90(11.71)	-13.33(14.55)	.071(.054)
Ambiguous effect	7.43(22.20)	-22.03(27.63)	-50.06(41.43)	-58.37(51.81)	-.105(.211)
Prof. influence on Ambiguous effect	4.93(8.40)	8.12(10.20)	9.50(15.41)	18.48(19.27)	.027(.078)
R4 (PP)					
Intercept (Unambiguous)	223.48(14.17)**	249.87(16.27)**	190.40(22.89)**	445.27(26.26)**	2.51(.138)**
Prof. influence on intercept	-6.46(5.45)	-.345(6.21)	-4.55(8.74)	-7.99(10.03)	.047(.053)
Ambiguous effect	-13.75(16.74)	9.33(20.51)	23.71(33.46)	-22.84(38.82)	.019(.204)
Prof. influence on Ambiguous effect	-2.00(6.32)	3.80(7.49)	4.50(12.82)	-1.38(14.94)	-.029(.077)
R5 (final word)					
Intercept (Unambiguous)	216.12(15.95)**		106.13(19.71)**	338.78(29.02)**	1.70(.099)**
Prof. influence on intercept	-3.30(6.13)		9.59(7.47)	5.94(11.05)	.048(.038)
Ambiguous effect	-7.05(17.81)		47.69(27.81)***	25.40(33.83)	.128(.145)
Prof. influence on Ambiguous effect	-5.83(6.55)		-18.29(10.29)***	-23.11(12.39)***	-.066(.054)

Note. Estimates are maximum likelihood. Prof. was centered at the sample mean, 39.44. Standard errors are in parentheses.
* : p < .05 ** : p < .01 *** : .05 < p < .10

In the further analysis, the error rates were higher in the ambiguous condition for both high and low proficiency groups.

The main effect of proficiency was highly significant in First-pass time (F(1, 730)=16.43, p<.01) and approached significance in Second-pass time (F(1, 730)=3.32, p=0.069). The high proficiency group was 25 msec. shorter in First-pass time and 20 msec. shorter in Second-pass time. The interaction between ambiguity and proficiency was significant in First-pass time (F(1, 730)=4.61, p=0.032). In the ambiguous condition, the high proficiency group was 39 msec. shorter. There was a highly significant difference (p<.01). It was not significant in Second-pass time (F(1, 730)=0.13, p>.05).

The interaction between proficiency and region was highly significant in First-pass time (F (4, 730)=8.64, p<.01). The high proficiency group was 86 msec. shorter in R2 and 40 msec. shorter in R3. There were highly significant differences in both two regions (both ps<.01). It was not significant in Second-pass time (F(4, 730)=1.01, p>.05).

The interaction among ambiguity, proficiency and region was not significant in First-pass time (F(4, 730)=1.89, p>.05), but it was significant in Second-pass time (F(4, 730)=3.03, p=0.017). In the ambiguous condition, the high proficiency group was 89 msec. longer in R3. There was a marginal difference (*p*=0.10). In the low proficiency group, the unambiguous condition was 139 msec. longer in R3 and 118 msec. shorter in R5 (the final word of the sentence). There were highly significant differences in both two regions (both *p*s<.01). The results of R3 indicate that the reading time of the low proficiency group in the ambiguous condition was relatively short.

The high proficiency group read the sentences faster, especially in First-pass time, and took slightly more time to read R3 in the ambiguous condition in Second-pass time. But they tended to fail to comprehend the ambiguous sentences according to the error rates of the comprehension questions. This means that the high proficiency group could understand the main information of the sentence, including the morphosyntactic information, faster and use it accurately, but they had some difficulty to process the ambiguous sentences correctly. On the other hand, the low proficiency group seemed to take more time to process the sentence, especially from the results of the reading time of the R5 in Second-pass time, but they could comprehend the sentences almost as well as the high proficiency group. This indicates that the morphosyntactic information may affect in Japanese EFL learners' sentence processing regardless of proficiency.

Table 13. Mean First-pass time and Second-pass time of MC sentences for ambiguity classified by proficiency (msec.)

			R1	R2	R3	R4	R5
First	Ambiguous	High	219	286	132	143	139
		Low	214	413	162	143	179
	Unambiguous	High	220	314	142	144	171
		Low	182	359	191	141	176
Second	Ambiguous	High	165	487	276	203	212
		Low	226	530	187	239	283
	Unambiguous	High	196	514	274	202	144
		Low	179	547	326	194	165

Table 14. Error rates for comprehension questions (%) (Experiment 2: MC sentences; Proficiency)

	Ambiguous	Unambiguous
High	24.24	15.15
Low	23.81	16.67

3.3.1.3 WM Capacity

Table 15 shows the results of Model 3 which tested for cross-level interactions of WM capacity and ambiguity. There were cross-level interactions between WM capacity and the magnitude of the unambiguous verb effect in first-pass time and go-past time in R2 (all *ps*<.05). The results indicate that these dependent measures decrease as learners' WM capacity increases, suggesting that high span readers with intermediate proficiency could process unambiguous MC sentences more efficiently. In addition, a marginal cross-level interaction between WM capacity and the magnitude of the ambiguous verb effect in first-pass time in R2 (*p*=.073) indicate that the first-pass time difference in R2 between ambiguous and unambiguous conditions increases with increases in WM capacity. It means that high span readers with intermediate proficiency are more sensitive to the morphological ambiguity of the verbs and could have assumed two possible sentence constructions (MC and RR constructions) in the ambiguous condition.

Table 15. The LME model for Experiment 2: MC sentences; WM Capacity

	First-pass (msec.)	Go-past (msec.)	Second-pass (msec.)	Total (msec.)	Fixation (time)
R1 (NP)					
Intercept (Unambiguous)	246.05(12.96)**		168.89(21.60)**	401.66(26.82)**	2.02(.117)**
WM influence on intercept	-3.37(2.63)		3.02(4.36)	1.68(5.45)	.011(.024)
Ambiguous effect	4.75(15.29)		-52.23(27.95)***	-27.74(31.23)	-.101(.145)
WM influence on Ambiguous effect	3.27(2.96)		-3.18(5.40)	-3.66(6.02)	-.004(.028)
R2 (main verb)					
Intercept (Unambiguous)	414.12(27.75)**	622.12(45.79)**	383.81(56.44)**	880.16(70.19)**	2.13(.148)**
WM influence on intercept	-12.39(5.54)*	-19.67(9.24)*	11.76(11.32)	-9.01(14.09)	.031(.030)
Ambiguous effect	44.28(36.27)	-111.35(61.45)***	21.63(79.89)	-22.54(95.50)	.154(.198)
WM influence on Ambiguous effect	12.79(7.05)***	18.76(11.89)	-8.02(15.74)	10.61(18.75)	.005(.038)
R3 (PP or OP)					
Intercept (Unambiguous)	241.63(16.26)**	330.26(24.91)**	265.88(30.28)**	523.15(38.21)**	2.60(.147)**
WM influence on intercept	-4.13(3.28)	5.93(5.04)	9.81(6.11)	6.74(7.71)	.006(.030)
Ambiguous effect	7.81(22.10)	-18.86(27.54)	-45.34(41.24)	-53.56(51.84)	-.090(.214)
WM influence on Ambiguous effect	3.13(4.31)	-.306(5.25)	-7.12(7.94)	-5.48(9.98)	-.006(.042)
R4 (PP)					
Intercept (Unambiguous)	223.53(14.69)**	249.58(15.60)**	190.13(22.61)**	444.58(26.29)**	2.52(.137)**
WM influence on intercept	-.665(2.96)	-2.91(3.10)	.157(4.50)	-.953(5.30)	-.032(.028)
Ambiguous effect	-14.19(16.54)	9.33(20.42)	24.31(33.00)	-23.46(38.83)	.014(.202)
WM influence on Ambiguous effect	4.96(3.14)	-1.82(3.88)	-8.74(6.44)	-4.51(7.59)	-.002(.039)
R5 (final word)					
Intercept (Unambiguous)	216.73(15.87)**		108.06(19.65)**	341.91(28.79)**	1.71(.100)**
WM influence on intercept	-3.84(3.17)		.967(3.96)	-3.37(5.82)	-.019(.020)
Ambiguous effect	-9.69(17.77)		43.08(28.22)	16.82(34.27)	.114(.145)
WM influence on Ambiguous effect	.137(3.36)		-1.38(5.47)	-.308(6.55)	.013(.028)

Note. Estimates are maximum likelihood. WM was centered at the sample mean, 27.96. Standard errors are in parentheses.
* : $p < .05$ ** : $p < .01$ *** : $.05 < p < .10$

In the further analysis, the error rates decreased in the unambiguous condition in the high span group, but contrary to expectations, the error rates of the unambiguous condition were higher than the ambiguous condition in the low span group.

The main effect of WM capacity was highly significant in both First-pass time (F(1, 430)=16.42, p<.01) and Second-pass time (F(1, 430)=4.45, p=0.035). The high span group was 31 msec. shorter in First-pass time and 33 msec. shorter in Second-pass time. The interaction between ambiguity and WM capacity was significant in First-pass time (F(1, 430)=4.26, p=0.040). In the unambiguous condition, the high span group was 46 msec. shorter. There was a highly significant difference (p<.01). It was not significant in Second-pass time (F(1, 430)=0.50, p>.05).

The interaction between WM capacity and region was highly significant in First-pass time (F(4, 430)=9.49, p<.01). The high span group was 111 msec. shorter in R2 and 51 msec. shorter in R5. There were highly significant differences in both two regions (both ps<.01). It was not significant in Second-pass time (F(4, 430)=0.87, p>.05).

The interaction among ambiguity, WM capacity and region was not significant in First-pass time (F(4, 430)=0.89, p>.05), but it was significant in Second-pass time (F(4, 430)=2.78, p=0.027). In the unambiguous condition, the high span group was 141 msec. shorter in R2. There was a significant difference (p=0.046). In addition, in the high span group, the unambiguous condition was 148 msec. shorter in R2. There was also a significant difference (p=0.040). The results of R2 indicate that the reading time of the high span group in the unambiguous condition was relatively short.

Similar to the results of Experiment 1, the high span group read the sentence faster in both First-pass time and the Second-pass time, especially at R2 in the unambiguous condition in Second-pass time. It indicates that high span readers could store and use the important morphosyntactic information more efficiently for processing the sentences. The low error rates of the unambiguous condition also support this. On the other hand, the low span group could not comprehend the unambiguous MC sentences more correctly than in the ambiguous condition, although the unambiguous condition was easier to process. The results of the longer reading times and the higher error rates indicate that low span readers could not store and process the morphosyntactic information correctly when they processed the sentences.

Table 16. Mean First-pass time and Second-pass time of MC sentences for ambiguity classified by WM capacity (msec.)

			R1	R2	R3	R4	R5
First	Ambiguous	High	229	326	134	153	135
		Low	194	441	132	103	183
	Unambiguous	High	232	231	167	131	140
		Low	256	338	200	145	193
Second	Ambiguous	High	171	565	269	182	213
		Low	159	587	209	284	270
	Unambiguous	High	203	417	193	176	202
		Low	255	558	266	177	156

Table 17. Error rates for comprehension questions (%) (Experiment 2: MC sentences; WM capacity)

	Ambiguous	Unambiguous
High	19.05	14.29
Low	20.83	25.00

3.3.2 Reduced Relative Clause Sentences

3.3.2.1 Overall

The error rates were 49.33% in the ambiguous condition and 44.00% in the unambiguous condition. The error rates were relatively high in both conditions. In addition, paired *t*-test (two-tailed) revealed that the difference between the two conditions was not significant ($t(24)=.582$, $p>.05$, $r=.118$). This means that intermediate Japanese EFL learners have difficulty in comprehending RR sentences regardless of the morphosyntactic information.

Table 18 shows the results of Model 1 for RR sentences in Experiment 2. Same as the analysis of MC sentences, it tested only for the effects of ambiguity (ambiguous vs. unambiguous). In R2 (relative verb), there were significantly shorter first-pass time (457 msec. vs. 255 msec.; $p<.01$) and go-past time (509 msec. vs. 366 msec.; $p<.05$) in the unambiguous condition than in the ambiguous condition. These results contradict to the results of MC sentences. Intermediate learners might distinguish past forms and past participle forms of the verbs in some way, or the familiarity of the verbs form might affect their sentence processing, but it is difficult to identify the reason. In contrast, there were significantly longer second-pass time (R1, R4), total time (R1, R4), and frequency of fixation (R1, R2, R3) in the unambiguous condition than in the ambiguous condition. Moreover, in R3, the increase of second-pass time in the unambiguous condition was marginally significant. These results indicate that the unambiguous morphosyntactic information was not used effectively for intermediate learners' ambiguity resolution and they had more difficulty to process unambiguous RR sentences.

Table 18. The LME model for Experiment 2: RR sentences; Overall

	First-pass (msec.)	Go-past (msec.)	Second-pass (msec.)	Total (msec.)	Fixation (time)
R1 (NP)					
Intercept (Unambiguous)	255.44(13.81)**		245.09(28.29)**	513.38(33.37)**	2.91(.235)**
Ambiguous effect	-25.94(20.02)		-115.25(38.16)**	-141.18(43.27)**	-.736(.299)*
R2 (relative verb)					
Intercept (Unambiguous)	255.48(32.07)**	366.17(42.61)**	639.53(93.72)**	923.67(106.52)**	3.79(.337)**
Ambiguous effect	202.01(45.62)**	142.36(61.36)*	-96.00(119.44)	113.13(140.32)	-1.17(.401)**
R3 (PP or OP)					
Intercept (Unambiguous)	237.86(22.46)**	414.54(31.52)**	551.52(70.69)**	781.44(69.66)**	4.47(.367)**
Ambiguous effect	39.62(32.53)	-57.12(41.49)	-163.68(85.02)***	-108.29(86.08)	-1.10(.435)*
R4 (main verb phrase)					
Intercept (Unambiguous)	300.13(24.75)**	433.81(41.27)**	579.15(56.33)**	895.84(59.54)**	3.57(.223)**
Ambiguous effect	1.63(33.66)	2.84(57.88)	-206.18(78.94)*	-218.19(84.32)*	-.377(.319)
R5 (ending)					
Intercept (Unambiguous)	272.89(24.21)**		234.17(42.72)**	529.53(47.45)**	2.56(.217)**
Ambiguous effect	-42.12(32.26)		27.14(59.91)	-58.12(61.93)	-.258(.273)

Note. Estimates are maximum likelihood. Standard errors are in parentheses.
* : $p < .05$ ** : $p < .01$ *** : $.05 < p < .10$

3.3.2.2 Proficiency

There was no effect observed in Model 2 in LME model, except for the significant increase of Frequency of fixation in R3 (PP or OP) in unambiguous condition along with the improvement of proficiency. The results indicate that the improvement of proficiency do not affect intermediate learners' use of the morphosyntactic information.

Table 19. The LME model for Experiment 2: RR sentences; Proficiency

	First-pass (msec.)	Go-past (msec.)	Second-pass (msec.)	Total (msec.)	Fixation (time)
R1 (NP)					
Intercept (Unambiguous)	256.78(14.59)**		243.04(29.05)**	512.87(34.50)**	2.89(.237)**
Prof. influence on intercept	-3.21(8.48)		12.08(17.10)	4.05(20.17)	.161(.139)
Ambiguous effect	-27.05(20.68)		-113.83(38.71)**	-140.78(44.10)**	-.708(.300)*
Prof. influence on Ambiguous effect	1.78(9.74)		-2.66(19.20)	5.33(22.40)	-.083(.153)
R2 (relative verb)					
Intercept (Unambiguous)	258.19(32.25)**	362.06(43.15)**	625.66(92.68)**	909.82(107.70)**	3.75(.329)**
Prof. influence on intercept	-10.51(18.55)	16.95(24.90)	85.89(54.81)	76.76(64.08)	.285(.192)
Ambiguous effect	199.11(45.62)**	146.08(61.75)*	-85.67(118.93)	126.87(141.27)	-1.15(.399)**
Prof. influence on Ambiguous effect	-6.59(21.37)	-34.15(28.75)	-84.68(60.65)	-86.67(71.33)	-.224(.210)
R3 (PP or OP)					
Intercept (Unambiguous)	235.78(22.87)**	415.13(32.40)**	546.19(71.60)**	775.97(70.33)**	4.40(.353)**
Prof. influence on intercept	9.15(13.34)	-1.13(18.69)	38.98(42.97)	42.28(42.63)	.424(.206)*
Ambiguous effect	41.69(32.97)	-57.65(42.21)	-157.56(86.00)***	-101.92(86.92)	-1.05(.428)*
Prof. influence on Ambiguous effect	-9.15(15.47)	-6.87(20.95)	-32.25(46.46)	-38.11(46.42)	-.341(.225)
R4 (main verb phrase)					
Intercept (Unambiguous)	299.86(25.16)**	429.50(41.35)**	571.00(57.99)**	889.59(60.69)**	3.58(.226)**
Prof. influence on intercept	.190(14.62)	23.74(23.84)	33.07(33.80)	26.46(35.39)	-.049(.143)
Ambiguous effect	2.05(34.02)	6.73(57.95)	-196.74(80.37)*	-211.51(85.43)*	-.380(.324)
Prof. influence on Ambiguous effect	-10.03(16.55)	-36.69(27.31)	-33.94(38.57)	-37.53(40.58)	.048(.164)
R5 (ending)					
Intercept (Unambiguous)	275.15(24.51)**		232.01(44.21)**	530.09(48.99)**	2.54(.219)**
Prof. influence on intercept	-12.43(14.44)		12.96(26.58)	.377(28.96)	.107(.127)
Ambiguous effect	-44.47(32.49)		29.53(61.24)	-59.36(63.28)	-.238(.276)
Prof. influence on Ambiguous effect	4.78(16.25)		-23.09(30.02)	-10.57(32.09)	-.053(.141)

Note. Estimates are maximum likelihood. Prof. was centered at the sample mean, 39.44. Standard errors are in parentheses.
* : *p* < .05 ** : *p* < .01 *** : .05 < *p* < .10

In the further analysis, the error rates were relatively high in all four conditions, but the high proficiency group in the unambiguous condition comprehended the sentences slightly more accurately.

The main effect of proficiency was highly significant in both First-pass time (F(1, 730)=86.14, p<.01) and Second-pass time (F(1, 730)=11.06, p<.01). The high proficiency group was 61 msec. shorter in First-pass time. In contrast, the high proficiency group was 51 msec. longer in Second-pass time. The interaction between ambiguity and proficiency was not significant in First-pass time (F(1, 730)=0.019, p>.05), but it was significant in Second-pass time (F(1, 730)=4.71, p=0.030). In the high proficiency group, the unambiguous condition was 73 msec. longer. There was a highly significant difference (p<.01). In the unambiguous condition, the high proficiency group was 84 msec. longer. There was a highly significant difference (p<.01).

The interaction between proficiency and region was highly significant in both First-pass time (F(4, 730)=3.42, p<.01) and Second-pass time (F(4, 730)=4.85, p<.01). In First-pass time, the low proficiency group was longer and there were highly significant differences in all five regions (all *p*s<.01). In Second-pass time, the high proficiency group was 94 msec. longer in R2, 111 msec. longer in R3 and 97 msec. longer in R4 (the first two words of the main verb phrase). There were highly significant differences in all three regions (all *ps*<.01). In contrast, the high proficiency group was 67 msec. shorter in R5 (the ending). There was a significant difference (p=0.049).

The interaction among ambiguity, proficiency and region was not significant in both First-pass time (F(4, 730)=0.46, p>.05) and Second-pass time (F(4, 730)=1.23, p>.05).

The high proficiency group read the sentences faster in First-pass time and took more time in reading the sentences with the unambiguous condition. This indicates that the high proficiency group noticed the morphosyntactic information with a faster reading time and tried to use the information in the sentence processing in Second-pass time. The decrease of the error rates in unambiguous condition shows that the high proficiency group might process the sentences more correctly than the other condition owing to the morphosyntactic information. However, the error rates were still relatively high in all four conditions, indicating that Japanese EFL learners may struggle to process syntactically complex sentences regardless of their proficiency.

Table 20. Mean First-pass time and Second-pass time of RR sentences for ambiguity classified by proficiency (msec.)

			R1	R2	R3	R4	R5
First	Ambiguous	High	187	276	158	210	142
		Low	218	380	208	265	203
	Unambiguous	High	129	131	147	194	162
		Low	187	239	174	238	234
Second	Ambiguous	High	208	619	343	426	188
		Low	191	617	278	330	280
	Unambiguous	High	268	618	519	484	259
		Low	248	433	363	387	300

Table 21. Error rates for comprehension questions (%) (Experiment 2: RR sentences; Proficiency)

	Ambiguous	Unambiguous
High	51.52	39.39
Low	47.62	47.62

3.3.2.3 WM Capacity

There was no effect observed in Model 3 in LME model. This result indicates that the increase of WM capacity do not affect intermediate learners' use of the morphosyntactic information. In addition, a cross-level interaction between WM capacity and the magnitude of the ambiguous verb effect in first-pass time in R2 was not observed, which marginally appeared at the processing of MC sentences. This means that high span readers with intermediate proficiency are not always sensitive to the morphological ambiguity in the ambiguous condition. It requires further investigation to reveal the reason why the results of cross-level interactions of WM capacity and ambiguity differed between MC and RR sentences.

Table 22. The LME model for Experiment 2: RR sentences; WM capacity

	First-pass (msec.)	Go-past (msec.)	Second-pass (msec.)	Total (msec.)	Fixation (time)
R1 (NP)					
Intercept (Unambiguous)	255.44(14.15)**		245.00(29.02)**	512.93(34.35)**	2.91(.241)**
WM influence on intercept	2.42(2.69)		-.090(5.54)	2.44(6.59)	.040(.046)
Ambiguous effect	-26.34(20.65)		-112.72(39.62)**	-140.33(45.09)**	-.723(.312)*
WM influence on Ambiguous effect	-2.79(4.19)		2.40(8.04)	-1.40(9.14)	-.019(.063)
R2 (relative verb)					
Intercept (Unambiguous)	256.11(32.48)**	363.70(42.87)**	637.74(95.93)**	920.32(109.27)**	3.79(.345)**
WM influence on intercept	-1.73(6.30)	9.25(8.32)	14.81(18.46)	8.44(20.97)	.059(.067)
Ambiguous effect	197.95(46.64)**	143.85(62.60)*	-91.10(124.96)	131.32(146.27)	-1.18(.422)**
WM influence on Ambiguous effect	-1.84(9.48)	-10.13(12.76)	-7.95(25.25)	5.43(29.60)	-.036(.085)
R3 (PP or OP)					
Intercept (Unambiguous)	238.18(21.66)**	416.02(32.25)**	549.26(72.44)**	780.23(71.80)**	4.48(.375)**
WM influence on intercept	-2.99(4.17)	-6.17(6.22)	4.10(13.93)	-1.80(13.77)	.077(.073)
Ambiguous effect	27.51(31.65)	-58.08(42.71)	-152.35(88.04)***	-105.09(89.34)	-1.19(.456)*
WM influence on Ambiguous effect	-10.68(6.42)	4.64(8.60)	6.45(18.10)	1.04(18.34)	-.095(.092)
R4 (main verb phrase)					
Intercept (Unambiguous)	300.42(25.24)**	432.71(42.23)**	577.23(58.82)**	894.82(61.59)**	3.56(.227)**
WM influence on intercept	-3.90(4.83)	-3.93(8.22)	8.84(11.34)	4.39(11.86)	.049(.043)
Ambiguous effect	3.08(34.50)	6.41(59.54)	-208.64(81.79)*	-221.29(87.06)*	-.404(.326)
WM influence on Ambiguous effect	5.80(7.08)	6.01(12.06)	-16.07(16.84)	-10.04(17.91)	-.085(.065)
R5 (ending)					
Intercept (Unambiguous)	273.68(24.46)**		235.09(44.37)**	530.00(48.85)**	2.56(.223)**
WM influence on intercept	-4.80(4.71)		3.26(8.39)	-4.03(9.32)	.045(.043)
Ambiguous effect	-42.41(33.10)		22.32(62.18)	-52.63(63.92)	-.287(.283)
WM influence on Ambiguous effect	4.09(6.69)		-7.58(12.42)	11.04(12.95)	-.056(.057)

Note. Estimates are maximum likelihood. WM was centered at the sample mean, 27.96. Standard errors are in parentheses.
* : $p < .05$ ** : $p < .01$ *** : $.05 < p < .10$

In the further analysis, the error rates were relatively high in all four conditions. In particular, the high span group had a higher error rates in both conditions.

The main effect of WM capacity was highly significant in both First-pass time ($F(1, 430)=10.11$, $p<.01$) and Second-pass time ($F(1, 430)=7.02$, $p<.01$). The high span group was 27 msec. shorter in First-pass time and 44 msec. shorter in Second-pass time. The interaction between ambiguity and WM capacity was not significant in both First-pass time ($F(1, 430)=0.69$, $p>.05$) and Second-pass time ($F(1, 430)=2.06$, $p>.05$).

The interaction between WM capacity and region was highly significant in First-pass time ($F(4, 430)=3.78$, $p<.01$). The high span group was 69 msec. shorter in R3 and 55 msec. shorter in R4. There were highly significant differences in both two regions (both $ps<.01$). It was not significant in Second-pass time ($F(4, 430)=0.44$, $p>.05$).

The interaction among ambiguity, WM capacity and region was highly significant in First-pass time ($F(4, 430)=7.67$, $p<.01$). In the ambiguous condition, the high span group was 123 msec. shorter in R3 and 115 msec. shorter in R4. There were highly significant differences in both two regions (both $ps<.01$). In the unambiguous condition, the high span group was 82 msec. shorter in R2. There was a significant difference ($p=0.028$). In addition, in the high span group, the unambiguous condition was 197 msec. shorter in R2. There was a highly significant difference ($p<.01$). In the low span group, the unambiguous condition was 78 msec. shorter in R3 and 103 msec. shorter in R4. There were significant differences in both two regions (R3: $p=0.031$; R4: $p<.01$). The interaction among ambiguity, WM capacity and region was not significant in Second-pass time ($F(4, 430)=1.15$, $p>.05$).

In First-pass time, the high span group read the sentences faster than the low span group. In addition, both high and low span group successfully read the region faster in the unambiguous condition (high: R2; low: R3 and R4). This indicates that both groups notice the existence of the morphosyntactic information successfully. But in Second-pass time, there was only the main effect of the WM capacity and no interaction appeared in the results. That means there was no effect of the morphosyntactic information in Second-pass reading time. Moreover, the high error rates of the comprehension questions revealed that participants could not use the morphosyntactic information and comprehend the sentences correctly. The results suggest that Japanese EFL learners cannot process RR sentences correctly by using the morphosyntactic information regardless of individual differences of WM capacity.

Table 23. Mean First-pass time and Second-pass time of RR sentences for ambiguity classified by WM capacity (msec.)

			R1	R2	R3	R4	R5
First	Ambiguous	High	211	352	122	203	166
		Low	184	296	245	318	182
	Unambiguous	High	198	156	152	221	191
		Low	175	238	167	215	222
Second	Ambiguous	High	220	572	225	333	194
		Low	160	593	290	355	249
	Unambiguous	High	184	465	322	272	203
		Low	285	486	388	398	231

Table 24. Error rates for comprehension questions (%) (Experiment 2: RR sentences; WM capacity)

	Ambiguous	Unambiguous
High	52.38	52.38
Low	41.67	45.83

3.3 General Discussion

The present study investigated how Japanese EFL learners with intermediate proficiency process temporarily ambiguous sentences in terms of their use of semantic and morphosyntactic information, focusing on the effects of proficiency and WM capacity. Learners processed RR sentences with the information of the inanimate NPs accurately and efficiently, which is consistent with previous L1 and L2 studies. In addition, the use of the semantic information was facilitated and automatized as learners' proficiency improved. However, the effects of the morphosyntactic information were very limited and intermediate learners could not use the information for disambiguating RR sentences regardless of the improvement of proficiency and the increase of WM capacity.

Trueswell et al. (1994) set the morphological ambiguity of the verbs as the baseline condition of the ambiguity of RR sentences, but the present study showed that intermediate learners do not use the unambiguous morphosyntactic information and they are not as sensitive to the ambiguity of the relative verbs. Based on these results, in Experiment 1, it is possible that learners are not sensitive to the ambiguity of RR sentences with animate initial NPs. Moreover, in the animate condition, the marginally significant increase of the first-pass time of R4 (main verb phrase) along with the development of their proficiency was not derived from ambiguity resolution. One of the possible reasons of the extra cost for proficient learners to process RR sentences with animate initial NPs is that since there are two possible agent nouns in the sentences, there might be some processing cost for associating thematic roles with two agent nouns.

The results of the experiments revealed that intermediate Japanese EFL learners rely more on the semantic information to construct syntactic representations. This dependence on the non-syntactic information for sentence processing is consistent with Clahsen and Felser's (2006) Shallow Structure Hypothesis.

With regard to the effects of intermediate learners' WM capacity, there was no effect on the use of the semantic information for their sentence processing, which is consistent with the previous study of Nakanishi (2007). In addition, few effects on the use of the morphosyntactic information were observed, and it seemed that high span readers did not maintain multiple possible constructions when they encountered morphologically ambiguous verbs as MacDonald et al. (1992) insisted. The analysis of the item conditions revealed that intermediate learners were not sensitive to the morphosyntactic information for ambiguity resolution. Based on the previous study of Nakanishi and Yokokawa (2011), there is the possibility that learners do not process the morphosyntactic information as syntactic cue to disambiguation and sentence processing. So it is argued that the absence of the effects of WM capacity on the morphosyntactic information is due to the lack of the process of the syntactic information among learners.

Therefore, it is considered that intermediate learners process only semantic and non-syntactic information in their WM without the dominant influence of the syntactic information when they read sentences. This means that even low span readers can use the semantic information on sentence processing, leading to the absence of cross-level interactions of WM capacity and animacy in Experiment 1. This also indicates the dependence of semantic and non-syntactic information on sentence processing for Japanese EFL learners with intermediate proficiency.

3.4 Concluding Remarks and Residual Problems

The present study revealed some aspects of the sentence processing employed by Japanese EFL learners in terms of their use of the explicit information. Some suggestions can be made for further research. First, how Japanese EFL learners with high and low proficiency disambiguate and process temporarily ambiguous sentences needs to be observed. The present study was conducted only within the intermediate group, so it is necessary to analyze the present data together with high and low proficiency groups to investigate the developmental process of learners' sentence processing along with the improvement of their proficiency.

Second, learners' use of semantic and morphosyntactic information need to be examined from a neurophysiologic perspective. It is difficult to investigate whether Japanese EFL learners use the explicit information immediately during sentence processing only by behavioral studies. As already mentioned in the previous chapter, the on-line use of linguistic information for Japanese EFL learners is investigated in some previous ERP studies (Kubota et al., 2003, 2004, 2005; Ojima et al., 2005; Tomita et al. 2003), but few neurophysiologic studies have been conducted to Japanese EFL learners so far. Investigations from both behavioral and neurophysiologic perspectives should be effective to reveal more detail about sentence processing of Japanese EFL learners.

In the next chapter, Japanese EFL learners' sensitivity to linguistic information for sentence processing, especially morphosyntatcic information, semantic information and phrase structural rules, is going to be examined from a neurophysiological perspective, using the ERP method.

4. Sensitivity to Linguistic Information during Sentence Processing: An Event-Related Potentials Study

In the previous chapter, Japanese EFL learners could use semantic information relatively easily, but the use of morphosyntactic information seemed to be absent in sentence processing. But it is difficult to explain how much Japanese EFL learners are sensitive to the linguistic information during sentence processing and how they use and process the information in syntactic parsing only by the results of the previous psycholinguistic experiments. To reveal these residual problems from the previous chapter, Japanese EFL learners' sensitivity to linguistic information during syntactic parsing is investigated in this chapter, using the event-related potentials (ERP) method mentioned in Chapter 2. Previous researches in Chapter 2 indicated that ERP responses to the linguistic information vary depending on L2 speakers' proficiency, especially for syntactic information. However, most of the participants in the previous studies had relatively high proficiency and it is not clear how learners with lower proficiency process those kinds of information or how their processing mechanisms are different. In addition, since few ERP studies have been conducted to Japanese EFL learners so far and the methods of the experiments are different among the previous studies, their mechanism of linguistic information processing still remains incompletely understood.

In order to examine less proficient learners' sensitivity to linguistic information for syntactic parsing, the present study conducted ERP experiment to investigate whether learners can detect the violations of the linguistic information, including (a) morphosyntactic information (regular/irregular verbs), (b) semantic information, and (c) phrase structural rules, in the target sentences. In the experiment, ERP components were recorded during participants read sentences with correct or incongruent information and they judged whether the sentences were grammatically or semantically correct. Proficiency of the participants was measured to examine whether the sensitivity to the linguistic information is different along with the proficiency scores.

4.1 Method

4.1.1 Participants

A total of 22 Japanese undergraduate and graduate EFL learners (10 women; mean age=21.14 years, *SD*=2.01 years, range=18-26 years) participated in the experiment in return for a small fee.

All of them had normal or corrected-to-normal vision. The participants are measured for their proficiency using *Versant English Test* (Pearson Education) and classified into groups in compliance with standards of CEFR. The test took about 15 minutes. Participants' range of proficiency was between the lower elementary group (A1 in CEFR; score range: 26-35) and the upper intermediate group (B2 in CEFR; score range: 58-68). All participants were given informed consent and asked their handedness by questionnaire before the experiment. One male participant who was judged as left-handed was excluded from all analysis. In addition, two participants (one woman) also excluded because of the technical errors. Therefore, the analyses in this study involved data from 19 instead of 22 participants.

Table 25. Descriptive statistics of the proficiency test (Versant English Test) (*n*=19)

	Range	Number	Maximum	Minimum	Mean	SD
Overall	80-20	19	60	30	41.21	9.24
B2	58-68	1	60	60	60	0
B1	47-57	4	55	52	53.50	1.29
A2	36-46	6	44	36	40.50	2.88
A1	26-35	8	35	30	33.25	1.83

4.1.2 Materials

All of the materials are included in Appendix B. All of the words in the materials were over 5.00 on a 7 point scale (7 = highly familiar; Yokokawa (Ed.), 2006) with the familiarity rate of words for Japanese EFL learners, except for the personal name and the country name.

4.1.2.1 Experiment 1: Sensitivity to Morphosyntactic Information

Simple declarative English sentences with regular or irregular verbs were made based on Newman et al. (2007). All sentences had similar structures, beginning with "Yesterday", followed by a pronoun (I, he, or, she), regular or irregular verbs, and the post-verbal argument (the noun phrase or the prepositional phrase). Incongruent condition was made by replacing the past tense form of the verb with its base form. 40 sentences, 20 in each of correct and incongruent conditions were arranged for both regular and irregular verb conditions in the experiment. Examples of the target sentences are as follows.

(51) Yesterday he *played* (**play*) a guitar. (regular verbs)

(52) Yesterday he *sang* (**sing*) a song. (irregular verbs)

4.1.2.2 Experiment 2: Sensitivity to Semantic Information

Simple declarative English sentences were made based on Neville et al. (1991), Newman et al. (2007) and Tomita et al. (2003). Semantically incongruent condition was made by replacing the object nouns of the sentences with nouns which were conceptually incompatible with the preceding verbs. 80 sentences, 40 in each of correct and incongruent conditions were arranged in the experiment. Example of the target sentence is as follows.

(53) Mike listened to Max's *speech* (**orange*) about war.

4.1.2.3 Experiment 3: Sensitivity to Phrase Structural Rules

Simple declarative English sentences were made same as Experiment 2 based on Neville et al. (1991) and Newman et al. (2007). Structurally incongruent condition was made by replacing a closed-class word immediately after the possessive'*s*. 80 sentences, 40 in each of correct and incongruent conditions were arranged in the experiment. Examples of the target sentences are as follows.

(54) Susan liked Jack's joke *about* the man.

(55) *Susan liked Jack's *about* joke the man.

4.1.3 Procedure

Experiments 1, 2 and 3 were conducted independently in numerical order. Each of the experiments was divided into 4 sessions and 20 sentences were included in each session. All of the target sentences were picked only once to build the sessions avoiding the redundancy of the correct and incongruent sentence pairs in the same session. Each session contained 10 correct and 10 incongruent sentences, which were presented randomly within the session.

Participants were applied a cap dedicated for the ERP experiment and were seated in front of the computer screen in a dark shielded room. They were required not to blink, look away or move their body when they read target sentences. The experiment took approximately 120-150 minutes including informed consent, instructions, ERP cap application and removal. Ten practice sentences were presented before the experiment. The sentences were cited from Ojima et al. (2005), including five sentences (three correct and two incongruent) in each of semantically and syntactically (S-V number agreement) conditions. All of the practice sentences were in a different structure than that of the target sentences.

The target sentences were presented on a 19 inch computer screen and the answers for the grammaticality/semantic judgment tasks were recorded with the Cedrus' "SuperLab Pro". All the characters were printed in Tahoma font. The size of the characters was set to 22.

The procedure of the experiment was as follows. First, participants press the "b" key or the "n" key on the keyboard to start the session when they are ready. 2000 msec. after, the mark "++++" was presented on the center of the monitor for 500 msec. and participants were required to stare at the mark. After a blank screen was presented for 500 msec., a sentence appeared one word at a time in the center of the computer monitor. Each word was presented for 300 msec., with 200 msec. intervals presenting a blank screen. Participants were required to read the sentence silently. After the last word of the sentence was presented, the question sentence "GOOD OR BAD?" was presented on the monitor for 3000 msec. Participants were required to press the "b" key for correct sentences and the "n" key for incongruent sentences before the sentence disappeared. They were instructed to press the key only once in each of the judgment task. The keys pressed for the judgment tasks and results of the answers were recorded. After the question sentence disappeared, a blank screen was presented for 2000 msec., then the mark "++++" was presented again and participants moved to the next trial. Participants were given a rest between experiments and allowed to take a rest arbitrarily between the sessions.

4.1.4 Data Acquisition and Analysis

ERP was detected using an EEG recording system "EEG-1100" from Nihon Kohden. Scalp electrical activity was recorded from 19 tin electrodes mounted in an ERP cap according to positions specified by the International 10–20 system (Jasper, 1958): *Fp1*, *Fp2*, *F3*, *F4*, *C3*, *C4*, *P3*, *P4*, *F7*, *F8*, *T3*, *T4*, *T5*, *T6*, *O1*, *O2*, *Fz*, *Cz*, *Pz*, Electrodes were also placed on both earlobes for referential derivation. Electrode impedance was maintained below 10 kΩ. The raw signal was controlled at a sampling rate of 200 Hz. The low-pass filter was set at 60 Hz. The timing of presentation of target word (correct/incongruent word) was detected and marked to the ERP data using the Cedrus' "StimTracker". The locations of the electrodes on the scalp are as follows.

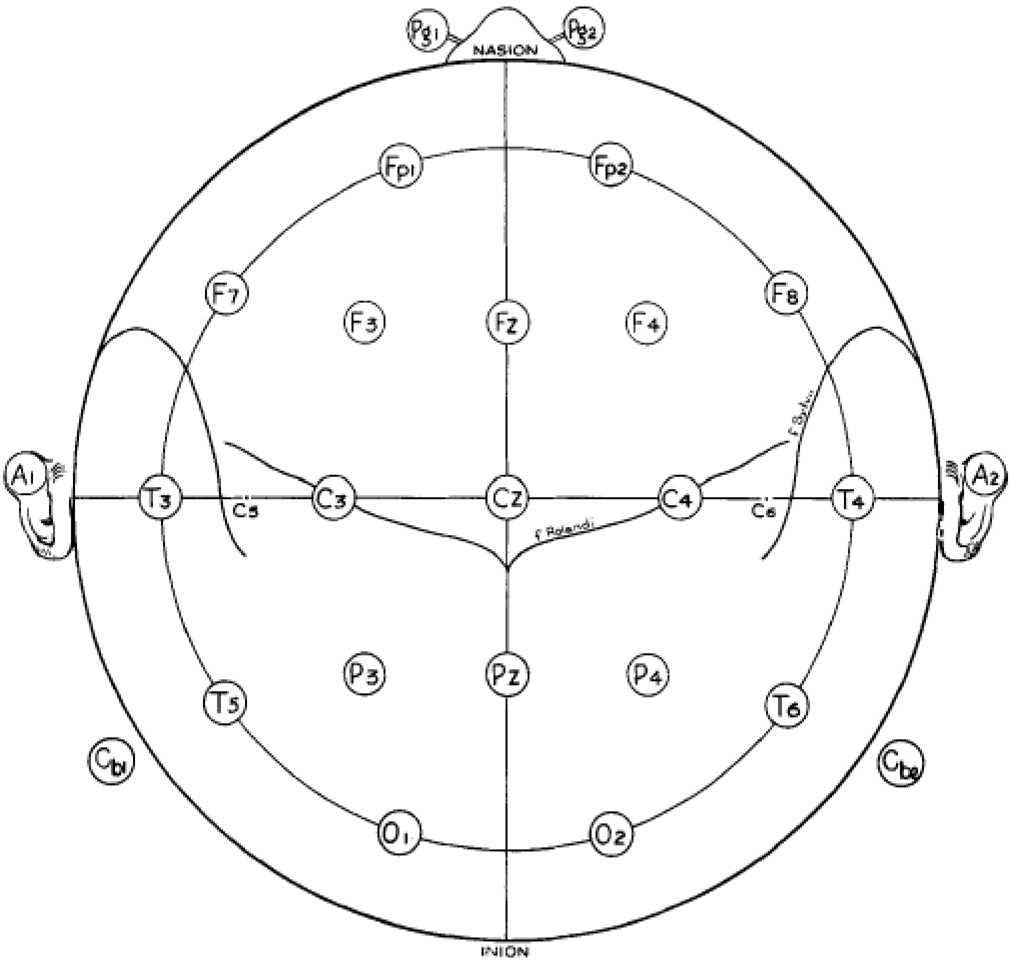

Figure 3. The locations of the electrodes on the scalp according to the criteria of International 10-20 System, adopted from Jasper (1958), p.374

Only trials on which participants responded to the judgment tasks correctly were included in the ERP analysis. In addition, participants who failed to judge more than twenty percent of the trials in each experiment were removed from the analysis of that experiment. One participant in Experiment 2 and four participants in Experiment 3 were removed.

Prior to the analysis, all channels from each subject were filtered using a 20 Hz digital low-pass filter. The waveforms from each electrode were averaged individually associating with each of correct/incongruent sentence types in each of the experiment. The averages were triggered

200 msec. prior to the onset of the target words (correct/incongruent word) and included 1000 msec. after the words were presented. The averaged data with a signal variation exceeding over 50 μV or less than -50 μV was rejected. Then, the data was baseline-adjusted relative to the mean voltage in the prestimulus 100-msec. interval and the mean amplitudes within the two separate time windows were calculated: 300-500 msec. time window (LAN/N400 effects) and 500-700 msec. time window (P600 effects). In Experiment 2, only the mean amplitude within the 300-500 msec. time window was analyzed.

The statistical analysis was conducted using the linear mixed-effects (LME) model, following the analysis of Newman et al. (2012). The mean amplitude was treated as the dependent variable and the participants were treated as random effects. The effects of item conditions of the trials (correct or incongruent) constituted the first level of the model. At the second level, the effects of proficiency were tested, treating the test scores as covariance. Proficiency was centered at the sample mean 41.21. In each experiment, two separate models were fitted for each dependent measure for each electrode. Model 1 tested only for the effects of item conditions. Model 2 tested for the effects of proficiency.

4.2 Results of Experiment 1: Sensitivity to Morphosyntactic Information

In the following discussion, the results of the anterior electrodes (F3, F4) and the midline electrodes (Fz, Cz, Pz) were reported.

4.2.1 Regular Verbs

The accuracy on judgments was 95.53% in both the correct and incongruent condition. It indicates that the participants accurately detected the violations of the morphosyntactic information of the regular verbs in the sentences.

300-500 msec.

Figure 4 and 5 shows the grand average ERPs when participants read sentences with correct and incongruent morphosyntactic information of the regular verbs (Figure 4: Fz; Figure 5: F3). The results of Model 1 in LME model (correct vs. incongruent) showed that the mean amplitude in the incongruent condition was significantly more negative than in the control condition over the Fz electrode (*t*=2.62, *p*=.018). In addition, there was a marginal significant negativity over the F3 electrode, the left anterior of the brain (*t*=1.79, *p*=.092). Japanese EFL learners seem to detect the violations of the morphosyntactic information of the regular verbs at the early stage of the sentence processing. The negativity is considered as the N400 components rather than LAN since the negativity effects were stronger in the anterior midline than in the left anterior. On the other hand, the significant positivity appeared over the Pz electrode (*t*=-3.11, *p*>.01). There was no proficiency effect observed in Model 2 in LME model, indicating that the improvement of proficiency do not affect the ERP components in this time window.

500-700 msec.

Same as the results of the 300-500 msec. time window, there was a marginal significant negativity over the Fz electrode (*t*=1.88, *p*=.077) and a marginal significant positivity over the Pz electrode (*t*=-1.83, *p*=.086) in Model 1 in LME model. The effects of proficiency (Model 2 in LME model) were observed over F4, Fz and Pz electrodes. With regards to the F4 and Fz, there were increasingly negative amplitudes in the incongruent condition (F4: *t*=1.76, *p*=.091; Fz: *t*=2.13, *p*=.043) and increasingly positive amplitudes in the correct condition (F4: *t*=-1.93, *p*=.073; Fz: *t*=-1.85, *p*=.082) as learners' proficiency developed. The results revealed a relative increase of the amplitudes of the positive potentials (P600) along with the development of proficiency, indicating that proficient learners process the morphosyntactic information as the information of syntax at the late stage of sentence processing. Meanwhile, there were increasingly negative amplitudes over Pz electrode in the incongruent condition as learners' proficiency developed (*t*=-1.87, *p*=.071).

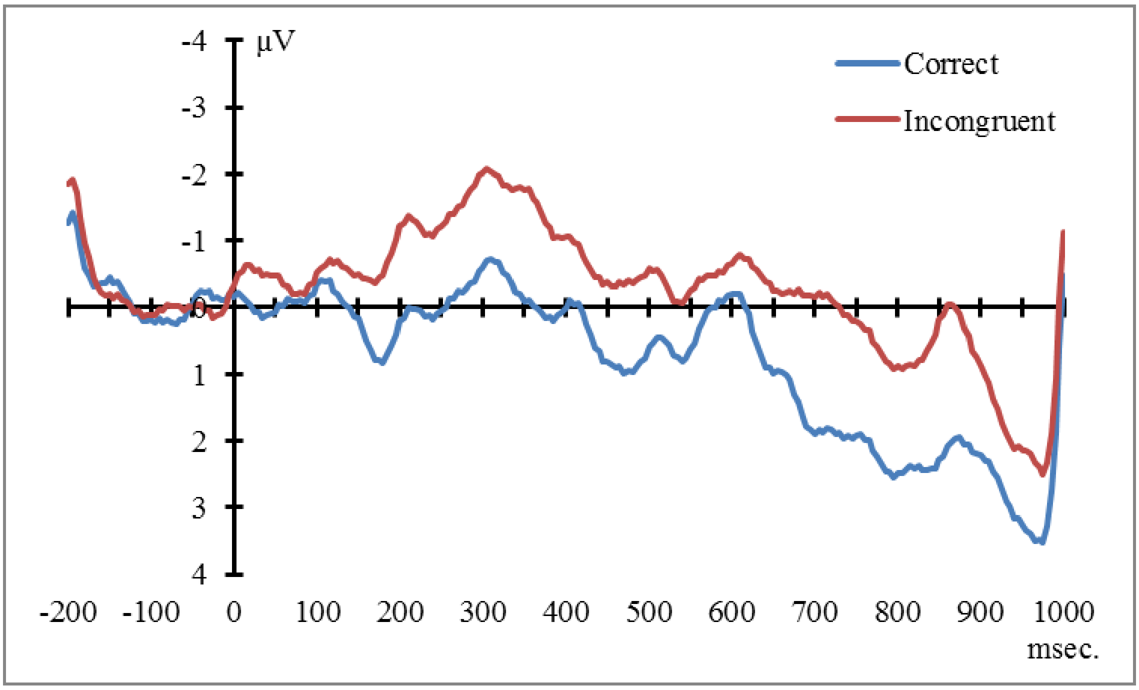

Figure 4. Grand average ERPs at Fz (Experiment 1: Regular verbs)

The negative is plotted upward.

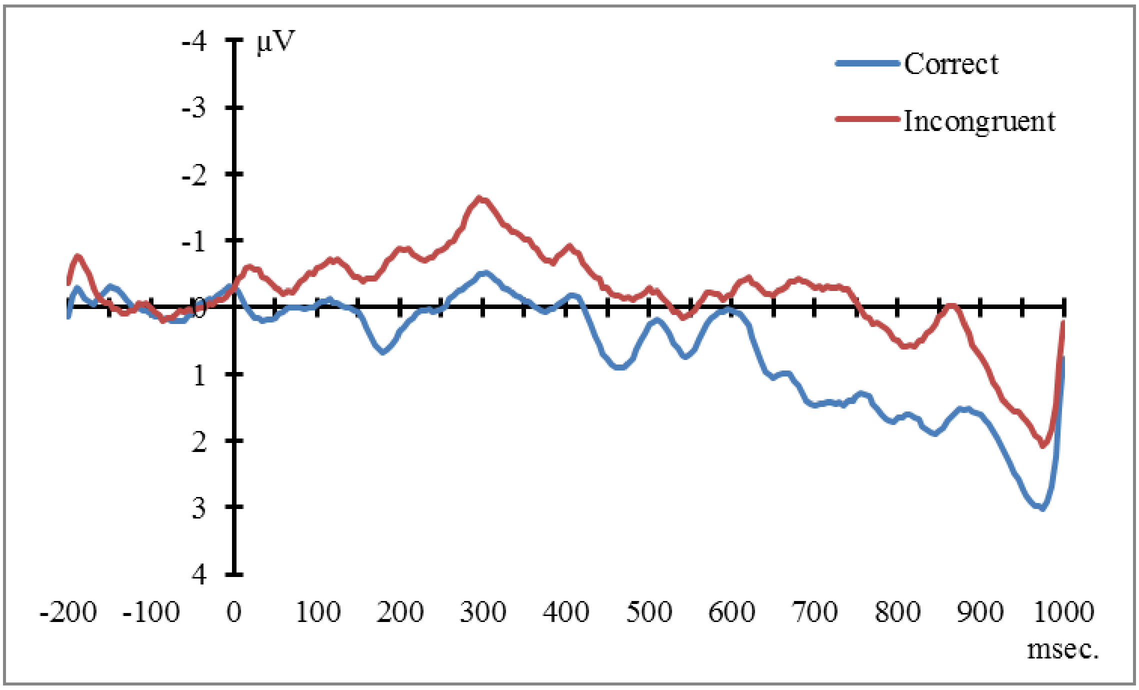

Figure 5. Grand average ERPs at F3 (Experiment 1: Regular verbs)

The negative is plotted upward.

4.2.2 Irregular Verbs

The accuracy on judgments was 95.79% in the correct condition and 92.73% in the incongruent condition. It indicates that the participants accurately detected the violations of the morphosyntactic information of the irregular verbs in the sentences.

300-500 msec.

Figure 6 and 7 shows the grand average ERPs when participants read sentences with correct and incongruent morphosyntactic information of the irregular verbs (Figure 6: Fz; Figure 7: F3). In Model 1 in LME model (correct vs. incongruent), no negative potentials appeared over the electrodes and the significant positivity appeared over the P3 electrode (t=-2.11, p=.05), indicating that Japanese EFL learners' mechanism of processing the morphosyntactic information is different between the regular verbs and the irregular verbs. With regards to the effects of proficiency (Model 2 in LME model), there were increasingly negative amplitudes over Cz and Pz electrodes in the incongruent condition (Cz: t=-3.88, p>.01; Pz: t=-3.40, p>.01). The results indicate that the amplitudes of the negativity over parietal and posterior of the brain relatively increase along with the development of proficiency. But from the perspective of the distribution of the potentials, the negativity is considered as the N400 components rather than LAN and proficient learners might process the morphosyntactic information of the irregular verbs semantically in sentence processing.

500-700 msec.

No ERP potentials appeared over the electrodes in Model 1 in LME model. In addition, increasingly negative amplitudes were found over Cz and Pz electrodes in the incongruent condition (Cz: t=-2.95, p>.01; Pz: t=-2.47, p=.021) in Model 2 in LME model, which is the same as the results of the 300-500 msec. time window. No positive potential (P600) reflecting morphosyntactic processing of the irregular verbs was found in learners' sentence processing.

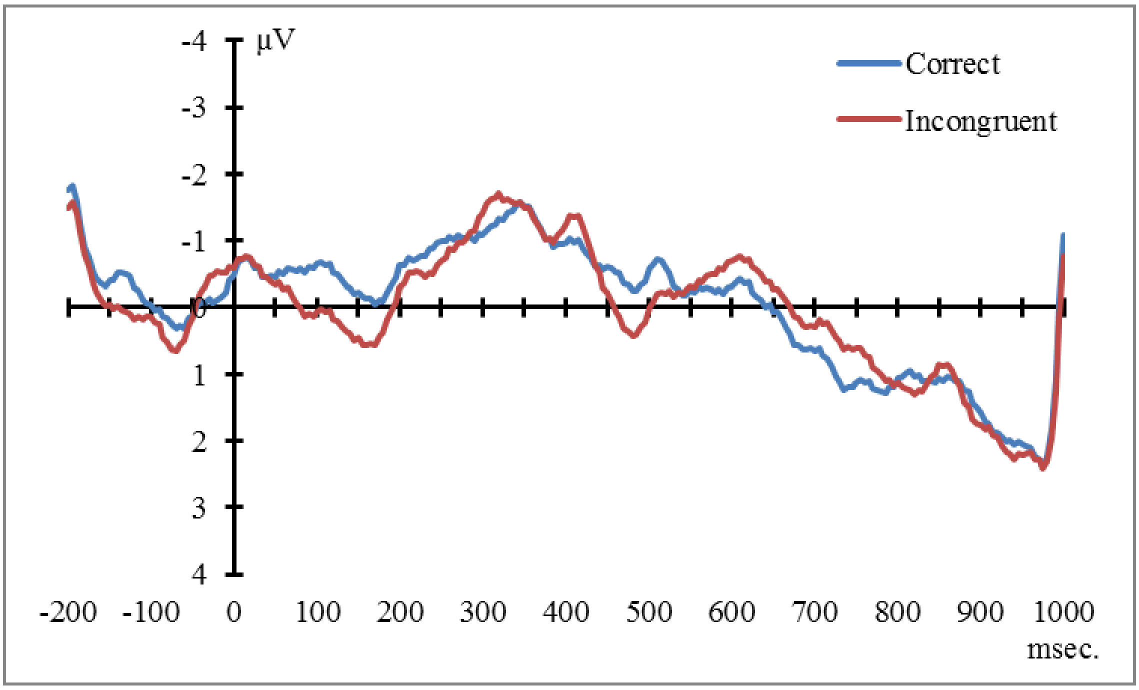

Figure 6. Grand average ERPs at Fz (Experiment 1: Irregular verbs)

The negative is plotted upward.

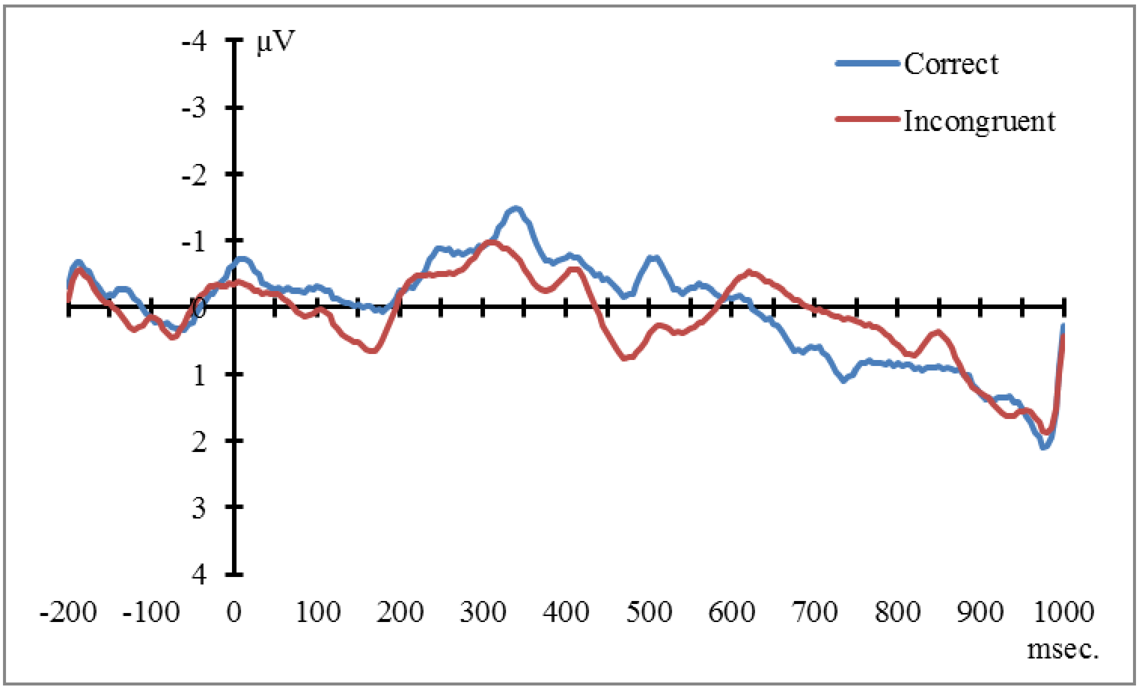

Figure 7. Grand average ERPs at F3 (Experiment 1: Irregular verbs)

The negative is plotted upward.

4.3 Results of Experiment 2: Sensitivity to Semantic Information

The accuracy on judgments was 92.89% in the correct condition and 91.32% in the incongruent condition. It indicates that the participants accurately detected the violations of the semantic information in the sentences.

300-500 msec.

Figure 8 and 9 shows the grand average ERPs when participants read sentences with correct and incongruent semantic information (Figure 8: Fz; Figure 9: F4). The results of Model 1 in LME model (correct vs. incongruent) showed that the mean amplitude in the incongruent condition was significantly more negative than in the control condition over the F4 and Fz electrodes (F4: t=3.06, p>.01; Fz: t=2.30, p=.035). The results indicate that Japanese EFL learners are sensitive to the semantic violations in the sentence like L1 speakers. On the other hand, the significant positivity appeared over the Pz electrode (t=-2.28, p=.036), same as the results of the morphosyntactic information of the regular verbs (Experiment 1). No proficiency effect were found in Model 2 in LME model, indicating that the improvement of proficiency do not affect the semantic processing.

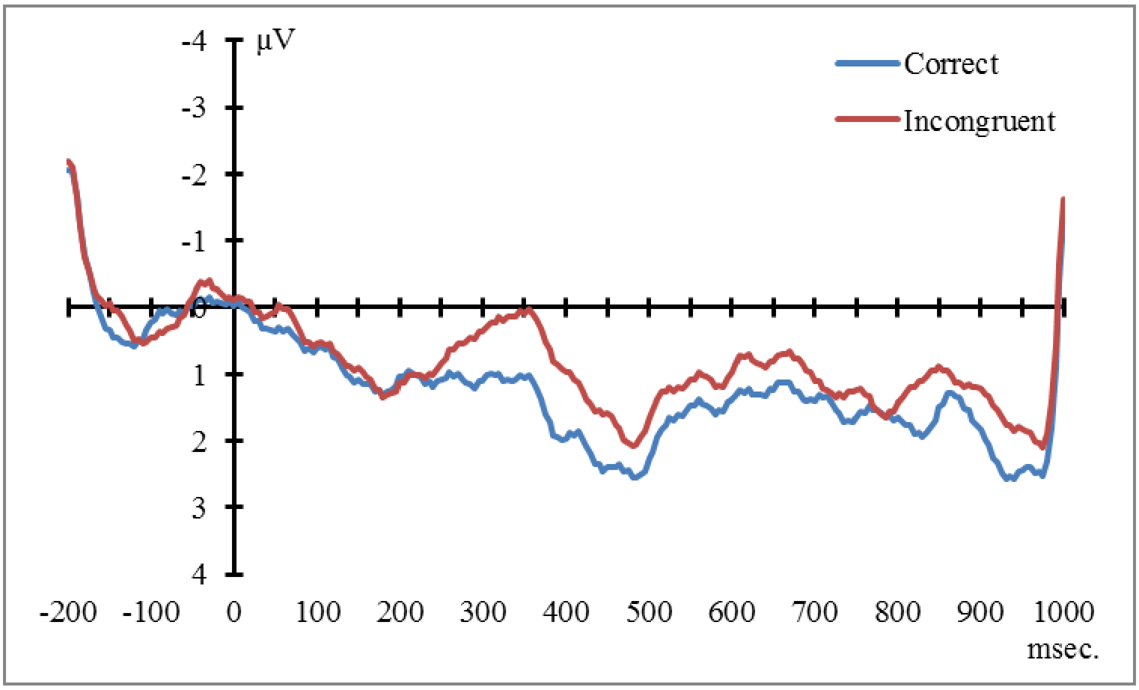

Figure 8. Grand average ERPs at Fz (Experiment 2)

The negative is plotted upward.

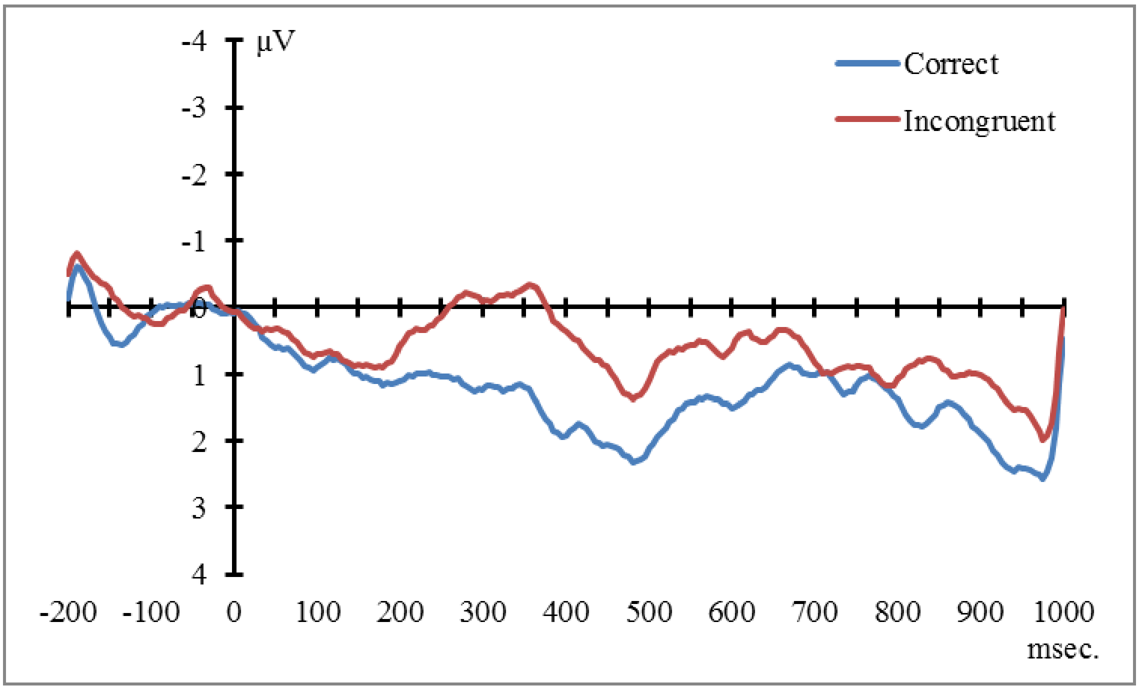

Figure 9. Grand average ERPs at F4 (Experiment 2)
The negative is plotted upward.

4.4 Results of Experiment 3: Sensitivity to Phrase Structural Rules

The accuracy on judgments was 93.16% in the correct condition and 82.63% in the incongruent condition. It indicates that the participants have some difficulty to detect the violations of the phrase structural rules in the sentences comparing to other linguistic information.

300-500 msec.

Figure 10 and 11 shows the grand average ERPs when participants read sentences with correct and incongruent phrase structural rules (Figure 10: Fz; Figure 11: F3). In Model 1 in LME model (correct vs. incongruent), no negative potentials appeared over the electrodes and the positivity appeared over the Pz electrode (t=-1.83, p=.079). The negative potentials like LAN or ELAN that reflects syntactic processing were not observed. These results indicate that Japanese EFL learners are not sensitive to the phrase structural rules for syntactic processing like L1 speakers. In Model 2 in LME model (the effects of proficiency), increasingly negative amplitudes were found over Cz electrode in the incongruent condition (t=-2.12, p=.044). The amplitudes of the negativity over parietal of the brain relatively increase along with the development of proficiency. But same as the results of the morphosyntactic information of the irregular verbs, the negativity is considered as the

N400 components, which reflect semantic processing, rather than LAN from the perspective of the distribution of the potentials.

500-700 msec.

No ERP potentials appeared over the electrodes in Model 1 in LME model. With regards to the effects of proficiency, there were increasingly negative amplitudes in the incongruent condition and increasingly positive amplitudes in the correct condition over Cz electrode (incongruent: t=-4.06, p>.01; correct: t=2.75, p=.017) as learners' proficiency developed in Model 2 in LME model. But no positive potentials (P600) reflecting syntactic processing were found in learners' sentence processing like L1 speakers.

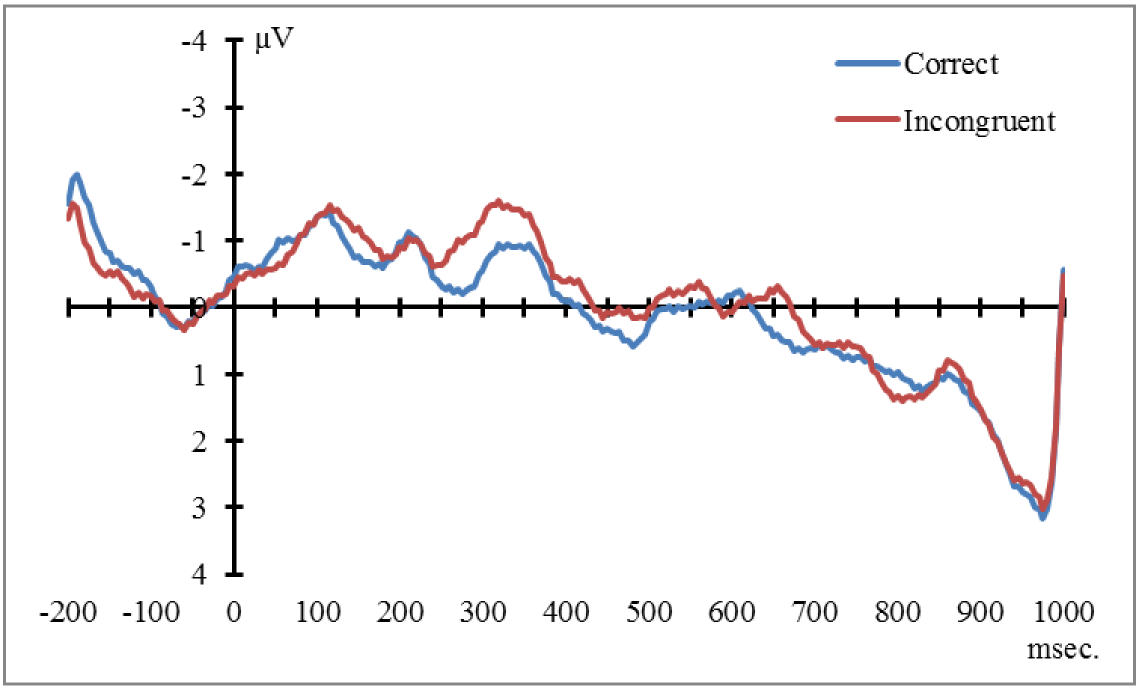

Figure 10. Grand average ERPs at Fz (Experiment 3)

The negative is plotted upward.

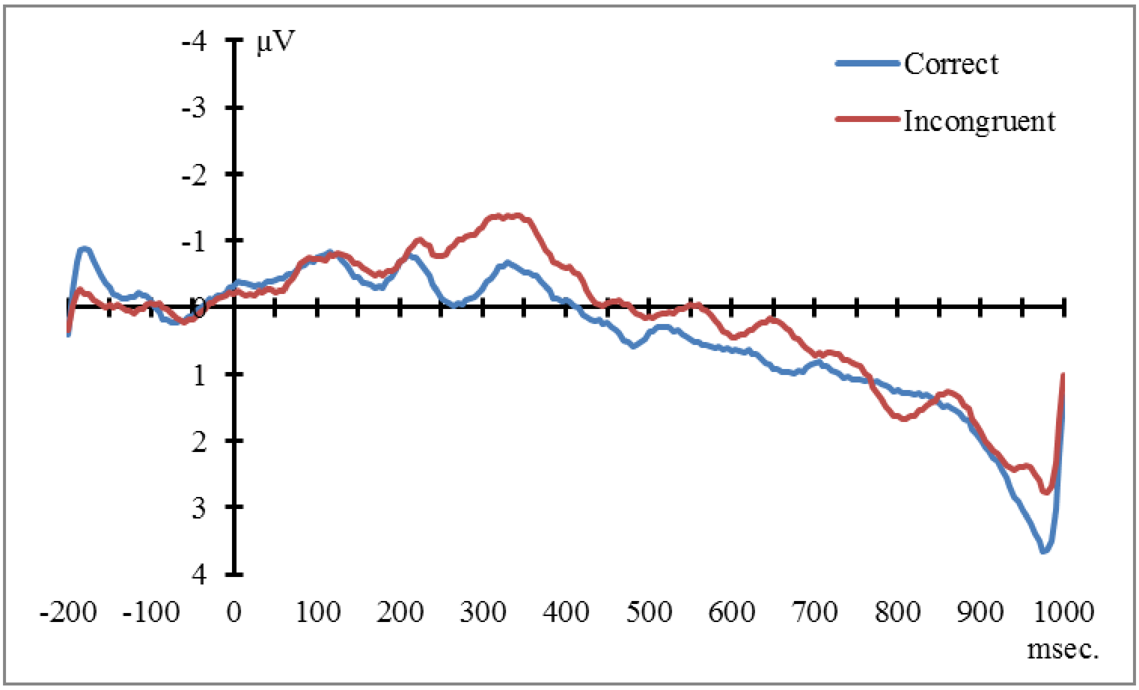

Figure 11. Grand average ERPs at F3 (Experiment 3)
The negative is plotted upward.

4.5 Discussions

From the results of the experiment, Japanese low-proficiency EFL learners are sensitive to the morphosyntactic information of the regular verbs and the semantic information like L1 speakers, but they are not sensitive to the morphosyntactic information of the irregular verbs and the phrase structural rules, regardless of the improvement of their proficiency.

The results revealed that they cannot process the morphosyntactic information of the irregular verbs and the phrase structural rules automatically. As for the morphosyntactic information of the irregular verbs, it is consistent with the results of the eye-tracking experiment in the previous chapter, which intermediate Japanese EFL learners failed to use the morphosyntactic information of the irregular verbs in parsing RR sentences. There is the possibility that learners are not sensitive to the difference between the past tense form and its base form of the irregular verbs and they need high processing costs to integrate the information into sentence processing. With regards to the phrase structural rules, the results are consistent with the previous studies of both psycholinguistic and neurophysiological experiments conducted to Japanese EFL learners and with Clahsen and Felser's (2006) Shallow Structure Hypothesis. In addition, N400-like components were observed in both the morphosyntactic information of the irregular verbs and the phrase structural rules as learners' proficiency developed. There is the possibility that these components reflect semantic processing in processing syntactic information (Kim & Osterhout, 2005), but the results need to be carefully discussed for further studies.

On the other hand, the sensitivity to the morphosyntactic information of the regular verbs and the difference of processing between the regular verbs and the irregular verbs were consistent with those of L1 speakers (Newman et al, 2007). Japanese low-proficiency EFL learners might process the morphosyntactic information of the regular verbs in a rule-governed manner and process the information accurately like L1 speakers. Moreover, the results showed that learners can detect the semantic violations in the sentences like L1 speakers, regardless of their proficiency.

But the ERP components of the morphosyntactic information of the regular verbs were different between L1 speakers and Japanese low-proficiency EFL learners in the 300-500 msec. time window. N400-like components were elicited in Japanese low-proficiency EFL learners instead of LAN, indicating that learners' information processing is different from that of L1 speakers. In addition, there was the dependency of proficiency in eliciting P600 components for learners. It is necessary to investigate how learners process the morphosyntactic information of the regular verbs in more detail and how their information processing changes as their proficiency develops for the further studies.

4.6 Concluding Remarks and Further Studies

From the results of the experiments in this chapter, Japanese low-proficiency EFL learners were sensitive to the semantic information, but they were not sensitive to the syntactic information including morphosyntactic and phrase structural rules comparing to L1 speakers. These results showed that learners' syntactic processing is not as automatic and revealed the dependence on the non-syntactic information including the semantic information for syntactic parsing, which are consistent with Clahsen and Felser's (2006) Shallow Structure Hypothesis.

Some suggestions can be made for further research. First, the information processing of the high proficiency group needs to be investigated and compared between the low proficiency group to reveal the developmental and automatization process of the sentence processing. Second, the ROI (region of interest) analysis which averages multiple electrodes within the region of the brain together needs to be done for further analysis. This method is useful to capture and investigate the characteristic of the components accurately. These further analyses are quite important to investigate how Japanese EFL learners process the linguistic information during sentence processing and the automatization process of the sentence processing.

In addition, it is important to investigate the possibility of learning the importance of the syntactic information during syntactic parsing for improving and automatizing learners' sentence processing. In the next chapter, the previous studies that investigated the effects of exposure on syntactic processing is reviewed, especially focusing on the "syntactic priming effects (Bock, 1986)" which is the behavioral phenomenon based on the repetition of the sentence structure. Then, the learnability of the syntactic information by the exposure is going to be investigated.

5. Exposure Effects on Sensitivity to Linguistic Information during Sentence Processing: An Event-Related Potentials Study

The previous studies and the experiments conducted in the previous chapters revealed that Japanese EFL learners are not sensitive to the syntactic information and have some difficulty in processing the information online during syntactic parsing. But as already mentioned in Chapter 1, it is crucial for readers to process and understand the syntactic structure correctly in comprehending English sentences. The semantic information alone is not enough to construct the structure accurately. It is important for learners to learn and develop accurate syntactic processing for the correct understanding of the sentences. Since Japanese EFL learners' syntactic representations are not developed enough, the learning task that focuses on syntactic information in the sentences seems to be effective to improve learners' sentence processing. In this chapter, learning effects on syntactic processing for L1 speakers and Japanese EFL learners are reviewed from the perspective of the psycholinguistic literature. Then, the changes of the sensitivity to the syntactic information after the exposure to the correct information including the morphosyntatcic information and the phrase structural rules is going to be examined from a neurophysiological perspective, using the ERP method.

5.1 Literature Review

5.1.1 Syntactic Priming Effects on Sentence Comprehension

With regards to the syntactic processing of the sentences, some previous research reported that the sentence processing was promoted when readers encounter the same sentence structure continuously. This repetition effects are called "syntactic priming effects (Bock, 1986)", which is often reported in the research of language production. For example, Pickering and Branigan (1998) conducted the sentence completion task using prepositional object (PO) structure and double object (DO) structure to L1 speakers. The results revealed that participants tended to produce PO structure when they encountered PO structure prior to the production (prime). On the other hand, participants tended to produce DO structure when they encountered DO structure prior to the production. Moreover, the syntactic priming effects were strengthened when verbs of the sentences were repeated, since the particular syntactic structures in the mental lexicon which are associated with verbs are activated by the repetition and used in sentence processing. The model of the representation of syntactic information associated with verbs is as follows.

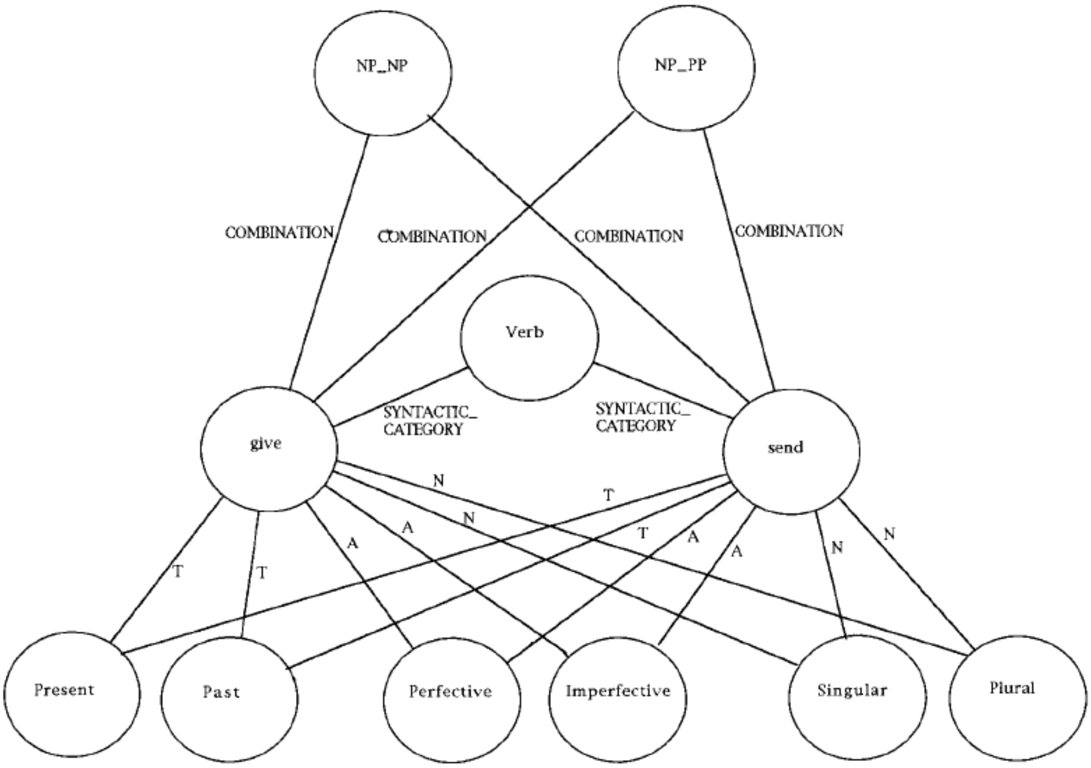

Figure 12. A partial model of the representation of syntactic information associated with verbs in the production lexicon, adopted from Pickering and Branigan (1998), p.635

There is much research that reports the syntactic priming effects in sentence production, but few studies that investigate the syntactic priming effects in sentence comprehension have been conducted so far. While speakers need to activate multiple syntactic structures to choose and produce the structures of the sentences actively in sentence production, sentence comprehension is a passive act and readers or speakers need to activate multiple structures only when the structures of the sentences are temporarily ambiguous, so there had been so little evidence for the syntactic priming effects of sentence comprehension (Pickering & Ferreira, 2008).

But the syntactic priming effects on sentence comprehension by L1 speakers have gradually been investigated in recent studies from both psycholinguistic and neurophysiological perspectives. For example, Branigan, Pickering and McLean (2005) investigated whether the syntactic priming effects affect syntactic ambiguity resolution in comprehension. They presented expressions including prepositional phrases that were ambiguous between high and low attachment (*e.g.* The policeman prodding the doctor with the gun) to participants conducting an expression-picture matching task. The results revealed that the repetition of the high-attached interpretation promoted the comprehension of the prepositional phrases and found the syntactic priming effects in sentence comprehension. In addition, the syntactic priming effects appeared only when verbs of the expressions (*e.g.* prodding) were repeated between the prime and the target.

Traxler and Tooley (2008) conducted eye-tracking experiment and self-paced reading experiment to investigate the repetition effects of verbs in the syntactic priming effects in sentence comprehension. They used RR sentences and controlled the repetition of the relative verbs and other factors that affect sentence comprehension. The results showed that the syntactic priming effects in comprehending RR sentence were observed only when relative verbs were repeated. It indicates that the repetition of verbs is crucial to the syntactic priming effects in sentence comprehension. Tooley, Traxler and Swaab (2009) conducted similar experiment using the ERP method and found that P600 which reflects syntactic complexity were reduced and syntactic processing was promoted during the comprehension of target RR sentences when the prime and target RR sentences contained the same relative verbs.

In addition, Noppeney and Price (2004) investigated the brain activation of L1 speakers when they encounter the same sentence structures in a row using fMRI. Noppeney and Price presented syntactically ambiguous sentences (early/late closure ambiguity and MC/RR structural ambiguity) to participants and found that the activation of the left anterior temporal region of the brain was decreased when participants read the sentences with the same structures repeatedly. The results indicate that the ambiguity resolution and the sentence processing of readers were promoted and became easier by the syntactic priming effects.

In the L2 field, Weber and Indefrey (2009) investigated the syntactic priming effects of sentence comprehension in German L2 learners of English using fMRI. In the experiment, sentences with passive structures in English were preceded either by a passive or by active sentences in English or German and participants silently read the sentences. The syntactic priming effects were observed and the activation of the left inferior frontal, left precentral and left middle temporal regions of the brain decreased when the passive structures were repeated regardless of the language of the sentences. Weber and Indefrey concluded that there was interaction between the language processing systems and that at least some syntactic information was shared between languages with similar syntactic structures. The recent studies revealed that the repetition of sentence structures is effective to promote not only the sentence production but also sentence comprehension in both in L1 and L2 processing.

5.1.2 Task Effects on Sentence Processing by L2 Learners

In recent studies, the effects of the task on syntactic processing by L2 learners are gradually investigated. For example, Nagai (2011) conducted the experiment that examined the effects of intensive exposure to the specific sentence structure. The exposure tasks were controlled among the four groups: (1) reading aloud, (2) repetition without looking, (3) word-order correction tasks with reading aloud and (4) word-order correction tasks with repetition without looking. The results revealed that the tasks that required memorizing the sentence structure (2, 4) promoted syntactic processing and had profound effects on learning.

In addition, Leeser, Brandl, and Weissglass (2011) investigated the effects of the task type when L2 Spanish learners process two types of grammatical violations: noun-adjective gender agreement and subject-verb inversion in wh-question. Participants were required to answer comprehension question or grammatically judgment task when they read grammatically correct or incongruent sentences. The results found that the grammatically judgment task affected the reading times of correct and incongruent sentences including noun-adjective gender agreement. It suggests that certain secondary task can influence L2 learners' sensitivity to the particular syntactic violations in the sentences. These two previous studies indicate that the task type that focuses on syntactic structure is very important for learners to process and comprehend the sentences.

5.1.3 Exposure and Learning Effects on L2 Syntactic Processing

From the neurophysiological perspective, the effects of learning on L2 sentence processing are investigated by observing the changes of the brain activation and ERP components after the tasks, which mentioned in Chapter 2. Osterhout et al. (2008) investigated the changes of the L2 learners' brain activation in classroom-based instruction and Morgan-short et al. (2012) used the artificial language to examine the effects of the implicit and explicit training on monolingual speakers.

Recently, the effects of the exposure to the correct syntactic information on sentence processing are investigated in the neurophysiological studies. In the experiment of Mueller, Oberecker, and Friederici (2009), non-native Italian participants listened to 80 correct Italian sentences containing a non-adjacent dependency between an auxiliary and the morphologically marked suffix of the verb. Then, they listened to the syntactically correct/incongruent sentences and answered the grammatical judgment task. Four alternating learning and testing phases were conducted. The results revealed that non-native Italian participants successfully learned the syntactic rules and displayed an N400-like negativity and late positivity in response to the violations. Citron, Oberecker, Friederici, and Mueller (2011) improved the method of Mueller et al. (2009) and changed the four alternating learning and test phase into continuous learning and test phase. As a result, more native-like ERP components were observed in the continuous phase design comparing to the alternating design.

In addition, some of the recent studies treat the P600 components as the evidence of L2 syntactic learning. Batterink and Neville (2013) investigated the effects of the implicit and explicit training on learning novel L2 syntactic rules conducting the syntactic judgment task using the ERP method. They found that the P600 components were elicited on learners who successfully learned the syntactic rules, regardless of the training condition. The amplitude of the P600 effects correlated with L2 learners' proficiency, revealing that L2 learners who successfully learned L2 syntactic rules can acquire explicit syntactic knowledge. The results indicate that the P600 components reflect the explicit attention to the L2 syntactic rules and there is the plasticity of the neural mechanism of later, attention-dependent processes. Loschky and Harrington (Forthcoming) also insists that attention to the syntactic rules related to the P600 components promotes the L2 learning. Moreover, Tanner, McLaughlin, Herschensohn and Osterhout (2013) compared the ERP components between L2 learners enrolled in third-year courses and L2 learners enrolled in first-year courses when learners read syntactically correct/incongruent sentences. They found that the P600 components elicited from the learners who achieve a high score in behavioral test, indicating that learners' ERP components to the syntactic information are qualitatively different associating with learning achievement.

From the previous studies in this chapter, it seems important to notice and focus on the syntactic information of the sentence for promoting the syntactic processing of learners. Since Japanese EFL learners' syntactic processing is not as automatic, the exposure that draws learners' attention to the syntactic information might effective to improve their syntactic processing. But it is not clear how learners notice the information and how the attention to the information affects and improves their sentence processing.

In order to examine the effects of noticing and learning on Japanese EFL learners' sentence processing, the present study conducted the exposure task based on Citron et al. (2011), focusing on (a) morphosyntactic (regular/irregular verbs) information and (b) phrase structural rules. After that, the ERP components were recorded in the same manner as Chapter 4 to investigate whether there is an improvement of sensitivity to the syntactic information in the sentences. The effects of task types on learning are also investigated based on Nagai (2011), dividing participants into two groups: (1) silent reading and (2) repetition without looking. Learners' proficiency was restricted to elementary level to investigate how they learn and improve non-automatic syntactic processing.

5.2 Method

5.2.1 Participants

A total of 24 Japanese undergraduate and graduate EFL learners (10 women; mean age=20.50 years, *SD*=2.15 years, range=18-24 years) participated in the experiment in return for a small fee. All of them had normal or corrected-to-normal vision. The participants are measured for their proficiency using *Versant English Test* (Pearson Education) and classified into groups in compliance with standards of CEFR. All participants were defined as the elementary level (A2 and A1 in CEFR; score range: 26-46) except one participant who scored 47 (B1 in CEFR). They were divided into two groups randomly consisting twelve people in each. According to the two-sample *t*-test, there were no significant differences of proficiency between the two groups ($t(22)=-0.22$, $p>.05$, $r=.05$). All participants were given informed consent and asked their handedness by questionnaire before the experiment. All of them were defined as right handed.

Table 26. Descriptive statistics of the proficiency test (Versant English Test) (*n*=24)

	Number	Maximum	Minimum	Mean	SD
Overall	24	47	27	36.75	5.34
Group A	12	45	27	36.50	5.57
Group B	12	47	29	37.00	5.34

5.2.2 Materials

5.2.2.1 Experiment 1: Morphosyntactic Information

Training Session

Simple declarative English sentences with regular or irregular verbs were made for presenting the present form and the past form of the verbs in the training session. All of the verbs were exactly the same as the ones used in the Experiment 1 in Chapter 4. 40 sentences, 20 in each of the present form and the past form conditions were arranged for both regular and irregular verb conditions. In the present form condition, the adverb of frequency was added in the sentences if it is necessary. In the past form condition, the time expressions used in the past were added in the sentences. In addition, the true/false comprehension question sentences were made in each of the sentences. The numbers of the "true" and "false" answers among the materials were made equal. Examples of the target sentences and comprehension questions are as follows. All of the target sentences appear in Appendix C.

(56) They often play tennis with their friends. (regular verbs: present)

Q: They can play tennis. (A: True)

(57) They played tennis with their friends last Monday. (regular verbs: past)

Q: They played tennis last Monday. (A: True)

(58) Susan often wins a lottery. (irregular verbs: present)

Q: Susan never buys a lottery. (A: False)

(59) Susan won a lottery last year. (irregular verbs: past)

Q: Susan didn't buy a lottery last year. (A: False)

Testing Session

The sentences used in the testing session are identical to the Experiment 1 in Chapter 4.

5.2.2.2 Experiment 2: Phrase Structural Rules

Training Session

80 simple declarative English sentences with nouns following prepositional phrases at the end of sentences were made for presenting the phrase structural rules in the training session. Some of

the sentences were picked from the semantically correct sentences used in the Experiment 2 in Chapter 4. The true/false comprehension question sentences were also made in each of the sentences. The numbers of the “true” and “false” answers among the materials were made equal. Examples of the target sentences and comprehension questions are as follows. All of the target sentences appear in Appendix C.

(60) Bob took a train to Tokyo.

Q: Bob went to Kyoto by train. (A: False)

(61) Tom made a reservation on a ship.

Q: Tom is going to take a ship. (A: True)

Testing Session

The sentences used in the testing session are identical to the Experiment 3 in Chapter 4.

5.2.3 Procedure

Two distinct training methods were conducted in the training session of the experiment: (1) silent reading and (2) repetition without looking. Participants in Group A conducted silent reading task in Experiment 1 (the morphosyntactic information) and conducted repetition task without looking in Experiment 2 (the phrase structural rules). On the other hand, participants in Group B conducted repetition task without looking in Experiment 1 and conducted silent reading task in Experiment 2. The testing session was conducted after the each of training sessions. The order of the Experiment 1 and 2 was counter-balanced within the group.

The training session contained 4 training phases and 80 training sentences were presented randomly in each of the training phase. Participants were exposed to 320 sentences in all four training phases and encountered with each of the training sentences four times during the session. Each session contained 10 sentences for practice before the training. Participants were allowed to take a rest arbitrarily between the phases. The procedures of the training methods are as follows. All of the training sentences were presented on a 19 inch computer screen with the Cedrus’ “SuperLab Pro”. All the characters were printed in Tahoma font. The size of the characters was set to 22.

Silent Reading

The mark "+" was presented at the center of the monitor and participants stared at the mark and pressed the spacebar when they were ready. Then, a sentence appeared at the center of the monitor in one line. Participants read the sentence silently from the beginning. They were required to read it as quickly and as accurately as possible. They pressed the spacebar immediately after they had comprehended the sentence.

A comprehension question was presented for one-quarter of the 80 training sentences in each phase. The comprehension questions which appeared in the training phases were different among the four training phases and each of them was presented only once during the training session. The numbers of the "true" and "false" answers of the comprehension questions were made equal among each of the training phases. In Experiment 1, the numbers of the comprehension questions were also made equal among the four conditions (regular vs. irregular and present vs. past conditions), avoiding the redundancy of the present vs. past pairs in the same phase. Participants pressed the "f" key for true and the "j" key for false depending on which of the answers they thought was the correct one. The answers for the questions were recorded. After participants answered the question or if the training sentences had no questions, the mark "+" was presented again and participants repeated the procedure. Participants were allowed to take a rest while the mark "+" was being shown on the monitor.

Repetition without Looking

The presentation of the training sentences was identical to the silent reading task. Participants were required to read and remember the sentence. When they pressed the spacebar after they had remember it, the training sentence disappeared and the mark (a) "〇〇〇〇〇〇〇〇〇" or (b) "×××××××××" appeared on the monitor. When the mark (a) was presented, participants were asked to repeat the sentence aloud without looking it. When the mark (b) was presented, participants were asked not to repeat the sentence. The rate of the appearance of the mark (a) was identical to the design of the comprehension questions in the silent reading task. The mark "+" was presented again 7000 msec. after presenting the mark (a) and 2000 msec. after presenting the mark (b). All of the participants' productions were recorded with the IC recorder during the training session.

With regards to the testing session, the procedure was identical to the ERP experiment in Chapter 4. The cap dedicated for the ERP experiment was applied to the participants between the training session and the testing session in the first half of the experiment. Five practice sentences were presented before the testing session. The sentences were cited from Ojima et al. (2005), including five sentences (three correct and two incongruent) of semantically conditions. The experiment took approximately 180-210 minutes including informed consent, instructions, ERP cap application and removal.

5.2.4 Data Acquisition and Analysis

The ERP data acquisition and analysis in the testing session was conducted in the same manner as the experiment in Chapter 4. In the statistical analysis, only the effects of item conditions of the trials (correct or incongruent) were analyzed for each task type.

In Group A, four male participants were excluded from all analysis because of the technical errors. In addition, one female participant was removed from the analysis of Experiment 1 due to the technical errors and one female participant who failed to judge more than twenty percent of the trials in Experiment 2 was removed from the analysis. In Group B, one male participant was excluded from all analysis and three male participants were removed from the analysis of Experiment 1 due to the technical errors. In Experiment 2, one female participant was removed from the analysis because of the technical errors and two male participants who failed to judge more than twenty percent of the trials were removed from the analysis. Therefore, the analyses in this study involved data from 7 instead of 12 participants in Group A and 8 instead of 12 participants in Group B. One-way ANOVA revealed that there were no significant differences of proficiency among the task type groups of each experiment ($F(3, 29)=0.73$, $p>.05$).

Table 27. Descriptive statistics of the analyzed data

		Number	Maximum	Minimum	Mean	SD
Group A	Ex.1	7	40	34	37.00	2.71
	Ex.2	7	45	34	38.57	3.69
Group B	Ex.1	8	42	29	36.00	4.54
	Ex.2	8	42	31	36.00	4.07

5.3 Results of Experiment 1: Morphosyntactic Information

In the following discussion, the results of the anterior electrodes (F3, F4) and the midline electrodes (Fz, Cz, Pz) were reported.

5.3.1 Regular Verbs

Silent Reading

In 300-500 msec. time window, positive potentials appeared over the Pz electrodes in LME model (correct vs. incongruent) (t=-1.97, p=.097), but the negative components observed in Experiment 1 in Chapter 4 were not found. In 500-700 msec. time window, positive potentials appeared over the Pz electrode (t=-2.36, p=.057), which were not observed in Experiment 1 in Chapter 4. From the perspective of the distribution of the potentials, this positivity is considered as the P600 components. The results revealed that Japanese EFL learners noticed the morphosyntactic information of the regular verbs in the training sentences of the silent reading task and used the information consciously in the grammaticality judgment task. Figure 13 shows the grand average ERPs of the Pz electrode when participants read sentences with correct and incongruent morphosyntactic information of the regular verbs.

Repetition without Looking

In both 300-500 msec. and 500-700 msec. time windows, no significant ERP potentials appeared over the electrodes in LME model. Moreover, no ERP components observed in Experiment 1 in Chapter 4 were found. There is the possibility that participants paid less attention to the morphosyntactic information of the regular verbs after they had completed the repetition task without looking. The results indicate that there were no effects of the task on the sensitivity to the morphosyntactic information of the regular verbs.

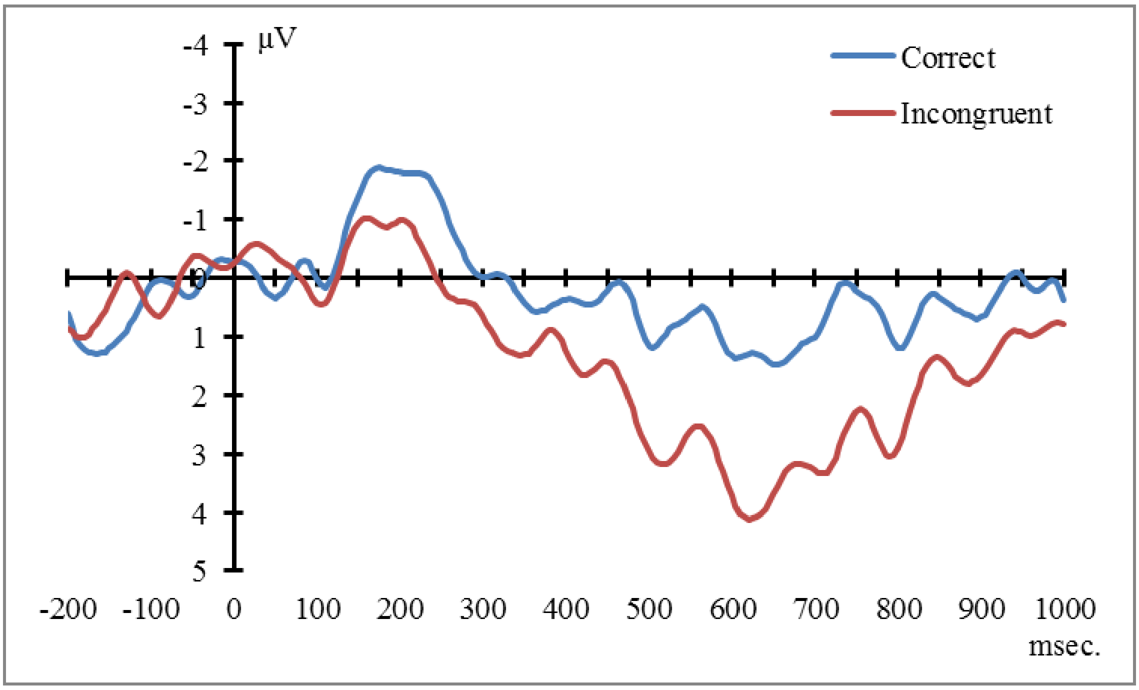

Figure 13. Grand average ERPs at Pz (Experiment 1; Regular verbs: Silent Reading)
The negative is plotted upward.

5.3.2 Irregular Verbs

Silent Reading

There were no significant ERP potentials appeared over the electrodes in both 300-500 msec. and 500-700 msec. time windows in LME model. Experiment 1 in Chapter 4 revealed that Japanese EFL learners were not sensitive to the morphosyntactic information of the irregular verbs, so the results indicate that the silent reading task could not improve learners' morphosyntactic processing of the irregular verbs. It seems difficult for learners to find the difference between the past tense form and its base form of the irregular verbs only by the mere exposure to the training sentences.

Repetition without Looking

In 300-500 msec. time window, no significant ERP potentials appeared over the electrodes in LME model, which is consistent with the results of the Experiment 1 in Chapter 4. In 500-700 msec. time window, positive potentials appeared over the Cz electrode (t=-2.10, p=.073), which were not observed in Experiment 1 in Chapter 4. From the perspective of the distribution of the potentials, this positivity is considered as the P600 components. The results showed that Japanese

EFL learners noticed the difference between the past tense form and its base form of the irregular verbs by reading the verbs in the training sentences aloud and distinguished the forms of the verbs consciously during the grammaticality judgment task. Figure 13 shows the grand average ERPs of the Pz electrode when participants read sentences with correct and incongruent morphosyntactic information of the irregular verbs.

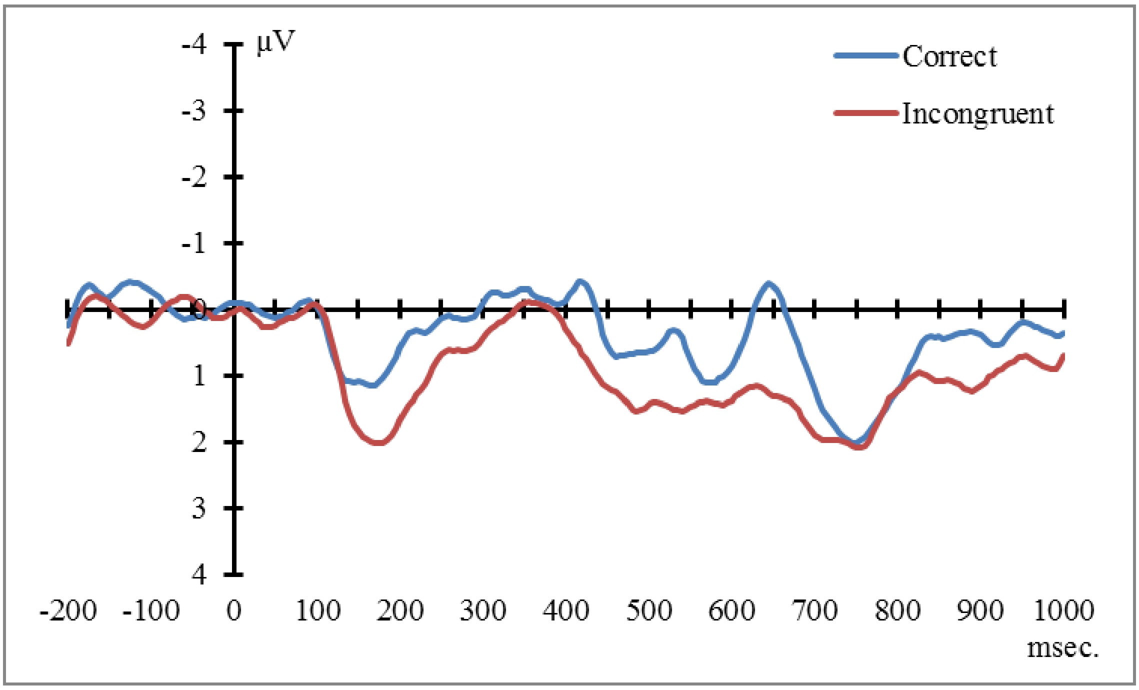

Figure 14. Grand average ERPs at Cz (Experiment 1; Irregular verbs: Repetition without Looking) The negative is plotted upward.

5.4 Results of Experiment 2: Phrase Structural Rules

Silent Reading

In 300-500 msec. time window, positive potentials appeared over the F3 and F4 electrodes in LME model (F3: t=-2.55, p=.038; F4: t=-3.45, p=.011), but there were no negative potentials like LAN or ELAN that reflects syntactic processing observed in the window. In 500-700 msec. time window, positive potentials appeared over the Cz electrode (t=-2.25, p=.059), which were not observed in Experiment 3 in Chapter 4. From the perspective of the distribution of the potentials, this positivity is considered as the P600 components. The results indicate that Japanese EFL learners failed to become automatized in processing the phrase structural rules through the silent reading task, but they seemed to find the grammatical rules during the task and used the rules consciously in the grammaticality judgment task. Figure 15 shows the grand average ERPs of the Cz electrode when participants read sentences with correct and incongruent phrase structural rules.

Repetition without Looking

In 300-500 msec. time window, positive potentials appeared over the F4 and Fz electrodes in LME model (F4: t=-1.99, p=.094; Fz: t=-2.71, p=.035), but there were no negative potentials like LAN or ELAN observed in the window. In 500-700 msec. time window, no ERP potentials appeared over the electrodes. In contrast to the silent reading task, no positive potentials (P600) reflecting syntactic processing were found from the grammaticality judgment task. The results indicate that participants failed to notice the phrase structural rules during the repetition task without looking and to use the rules for the grammaticality judgment task.

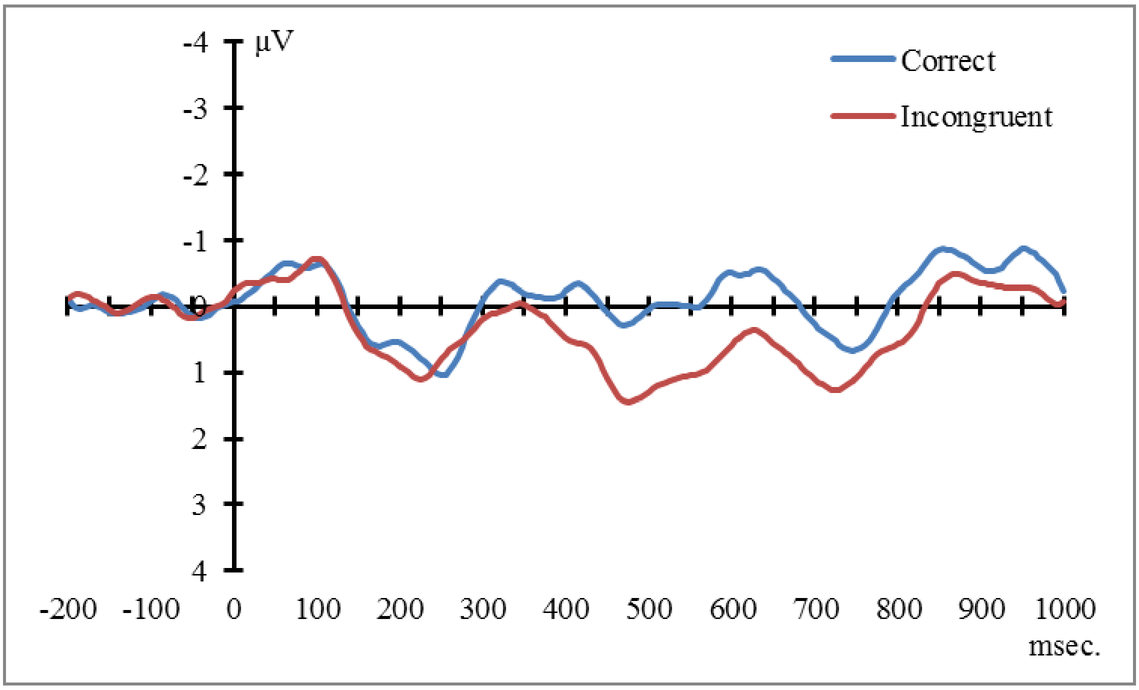

Figure 15. Grand average ERPs at Cz (Experiment 2: Silent Reading)
The negative is plotted upward.

5.5 Discussions

From the results of the experiment, Japanese low-proficiency EFL learners could notice the morphosyntactic information of the regular verbs in the sentences by the silent reading task. On the other hand, they learned the morphosyntactic information of the irregular verbs in the sentences through the repetition task without looking. As for the phrase structural rules, learners could notice the rules in the sentences and could use it in the grammaticality judgment task when they completed the silent reading task, but they did not learn the rules by the repetition task without looking.

With reference to the morphosyntactic information of the verbs, dual-system model for processing the past tense forms of the verbs is proposed by the previous studies (Pinker & Ullman, 2002; Ullman, 2004). According to the model, the past tense forms of the regular verbs are constructed with the automatic application of a rule that the suffix *–ed* is attached to the verb stem, while the past tense forms of the irregular verbs are retrieved from memory, as they occupy separate lexical entries than their stems. This model is supported from the neurophysiological perspective (Newman et al., 2007).

As for the morphosyntactic information of the regular verbs, learners' sensitivity to the information was improved by the silent reading task, but not by the repetition task without looking. Since the repetition task requires high processing costs, learners might fail to notice for the application of the rule of the past tense forms during the task. The results indicate that silent reading is more effective to learn the rule than reading aloud. On the other hand, the repetition task was more effective to notice the difference between the past tense form and its base form of the irregular verbs than silent reading task. These forms are completely different in the lexical form and the pronunciation, so the lexical differences of the verbs were strengthened and memorized by reading aloud the training sentences. Reading aloud is more suitable for learning the morphosyntactic information of the irregular verbs than silent reading.

In the regular verb condition, no negative components were elicited in 300-500 msec. time window after the task was conducted. The results contradict to the Experiment 1 in Chapter 4. The difference of the task between the training session and the testing session might affect learners' sentence processing in the testing session (Leeser et al., 2011). In addition, some other strategy of the sentence processing might be formulated in learners during the training task. But the results need to be carefully discussed for further studies.

With regards to the phrase structural rules, the results of this experiment revealed that the neural mechanism of processing rules was changed by the silent reading task. Besides, the repetition task without looking did not promote the learning of the phrase structural rules and learners did not become sensitive to the violations of the rules. It is possible that the repetition of the sentences required high processing costs for learners and the task interfered the learning of the phrase structural rules. They might paid attention to repeat the sentence correctly and failed to notice the rules in the training sentences. The results also supports that silent reading is more effective to learn the grammatical rules including morphosyntactic and phrase structural rules than reading aloud.

5.6 Concluding Remarks and Further Studies

The results of the experiment revealed that the learnability of the linguistic information for Japanese low-proficiency EFL learners is different between the morphosyntactic information of the verbs and the phrase structural rules. As for the morphosyntactic information of the regular verbs and phrase structural rules, the mere exposure task with comprehension might help learners to notice and learn the rules. On the other hand, reading aloud the sentences might help learners to learn the morphosyntactic information of the irregular verbs.

Some suggestions can be made for further research. First, the task effects for the high proficiency group on learning the linguistic information need to be observed. There might be some differences in the changes of the sensitivity to the information. Second, the effects of other kinds of task on learning the linguistic information need to be investigated. In this experiment, only two tasks were used to investigate the task effects of learning, but more conflict task that focuses on the syntactic information might be effective for learning. For example, the sorting task of phrases needs to construct the syntactic structure of the sentences, so learners might notice the rules of the phrase structure and the role of the morphosyntactic information in the syntactic structure during the task. This investigation might help to find what kind of learning tasks is effective for Japanese EFL learners to improve their sentence processing including syntactic processing.

6. General Discussion

In this dissertation, the mechanism of syntactic parsing for Japanese EFL learners and the effects of proficiency on the automaticity in syntactic parsing were investigated, especially focusing on the use and the process of linguistic information such as morphological, syntactic and semantic information. This chapter summarizes the results of the psycholinguistic and neurophysiological experiments conducted in the dissertation and discusses Japanese EFL learners' automaticity in sentence processing and learnability of syntactic information. Then, the pedagogical implications are discussed based on the results of the experiments.

6.1 Summary of the Study

In Chapter 3, an eye-tracking experiment was conducted to explore when and how the semantic and morphosyntactic information affects intermediate Japanese EFL learners' sentence processing to avoid the garden-path and construct syntactic representations and how the effects of linguistic information differ depending on the development of proficiency and the increase of WM capacity. In Experiment 1, the use of animacy (the semantic information) was examined when learners process temporarily ambiguous and unambiguous RR sentences. The results revealed that the semantic information facilitates sentence processing of learners and that the use of the information becomes automatized as learners' proficiency develops. In Experiment 2, the use of the morphosyntactic information was examined when learners process temporarily ambiguous and unambiguous MC and RR sentences. There was little effect of morphosyntactic information of the verbs on processing temporarily ambiguous sentences. Especially in RR sentences, learners failed to comprehend the sentences and took more time to process unambiguous relative clause sentences than ambiguous RR sentences. The results showed that intermediate Japanese EFL learners rely more on the semantic information to construct syntactic representations, which is consistent with Clahsen and Felser's (2006) Shallow Structure Hypothesis.

In Chapter 4, an ERP experiment was conducted to investigate the sensitivity to linguistic information during syntactic parsing by Japanese EFL learners with intermediate and low proficiency. ERP components were recorded during participants read sentences with correct or incongruent linguistic information including (a) morphosyntactic information (regular/irregular verbs), (b) semantic information, and (c) phrase structural rules. The effects of proficiency were also examined whether the sensitivity to the linguistic information is different along with the development of proficiency. The experiment showed that N400-like components elicited against the morphosyntactic violations of the regular verbs and the semantic violations, regardless of learners' proficiency. In addition, P600 effects of the morphosyntactic violations of the regular verbs became stronger along with the development of proficiency. With regards to the morphosyntactic violations of the irregular verbs and the phrase structural violations, no ERP components were detected. The results revealed that Japanese EFL learners with intermediate and low proficiency were sensitive to the semantic information, but they were not sensitive to the syntactic information including morphosyntactic and phrase structural rules.

In Chapter 5, the changes of the sensitivity to the syntactic information after the exposure to the correct information were investigated using the ERP method. The exposure tasks focusing on (a) morphosyntactic information (regular/irregular verbs) and (b) phrase structural rules were conducted to Japanese EFL learners with low proficiency. The effects of task type on exposure are also investigated, dividing participants into two groups: (1) silent reading and (2) repetition without looking. After that, the ERP experiment was conducted in the same manner as Chapter 4. As a result, P600 components against the morphosyntactic violations of the regular verbs and the phrase structural rules elicited from the participants who completed the silent reading task. On the other hand, P600 components against the morphosyntactic violations of the irregular verbs were detected from the participants who completed the repetition task without looking. The results revealed that the learnability of the linguistic information is different between the morphosyntactic information of the verbs and the phrase structural rules for Japanese EFL learners with low proficiency.

6.2 The Automaticity of Syntactic Parsing for Japanese EFL Learners

The results of the experiments in Chapters 3 and 4 revealed that it is impossible to assume that Japanese EFL learners can process the syntactic information automatically in online sentence processing from both psycholinguistic and neurophysiological perspectives.

Most of the research of sentence processing by native speakers of English indicates that readers compute and construct the syntactic structures of the sentences online by utilizing the syntactic information and considered whether they can process the semantic information simultaneously (Ferreira & Clifton, 1986; Just & Carpenter, 1992; Trueswell et al, 1994). In addition, from the neurophysiological perspective, it is argued that sentence comprehension has three steps (initial structure building, semantic integration, and late syntactic integration) and that the syntactic information is processed first in syntactic construction, which reflects LAN (ELAN) (Friederici, 2002; Friederici & Kotz, 2003). With regards to the morphosyntactic information of the verbs, MacDonald et al. (1992) insisted that L1 speakers can compute the possible sentence structures from the morphosyntactic information and Trueswell et al. (1994) defined the morphological ambiguity of the relative verbs as the baseline condition of the ambiguity of RR sentences.

On the other hand, in Chapter 3, Japanese EFL learners with intermediate proficiency could not compute the possible syntactic structures of the temporarily ambiguous sentences from the morphosyntactic information of the verbs. In addition, learners failed to process syntactically complex RR sentences regardless of the conditions of relative verbs. Based on the results of Chapter 4, there is the possibility that the absence of the initial syntactic processing caused the failure of the sentence comprehension in Chapter 3. Since learners do not process the morphosyntactic information of the verbs and the phrase structural rules online in their syntactic parsing, they could not predict the garden-path phenomenon and define the sentence structure from those information and rules.

In Chapter 4, learners performed well on the grammaticality judgment task of the irregular verbs in the experiment. But since there were no P600 components that reflect the reanalysis and repair of the sentence processing, it is possible that learners have the knowledge of the difference between the past tense form and its base form of the irregular verbs, but they cannot use it in online sentence processing. In addition, negative potentials were observed from learners when they encountered the morphosyntactic violations of the regular verbs, which is consistent with the experimental results of L1 speakers (Newman et al, 2007). But the ERP effects were different between the two. In L1 speakers, LAN and P600 components were elicited over the violations while N400-like components were found and there was the dependency of proficiency on P600 components in Japanese EFL learners. There is the possibility that learners do not process the morphosyntactic information of the regular verbs syntactically and treat as the semantic information. In addition, in the experiment of Chapter 3, there was the dependency of WM capacity on processing

MC sentences with the regular verbs, but the dependency was not observed in RR sentences. These results might also indicate the imperfection of the syntactic processing of the morphosyntactic information.

Nakanishi and Yokokawa (2011) argued that Japanese EFL learners' syntactic processing requires high processing costs in their WM capacity. Learners' non-automatic syntactic processing revealed in this dissertation might be one of the causes of the high processing costs. In addition, there was little effect of proficiency and WM capacity on processing syntactic information in the present study. Some of the previous neurophysiological studies insisted that L2 learners with high-proficiency are sensitive to the syntactic information (Kubota et al., 2003, 2004, 2005; Ojima et al., 2005), but the results of the present experiments indicate that Japanese EFL learners' syntactic processing is not yet automatized within the range of intermediate and low proficiency.

Since syntactic processing by Japanese EFL learners with intermediate and low proficiency is not as automatic, they have to rely on the semantic information on comprehending the sentences. Chapter 3 and 4 showed that learners are sensitive to the semantic information and used it to process the temporarily ambiguous sentences regardless of their proficiency. Moreover, the use of the semantic information in sentence processing becomes automatized along with the development of their proficiency. But the use of the semantic information by learners is different from that of L1 speakers. As already mentioned in 6.2, L1 speakers use the information during sentence processing on the assumption that they process the syntactic information and construct the initial structures of the sentences. In contrast, learners cannot construct the syntactic structures in initial structure building stage, so they have to rely on the semantic information to build and comprehend the structures. It is believed that this heavy reliance on semantic information makes learners more sensitive to the semantic information of the sentences during syntactic parsing, which is consistent with the previous studies conducted to Japanese EFL learners and with Clahsen and Felser's (2006) Shallow Structure Hypothesis.

6.3 The Learnability of Processing Syntactic Information

In response to the results of the experiments in Chapters 3 and 4, the exposure effects on the sensitivity to the syntactic information in sentence processing were investigated in Chapter 5 to reveal the learnability of the syntactic information. The results showed that Japanese low-proficiency EFL learners noticed and learned the syntactic rules including the morphosyntactic processing of the regular verbs and the phrase structural rules by the silent reading task. On the other hand, learners learned the lexical differences between the past tense form and its base form of the irregular verbs by the repetition task without looking.

From the results in Chapter 5, no negative components (LAN) were observed after exposing correct morphosyntactic information of the regular verbs and phrase structural rules, so learners' (morpho)syntactic processing did not become automatized like L1 speakers through the learning tasks. But P600 components observed from the learners who completed the silent reading task indicate that they could acquire explicit knowledge of the syntactic rules (Batterink & Neville, 2013). On the other hand, learners failed to learn the syntactic rules by repeating the sentences without looking. These results contradict to the previous study of Nagai (2011), which insisted that tasks which require memorizing the sentence structure promoted syntactic processing and learning. Since learners' syntactic processing is not as automatic and requires high processing costs in their WM capacity (Nakanishi & Yokokawa, 2011), there is the possibility that reading the training sentences aloud took too much costs and that the training task interfered processing the syntactic rules such as attaching the suffix *–ed* to the verb stem (Pinker & Ullman, 2002; Ullman, 2004) or constructing the syntactic structures.

As for the morphosyntactic information of the irregular verbs, the repetition task without looking was more effective to learn the information than the silent reading task. It is possible that learners' phonological loops of the WM (Baddeley, 2000; Baddeley, Gathercole, & Papagno, 1998; Baddeley & Hitch, 1974) were activated and that phonological forms of the past tense form and its base form of the irregular verbs helped memorizing and learning differences between the two. Reading sentences aloud and learning the morphosyntactic information of the irregular verbs might not be competitive since the information processing does not require applying rules but retrieving the verbs from memory (Pinker & Ullman, 2002; Ullman, 2004).

There is the possibility that the results of the experiment in chapter 5 are attributed to short-term activation of the particular information in the sentence (residual activation) rather than longer term adaptation within the cognitive mechanisms from the results of intensive learning, especially in the learning effects of syntactic rules, which is argued in syntactic priming studies on sentence production (*e.g.* Bock & Griffin, 2000). Since the testing session was conducted right after the training session was completed, the residual activation of the information from the training might affect the results of the experiment and there might not be the learning effects of the exposure to the information. But the training sentences were not temporarily ambiguous like the sentences used in the previous research on the syntactic priming effects in comprehending sentences (*e.g.* Branigan, Pickering, & McLean, 2005; Traxler & Tooley, 2008; Tooley, Traxler, & Swaab, 2009) and had one valid parse. So it is believed that participants in Chapter 5 activated only one robust syntactic structure and that there were strong repetition effects on learning the morphosyntactic information of the regular verbs and the phrase structural rules through the exposure to the training sentences. The P600 components which were observed in Chapter 5 but not in Chapter 4 indicate that the neural changes of the information processing by the training task. The present experiments revealed learners' plasticity of the neural mechanism which reflects the reanalysis and repair of the sentence processing through the exposure to the correct syntactic information in sentences (Batterink & Neville, 2013).

6.4 Pedagogical Implications

The present study discussed Japanese EFL learners' automaticity in sentence processing and learnability of syntactic information including the morphosyntactic information of the verbs and the phrase structural rules. The results of the experiments revealed that learners have difficulty in using syntactic information on sentence processing and no evidence was found that learners' syntactic processing became automatized along with the development of their proficiency or after the exposure task. But there is the possibility that learners are able to notice the morphosyntactic information of the verbs and the phrase structural rules and use it for sentence processing after they exposed to the correct information. The previous studies insisted that the attention to the syntactic information promotes the L2 learning (Loschky & Harrington, Forthcoming) and that the sensitivity to the information correlates with learning achievement (Batterink & Neville, 2013; Tanner et al., 2013). It is believed that noticing and focusing on the syntactic information of the sentence are important for promoting the syntactic processing by Japanese EFL learners.

To promote the learning of the syntactic processing, instructors should give learners the task that focuses on syntactic information intensively. As for the phrase structural rules, it seems to be effective for learners to increase the opportunity to process and comprehend the sentences with the particular structure. The tasks which require high processing costs might not effective for learners with low proficiency to learn the rules, such as the repetition task without looking. With regards to the morphosyntactic information of the verbs, it is considered that the tasks which emphasize the structure of the sentence are more effective for Japanese EFL learners such as the word-order correction task or the sorting task of phrases. Since the mere exposure tasks did not promote the learning of the morphosyntactic processing, the more conflict task that focuses on the morphosyntactic information might be effective for Japanese EFL learners with low proficiency.

7. Conclusions and Further Studies

In this dissertation, the aspects of syntactic parsing by Japanese EFL learners and its automaticity were investigated from the perspective of their use of the explicit linguistic information in the sentences from both psycholinguistic and neurophysiological perspectives. The present study revealed that Japanese EFL learners with intermediate and low proficiency have difficulty in processing syntactic information in the sentences and rely more on semantic information in syntactic parsing. In addition, some possibilities were found that learners learn to be able to notice and use the syntactic information on sentence processing through the appropriate task which focuses on particular information.

There are some limitations in the study, and some suggestions can be made for further research. First, the correlation between proficiency and WM capacity should be analyzed to supplement and deeper discussion on the findings of this study. The investigation of the relationship between these two important factors is crucial to examine Japanese EFL learners' mechanism of syntactic parsing. Second, in the previous study of Trueswell et al. (1994), they manipulated the semantic combination (thematic fit) between the noun phrases and relative verbs to control the ambiguity of the sentences more strictly. In the present eye-tracking study, the thematic fits of the noun phrases and relative verbs were not considered, so investigating the effects of the thematic fit for parsing might be effective to reveal how linguistic information including semantic and morphosyntactic information is used in sentence processing.

In addition, the developmental process of learners' brain from the perspective of the brain activation need to be investigated, which is difficult to detect by the ERP study. As briefly mentioned in Chapter 2, functional MRI (fMRI) or optical topography are used to investigate the activation of the brain when learners process the target language (Nauchi & Sakai, 2009; Oishi, 2006; Yusa et al., 2011). Moreover, Newman, Pancheva, Ozawa, Neville, and Ullman (2001) investigated the activation of the brain when native speakers of English saw syntactic and semantic violations in the sentence using event-related fMRI. These experimental methods should be introduced for future studies to reveal more detailed characteristics of syntactic parsing by Japanese EFL learners.

Lastly, it is necessary to examine how to reflect the characteristics of Japanese EFL learners' syntactic parsing and its developmental process to the English education in Japan. This examination can lead to invent the new teaching or testing method for learners. It is the final goal of this research and might be difficult to achieve, but it could be helpful to improve English education in Japan.

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Appendix A: Target sentences and comprehension questions on Chapter 3

Notice: Slashes indicate the regions for data analysis.

(True) or (False) after the question sentences are the right answers of the questions.

Experiment 1

(a): animate condition (b): inanimate condition

1. (a) The teacher / loved / by the class / was very / easy to understand.

   Question: The teacher was very easy to understand. (True)

   (b) The lesson / loved / by the class / was very / easy to understand.

   Question: The lesson was very easy to understand. (True)

2. (a) The student / graded / by the teacher / got a / low mark.

   Question: The student was graded by the teacher. (True)

   (b) The paper / graded / by the teacher / got a / low mark.

   Question: The paper was graded by the teacher. (True)

3. (a) The doctor / requested / by the hospital / finally arrived.

   Question: The doctor was requested by the hospital. (True)

   (b) The machine / requested / by the hospital / finally arrived.

   Question: The machine was requested by the hospital. (True)

4. (a) The baby / left / by the woman / came back / yesterday.

   Question: The baby came back yesterday. (True)

   (b) The bag / left / by the woman / came back / yesterday.

   Question: The bag came back yesterday. (True)

5. (a) The artist / reported / by the student / was a / complete mystery.

   Question: The artist reported the student. (False)

(b) The painting / reported / by the student / was a / complete mystery.

Question: The student was a complete mystery. (False)

6. (a) The man / kicked / by the child / suddenly fell / down.

Question: The man kicked the child. (False)

(b) The tree / kicked / by the child / suddenly fell / down.

Question: The child suddenly fell down. (False)

7. (a) The president / protected / by the police / arrived too / late.

Question: The police protected the president. (True)

(b) The package / protected / by the police / arrived too / late.

Question: The police protected the package. (True)

8. (a) The guest / transported / by the driver / stayed in / the car.

Question: The driver transported the guest. (True)

(b) The gold / transported / by the driver / stayed in / the car.

Question: The driver transported the gold. (True)

9. (a) The father / pulled / by the son / moved very / little.

Question: The father moved very little. (True)

(b) The desk / pulled / by the son / moved very / little.

Question: The desk moved very little. (True)

10. (a) The girl / found / by the gentleman / was in / the city museum.

Question: The gentleman found the girl. (True)

(b) The key / found / by the gentleman / was in / the city museum.

Question: The gentleman found the key. (True)

11. (a) The woman / damaged / by the cat / was very / old.

Question: The woman damaged the cat. (False)

(b) The table / damaged / by the cat / was very / old.

Question: The cat was very old. (False)

12. (a) The king / visited / by the people / was famous / around the world.

Question: The king visited the people. (False)

(b) The country / visited / by the people / was famous / around the world.

Question: The people was famous around the world. (False)

13. (a) The boy / described / by the writer / was very / interesting.

Question: The boy described the writer. (False)

(b) The story / described / by the writer / was very / interesting.

Question: The writer was very interesting. (False)

14. (a) The lady / selected / by the producer / was quite / beautiful.

Question: The lady selected the producer. (False)

(b) The dress / selected / by the producer / was quite / beautiful.

Question: The producer was quite beautiful. (False)

15. (a) The child / observed / by the doctor / died in / the morning.

Question: The child observed the doctor. (False)

(b) The plant / observed / by the doctor / died in / the morning.

Question: The doctor died in the morning. (False)

16. (a) The leader / supported / by the staff / completely succeeded.

Question: The leader supported the staff. (False)

(b) The party / supported / by the staff / completely succeeded.

Question: The staff completely succeeded. (False)

Experiment 2

(c): ambiguous condition (d): unambiguous condition

Verb pair: push (pushed) / drive (drove, driven)

1.

MC sentence

(c) The old man / pushed / through the gate / to the front / door.

Question: The old man pushed through the gate. (True)

(d) The old man / drove / through the gate / to the front / door.

Question: The old man drove through the gate. (True)

RR sentence

(c) The old man / pushed / through the gate / came into / the garden.

Question: The old man came into the garden. (True)

(d) The old man / driven / through the gate / came into / the garden.

Question: The old man was driven through the gate. (True)

2.

MC sentence

(c) The young policeman / pushed / through the public / to the police / station.

Question: The young policeman was pushed through the public. (False)

(d) The young policeman / drove / through the public / to the police / station.

Question: The young policeman was driven through the public. (False)

RR sentence

(c) The young policeman / pushed / through the public / arrived at / the station.

Question: The young policeman pushed through the public. (False)

(d) The young policeman / driven / through the public / arrived at / the station.

Question: The young policeman drove through the public. (False)

3.

MC sentence

(c) The wild guy / pushed / through the wall / to the main / street.

Question: The wild guy pushed through the wall. (True)

(d) The wild guy / drove / through the wall / to the main / street.

Question: The wild guy drove through the wall. (True)

RR sentence

(c) The wild guy / pushed / through the wall / approached the / tall building.

Question: The wild guy was pushed through the wall. (True)

(d) The wild guy / driven / through the wall / approached the / tall building.

Question: The wild guy approached the tall building. (True)

Verb pair: supply (supplied) / give (gave, given)

4.

MC sentence

(c) The poor mother / supplied / a little money / to the young / daughter.

Question: The poor mother was supplied a little money. (False)

(d) The poor mother / gave / a little money / to the young / daughter.

Question: The poor mother was given a little money. (False)

RR sentence

(c) The poor mother / supplied / a little money / bought a / few books.

Question: The poor mother supplied a little money. (False)

(d) The poor mother / given / a little money / bought a / few books.

Question: The poor mother gave a little money. (False)

5.

MC sentence

(c) The kind gentleman / supplied / very good food / to the sick / people.

Question: The kind gentleman was supplied very good food. (False)

(d) The kind gentleman / gave / very good food / to the sick / people.

Question: The kind gentleman was given very good food. (False)

RR sentence

(c) The kind gentleman / supplied / very good food / cooked for / the family.

Question: The kind gentleman supplied very good food. (False)

(d) The kind gentleman / given / very good food / cooked for / the family.

Question: The kind gentleman gave very good food. (False)

6.

MC sentence

(c) The chief manager / supplied / the wrong information / to the angry / customer.

Question: The chief manager supplied the wrong information. (True)

(d) The chief manager / gave / the wrong information / to the angry / customer.

Question: The chief manager gave the wrong information. (True)

RR sentence

(c) The chief manager / supplied / the wrong information / checked the / truth quickly.

Question: The chief manager checked the truth quickly. (True)

(d) The chief manager / given / the wrong information / checked the / truth quickly.

Question: The chief manager was given the wrong information. (True)

Verb pair: teach (taught) / show (showed, shown)

7.

MC sentence

(c) The little boy / taught / all the dances / for the spring / performance.

Question: The little boy was taught all the dances. (False)

(d) The little boy / showed / all the dances / for the spring / performance.

Question: The little boy was shown all the dances. (False)

RR sentence

(c) The little boy / taught / all the dances / was in / the performance.

Question: The little boy taught all the dances. (False)

(d) The little boy / shown / all the dances / was in / the performance.

Question: The little boy showed all the dances. (False)

8.

MC sentence

(c) The old scientist / taught / the computer program / from the difficult / manual.

Question: The old scientist taught the computer program. (True)

(d) The old scientist / showed / the computer program / from the difficult / manual.

Question: The old scientist showed the computer program. (True)

RR sentence

(c) The old scientist / taught / the computer program / expressed the / design clearly.

Question: The old scientist expressed the design clearly. (True)

(d) The old scientist / shown / the computer program / expressed the / design clearly.

Question: The old scientist was shown the computer program. (True)

9.

MC sentence

(c) The new volunteer / taught / the difficult task / without very much / trouble.

Question: The new volunteer taught the difficult task. (True)

(d) The new volunteer / showed / the difficult task / without very much / trouble.

Question: The new volunteer showed the difficult task. (True)

RR sentence

(c) The new volunteer / taught / the difficult task / became a / good student.

Question: The new volunteer was taught the difficult task. (True)

(d) The new volunteer / shown / the difficult task / became a / good student.

Question: The new volunteer became a good student. (True)

Verb pair: send (sent) / write (wrote, written)

10.

MC sentence

(c) The famous actor / sent / a long message / to the movie / director.

Question: The famous actor sent a long message. (True)

(d) The famous actor / wrote / a long message / to the movie / director.

Question: The famous actor was written a long message. (False)

RR sentence

(c) The famous actor / sent / a long message / understood the / true meaning.

Question: The famous actor was sent a long message. (True)

(d) The famous actor / written / a long message / understood the / true meaning.

Question: The famous actor wrote a long message. (False)

11.

MC sentence

(c) The guitar player / sent / a love letter / to the beautiful / woman.

Question: The guitar player was sent a love letter. (False)

(d) The guitar player / wrote / a love letter / to the beautiful / woman.

Question: The guitar player was written a love letter. (False)

RR sentence

(c) The guitar player / sent / a love letter / sang a / love song.

Question: The guitar player sent a love letter. (False)

(d) The guitar player / written / a love letter / sang a / love song.

Question: The guitar player wrote a love letter. (False)

12.

MC sentence

(c) The young girl / sent / a birthday card / to the new / friend.

Question: The young girl was sent a birthday card. (False)

(d) The young girl / wrote / a birthday card / to the new / friend.

Question: The young girl wrote a birthday card. (True)

RR sentence

(c) The young girl / sent / a birthday card / thought about / the present.

Question: The young girl sent a birthday card. (False)

(d) The young girl / written / a birthday card / thought about / the present.

Question: The young girl thought about the present. (True)

Appendix B: Target sentences on Chapter 4

Notice: The mark "*" indicates incongruent.

Italic words are the target words of the sentences.

Experiment 1

Regular verb condition

1. Yesterday he *played* (**play*) a guitar.
2. Yesterday she *helped* (**help*) a stranger.
3. Yesterday I *planned* (**plan*) a party.
4. Yesterday he *stopped* (**stop*) a car.
5. Yesterday she *asked* (**ask*) a question.
6. Yesterday she *talked* (**talk*) with Jack.
7. Yesterday he *closed* (**close*) a door.
8. Yesterday he *missed* (**miss*) a train.
9. Yesterday she *watched* (**watch*) our baby.
10. Yesterday she *worked* (**work*) with Kevin.
11. Yesterday she *pushed* (**push*) a button.
12. Yesterday he *cleaned* (**clean*) a room.
13. Yesterday she *walked* (**walk*) after lunch.
14. Yesterday he *called* (**call*) a friend.
15. Yesterday he *scored* (**score*) a point.
16. Yesterday she *used* (**use*) a map.
17. Yesterday he *signed* (**sign*) a letter.
18. Yesterday he *cried* (**cry*) with joy.
19. Yesterday she *looked* (**look*) at Susan.
20. Yesterday he *kicked* (**kick*) a tree.

Irregular verb condition

1. Yesterday she *took* (**take*) a bath.
2. Yesterday I *lost* (**lose*) a key.

3. Yesterday I *taught* (*teach*) a class.

4. Yesterday she *drove* (*drive*) our car.

5. Yesterday she *ran* (*run*) a mile.

6. Yesterday he *sang* (*sing*) a song.

7. Yesterday I *slept* (*sleep*) in bed.

8. Yesterday she *thought* (*think*) about chocolate.

9. Yesterday I *ate* (*eat*) an apple.

10. Yesterday she *spoke* (*speak*) with Maria.

11. Yesterday she *wrote* (*write*) a book.

12. Yesterday she *sent* (*send*) a letter.

13. Yesterday he *built* (*build*) a house.

14. Yesterday he *told* (*tell*) a story.

15. Yesterday I *swam* (*swim*) with Nancy.

16. Yesterday he *caught* (*catch*) a cold.

17. Yesterday she *won* (*win*) a game.

18. Yesterday I *sold* (*sell*) a car.

19. Yesterday she *bought* (*buy*) one ticket.

20. Yesterday she *broke* (*break*) a glass.

Experiment 2

1. Mike listened to Max's *speech* (*orange*) about war.

2. The man read Mike's *report* (*team*) of the lecture.

3. I bought the *camera* (*night*) at the store.

4. John discovered Bob's *picture* (*mouth*) of his family.

5. The visitors believed Jack's *advice* (*snow*) about the money.

6. We ate the *bread* (*drama*) with our hands.

7. The students sang Lisa's *songs* (*eyes*) about freedom.

8. The scientist explained Nancy's *review* (*today*) of the book.

9. The boys heard Kevin's *stories* (*earth*) about America.

10. Yesterday she drank some *milk* (*advice*) from their factory.

11. The students enjoyed Bill's *review* (**sky*) of the play.

12. Yesterday I sold Mike's *house* (**winter*) to Ken.

13. Yesterday Sam put Kate's *bag* (**culture*) on the floor.

14. The newspaper printed Bill's *picture* (**gas*) of the accident.

15. Yesterday John sent the *package* (**museum*) to his sister.

16. Yesterday I drank Max's *beer* (**land*) from Germany.

17. The writer published Harry's *report* (**hat*) about drugs.

18. They hurt Mike's *pride* (**water*) for no reason.

19. The man bought Ken's *painting* (**past*) of the island.

20. The teacher found Tom's *poem* (**second*) about the moon.

21. Yesterday I met his *friend* (**mouth*) from Spain.

22. Emily published my *novel* (**circle*) from last year.

23. She opened the *present* (**baby*) from her mother.

24. I saw the *girl* (**century*) with long hair.

25. Yesterday he drank my *wine* (**ability*) from France.

26. I ordered the *coffee* (**future*) from Brazil.

27. Yesterday they watched the *movie* (**peace*) about Italy.

28. Bob understood the *problem* (**pocket*) of the company.

29. Yesterday I expressed some *interest* (**light*) in the project.

30. I support the *education* (**color*) of the poor.

31. I wrote that *speech* (**shoulder*) about economy.

32. Yesterday I met Harry's *wife* (**job*) in Canada.

33. I finished the *task* (**moon*) without her help.

34. Yesterday I ate my *food* (**paper*) at the restaurant.

35. Yesterday I found Naomi's *dog* (**moment*) in the garden.

36. Yesterday I read some *books* (**brothers*) about science.

37. Yesterday I told the *news* (**sun*) to my friend.

38. Yesterday I taught the *dance* (**hair*) to the students.

39. Mary added some *sugar* (**death*) to her coffee.

40. Sarah drank the *tea* (**subject*) from China.

Experiment 3

1. Susan liked Jack's joke *about* the man.

*Susan liked Jack's *about* joke the man.

2. Yesterday I found Maria's poem *about* the moon.

*Yesterday I found Maria's *about* poem the moon.

3. Yesterday I rented Tom's film *about* Spain.

*Yesterday I rented Tom's *about* film Spain.

4. The woman doubted Harry's respect *for* his teachers.

*The woman doubted Harry's *for* respect his teachers.

5. Yesterday I shared Emily's secret *with* the teacher.

*Yesterday I shared Emily's *with* secret the teacher.

6. Yesterday Max drank Bob's water *from* Japan.

*Yesterday Max drank Bob's *from* water Japan.

7. She heard Kevin's report *of* my problem.

*She heard Kevin's *of* report my problem.

8. We bought Emily's house *in* July.

*We bought Emily's *in* house July.

9. Yesterday Kate attended Sam's concert *with* her friend.

*Yesterday Kate attended Sam's *with* concert her friend.

10. Yesterday I read Bob's letter *in* the afternoon.

*Yesterday I read Bob's *in* letter the afternoon.

11. She sold Mike's gold *on* his birthday.

*She sold Mike's *on* gold his birthday.

12. Yesterday I gave Nancy's dress *to* Sally.

* Yesterday I gave Nancy's *to* dress Sally.

13. Yesterday I read Bob's book *to* my daughter.

*Yesterday I read Bob's *to* book my daughter.

14. She carried Harry's dish *to* her mother.

*She carried Harry's *to* dish her mother.

15. Yesterday I gave Sarah's cake *to* the children.

*Yesterday I gave Sarah's *to* cake the children.

16. Yesterday I ate Susan's potato *from* her garden.

*Yesterday I ate Susan's *from* potato her garden.

17. The students heard Jack's lecture *about* the planets.

*The students heard Jack's *about* lecture the planets.

18. Yesterday I read Kevin's book *about* Africa.

*Yesterday I read Kevin's *about* book Africa.

19. Yesterday I published Sam's poem *about* love.

*Yesterday I published Sam's *about* poem love.

20. My family rented Tom's house *for* the summer.

*My family rented Tom's *for* house the summer.

21. The newspaper printed Max's version *of* the story.

*The newspaper printed Max's *of* version the story.

22. Yesterday I sold Emily's picture *of* her father.

*Yesterday I sold Emily's *of* picture her father.

23. Yesterday I heard Sally's story *of* her escape.

*Yesterday I heard Sally's *of* story her escape.

24. Yesterday I discovered Mary's love *of* music.

*Yesterday I discovered Mary's *of* love music.

25. Yesterday I cut Max's apple *with* my knife.

*Yesterday I cut Max's *with* apple my knife.

26. My brother lost Lisa's ring *after* the wedding.

*My brother lost Lisa's *after* ring the wedding.

27. Yesterday I answered John's message *with* pleasure.

*Yesterday I answered John's *with* message pleasure.

28. They discussed Bill's job *at* the party.

*They discussed Bill's *at* job the party.

29. The scientist doubted Bill's knowledge *of* weather.

*The scientist doubted Bill's *of* knowledge weather.

30. Ken passed Naomi's note *to* his friend.

*Ken passed Naomi's *to* note his friend.

31. Yesterday I took Maria's sister *to* the library.

*Yesterday I took Maria's *to* sister the library.

32. Yesterday Jack offered Nancy's help *to* the lady.

*Yesterday Jack offered Nancy's *to* help the lady.

33. Yesterday I left Sarah's sugar *on* the table.

*Yesterday I left Sarah's *on* sugar the table.

34. The children enjoyed Tom's stories *about* the country.

*The children enjoyed Tom's *about* stories the country.

35. The visitors believed Jack's advice *about* the money.

*The visitors believed Jack's *about* advice the money.

36. The writer published Harry's report *about* drugs.

*The writer published Harry's *about* report drugs.

37. The students enjoyed Bill's review *of* the play.

*The students enjoyed Bill's *of* review the play.

38. The students sang Lisa's songs *about* freedom.

*The students sang Lisa's *about* songs freedom.

39. The man bought Ken's painting *of* the island.

*The man bought Ken's *of* painting the island.

40. The boys heard Kevin's stories *about* America.

*The boys heard Kevin's *about* stories America.

Appendix C: Training sentences and comprehension questions on Chapter 5

Notice: (True) or (False) after the question sentences are the right answers of the questions.

Experiment 1

Regular verb condition

(e): present form condition (f): past form condition

1. (e) They often play tennis with their friends.

   Question: They can play tennis. (True)

   (f) They played tennis with their friends last Monday.

   Question: They played tennis last Monday. (True)

2. (e) Bob often helps Lisa with her homework.

   Question: Lisa often finishes her homework by herself. (False)

   (f) Bob helped Lisa with her homework last week.

   Question: Bob finished his homework last week. (False)

3. (e) Susan often plans a trip to Kyoto.

   Question: Susan often makes a plan to visit Kyoto. (True)

   (f) Susan planned a trip to Kyoto last month.

   Question: Susan made a plan to visit Tokyo last week. (False)

4. (e) Harry sometimes stops at a store.

   Question: Harry sometimes goes shopping at a store. (True)

   (f) Harry stopped at a store yesterday.

   Question: Harry went shopping at a store yesterday. (True)

5. (e) They sometimes ask Bill for an interview.

   Question: Bill sometimes does an interview with them. (False)

(f) They asked Bill for an interview last Sunday.

Question: Bill did an interview with them last year. (False)

6. (e) They always talk in the room.

Question: They always use the room when they are talking. (True)

(f) They talked in the room last week.

Question: They talked to each other last week. (True)

7. (e) They close their shop at six.

Question: The shop closes at seven. (False)

(f) They closed their shop at six yesterday.

Question: The shop closed at six yesterday. (True)

8. (e) They sometimes miss a bus in the morning.

Question: They always catch a bus in the morning. (False)

(f) They missed a bus yesterday.

Question: They managed to catch a bus yesterday. (False)

9. (e) Max often watches the baseball game.

Question: Max likes to watch the soccer game. (False)

(f) Max watched the baseball game last month.

Question: Max played the baseball three months ago. (False)

10. (e) Mike works in a car factory.

Question: Mike builds a car in a factory. (True)

(f) Mike worked in a car factory last year.

Question: Mike used to work in a car factory. (True)

11. (e) Ken sometimes pushes a baby carriage.

Question: Ken is a baby. (False)

(f) Ken pushed a baby carriage yesterday.

Question: Ken was in a baby carriage yesterday. (False)

12. (e) Sally always cleans her hands.

Question: Sally always keeps her hands clean. (True)

(f) Sally cleaned her hands yesterday.

Question: Sally's hands were cleaned yesterday. (True)

13. (e) They always walk to school.

Question: They go to school by bus. (False)

(f) They walked to school yesterday.

Question: Yesterday they took a train to go to school. (False)

14. (e) Lisa calls herself an artist.

Question: Lisa thinks that she is an artist. (True)

(f) Lisa called herself an artist last year.

Question: Lisa thought that she was an artist last year. (True)

15. (e) Maria usually scores ninety points on the test.

Question: Maria usually does well on the test. (True)

(f) Maria scored ninety points on the test last week.

Question: Maria failed the test last week. (False)

16. (e) The teacher often uses a computer for work.

Question: The teacher never uses a computer. (False)

(f) The teacher used a computer for work yesterday.

Question: Yesterday the teacher didn't use a computer. (False)

17. (e) Naomi always signs her autographs for her fans.

Question: Naomi's fans can't get her autographs. (False)

(f) Naomi signed her autographs for her fans last month.

Question: Naomi's fans got her autographs two years ago. (False)

18. (e) The girl always cries in the park.

Question: When the girl goes to the park, she always cries. (True)

(f) The girl cried in the park last Friday.

Question: The girl went to the park last Friday. (True)

19. (e) They sometimes look at each other.

Question: They sometimes look at one another. (True)

(f) They looked at each other yesterday.

Question: Yesterday they looked at one another. (True)

20. (e) They sometimes kick the door open.

Question: They never push the door open with their feet. (False)

(f) They kicked the door open last month.

Question: They pushed the door open with their feet last month. (True)

Irregular verb condition

(e): present form condition (f): past form condition

1. (e) They always take some flowers to the hospital.

Question: They always pick some flowers in the hospital. (False)

(f) They took some flowers to the hospital yesterday.

Question: Yesterday they went to the hospital. (True)

2. (e) The king sometimes loses his power.

Question: The king doesn't have any power. (False)

(f) The king lost his power yesterday.

Question: The king doesn't have any power now. (True)

3. (e) Kevin teaches English at high school.

Question: Kevin is an English teacher. (True)

(f) Kevin taught English at high school last year.

Question: Kevin was a high school student last year. (False)

4. (e) Sarah often drives a sports car.

Question: Sarah can drive a car. (True)

(f) Sarah drove a sports car last week.

Question: Last week Sarah rode a sports car. (True)

5. (e) Sam always runs away from the police.

Question: Sam is a police officer. (False)

(f) Sam ran away from the police yesterday.

Question: Sam was arrested by the police yesterday. (False)

6. (e) Mary often sings in her house.

Question: Mary doesn’t like to sing. (False)

(f) Mary sang in her house last Sunday.

Question: Mary was not at home last Sunday. (False)

7. (e) John sometimes sleeps at his desk.

Question: John’s bed is near his desk. (False)

(f) John slept at his desk yesterday.

Question: Yesterday John kept awake for a day. (False)

8. (e) They always think that money is everything.

Question: Money is important for them. (True)

(f) They thought that money was everything last year.

Question: Money was important for them last year. (True)

9. (e) They often eat food with a fork.

Question: They often use a fork to eat food. (True)

(f) They ate food with a fork yesterday.

Question: They used a fork to eat food yesterday. (True)

10. (e) Nancy always speaks in a small voice.

Question: Nancy doesn't speak loud. (True)

(f) Nancy spoke in a small voice last Monday.

Question: Nancy spoke loud last Monday. (False)

11. (e) Jack sometimes writes an essay on music.

Question: Jack doesn't know about music. (False)

(f) Jack wrote an essay on music last month.

Question: The essay was written by Jack. (True)

12. (e) They always send Kate a birthday card.

Question: Kate always receives a birthday card from them. (True)

(f) They sent Kate a birthday card last week.

Question: Kate received a birthday card from them. (True)

13. (e) They build the ship in Brazil.

Question: The ship is made in Brazil. (True)

(f) They built the ship in Brazil last year.

Question: Last year they made the ship in Brazil. (True)

14. (e) They usually tell Ken the truth.

Question: Ken never tells the truth to them. (False)

(f) They told Ken the truth last Friday.

Question: Ken told the truth to them last Friday. (False)

15. (e) They often swim in the pool.

Question: They can’t swim. (False)

(f) They swam in the pool last month.

Question: They went to the pool two months ago. (False)

16. (e) Tom always catches a ball with two hands.

Question: It is hard for Tom to catch a ball. (False)

(f) Tom caught a ball with two hands yesterday.

Question: Tom failed to catch a ball yesterday. (False)

17. (e) Susan often wins a lottery.

Question: Susan never buys a lottery. (False)

(f) Susan won a lottery last year.

Question: Susan didn’t buy a lottery last year. (False)

18. (e) They sell vegetables at the store.

Question: The store sells vegetables. (True)

(f) They sold vegetables at the store last month.

Question: The store doesn’t sell vegetables now. (True)

19. (e) Emily sometimes buys food with a credit card.

Question: Emily sometimes uses a credit card to buy food. (True)

(f) Emily bought food with a credit card last week.

Question: Last week Emily used a credit card to buy food. (True)

20. (e) John often breaks his promise.

Question: John rarely keeps his promise. (True)

(f) John broke his promise yesterday.

Question: Yesterday John kept his promise. (False)

Experiment 2

1. Bob took a train to Tokyo.

Question: Bob went to Kyoto by train. (False)

2. Tom made a reservation on a ship.

Question: Tom is going to take a ship. (True)

3. Mike passed the entrance exam for university.

Question: Mike failed the entrance exam. (False)

4. Jack took a medicine for the stomach.

Question: Jack is in good health. (False)

5. Lisa took the phone on the table.

Question: The phone is on the table. (True)

6. Emily received the package from France.

Question: The package is from France. (True)

7. Max opened the door to the house.

Question: The door was opened by Max. (True)

8. Susan planned a trip to Japan.

Question: Susan plans to go to China. (False)

9. Nancy enjoyed the view along the road.

Question: Nancy didn’t like the view. (False)

10. Susan found a picture on the wall.

Question: The picture was on the wall. (True)

11. The woman put the ring on her finger.

Question: The woman is wearing a ring. (True)

12. The man held a gun in his hand.

Question: The man doesn’t have a gun. (False)

13. Harry found a job for his mother.

Question: Harry’s mother has her job. (False)

14. The girl found her way to the station.

Question: The girl arrived at the station. (True)

15. Bill ate his dinner in a restaurant.

Question: Bill went to a restaurant. (True)

16. Kevin bought a book on economy.

Question: Kevin wrote a book. (False)

17. The doctor had some questions about the document.

Question: The doctor understood the document completely. (False)

18. Ken gave some books to Mary.

Question: Mary got some books. (True)

19. Kevin took his father to the airport.

Question: Kevin’s father went to the airport. (True)

20. Sam bought the ticket of a musical.

Question: Sam is going to perform in a musical. (False)

21. The student put the book on the desk.

Question: Question: The book is on the desk. (True)

22. Maria watched that drama on television.

Question: Maria missed that drama. (False)

23. Sarah saw her friend in the theater.

Question: Sarah’s friend was in the theater. (True)

24. Jack visited his grandmother in April.

Question: Jack saw his grandmother in August. (False)

25. Kate threw the letter in the fire.

Question: Kate burned the letter. (True)

26. We must protect our children from violence.

Question: It is important to protect children from violence. (True)

27. Students must put the name tag to their bags.

Question: Students don't need the name tag. (False)

28. Jack can finish this job in a day.

Question: Jack needs three days to finish the job. (False)

29. Lisa received a call in the morning.

Question: Lisa made a call. (False)

30. Naomi heard the news about the accident.

Question: Naomi knows about the accident. (True)

31. Tom cleaned his room with Sally.

Question: Tom and Sally cleaned Tom's room. (True)

32. Bob cuts his hair by himself.

Question: Bob doesn't cut his hair. (False)

33. Mike listened to the speech about war.

Question: Mike made the speech. (False)

34. The man read the report of the lecture.

Question: The report was written by the man. (False)

35. Max bought the camera at the store.

Question: Max went to the store to buy the camera. (True)

36. John discovered the picture of his family.

Question: John found the picture. (True)

37. The boy ate the bread with his hands.

Question: The boy used a fork to eat the bread. (False)

38. The teacher explained the meaning of the word.

Question: The teacher doesn't know about the meaning of the word. (False)

39. Sally drank some milk from the factory.

Question: The milk was made in the factory. (True)

40. Susan sold her house to Ken.

Question: Ken bought the house. (True)

41. Sam put his bag on the floor.

Question: Sam’s bag is on the floor. (True)

42. The newspaper printed the picture of the accident.

Question: No picture appeared in the newspaper. (False)

43. John sent the package to his sister.

Question: John’s sister sent the package. (False)

44. The boy hurt his leg in the afternoon.

Question: The boy has pain in his leg. (True)

45. The teacher wrote a poem about the moon.

Question: The poem is written by the teacher. (True)

46. John met his friend from Spain.

Question: John is from Spain. (False)

47. Emily published her novel in September.

Question: Emily wrote the novel. (True)

48. Lisa opened the present from her mother.

Question: Lisa’s mother received the present. (False)

49. Nancy saw the girl with long hair.

Question: Nancy has long hair. (False)

50. Kate drank her wine from France.

Question: The wine was made in France. (True)

51. Naomi ordered the coffee from Brazil.

Question: Naomi wanted to drink the coffee from Brazil. (True)

52. Sarah watched the movie about Italy.

Question: Sarah went to Italy. (False)

53. Bob understood the problem of the company.

Question: Bob doesn’t know about the problem. (False)

54. Bill expressed some interest in the project.

Question: Bill is interested in the project. (True)

55. The woman supports the education of the poor.

Question: The woman is poor. (False)

56. Kevin wrote that speech about economy.

Question: The speech was written by Kevin. (True)

57. Sam met his mother in Canada.

Question: Sam’s mother lives in Canada. (True)

58. The man finished the task in the evening.

Question: The task was finished in the morning. (False)

59. Naomi found her dog in the garden.

Question: Naomi’s dog isn’t in the garden. (False)

60. The student read some books about science.

Question: The student got to know more about science. (True)

61. The man told the news to his friend.

Question: The man heard the news from his friend. (False)

62. Max taught the dance to the students.

Question: Max learned the dance from the students. (False)

63. Emily added some sugar to her coffee.

Question: Emily drank coffee without sugar. (False)

64. Sarah drank the tea from China.

Question: The tea is from China. (True)

65. Maria threw her bag into the room.

Question: Maria's bag was thrown into the room. (True)

66. Mary sold her painting of her father.

Question: Mary's father sold the painting. (False)

67. Nancy turned the pages of her magazine.

Question: Nancy is reading her magazine. (True)

68. Bill translated his book for the children.

Question: The book was translated by Bill. (True)

69. Naomi kissed her daughter on the cheek.

Question: Naomi kissed her daughter's cheek. (True)

70. Harry wanted the farm on the hill.

Question: Harry owns the firm. (False)

71. Kate provided a solution to the problem.

Question: Kate has difficulty to solve the problem. (False)

72. Tom wrote the answer on the blackboard.

Question: The answer was written by Tom. (True)

73. Mike likes his teacher of science.

Question: Mike is a science teacher. (False)

74. Mary introduced her mother to John.

Question: John's mother was introduced by Mary. (False)

75. Sally printed her photos by the printer.

Question: Sally used the printer to print her photos. (True)

76. Jack taught the history of art.

Question: Jack knows about the history of art. (True)

77. Students held a party for their teacher.

Question: The teacher planned the party. (False)

78. Max read the article about the actor.

Question: The actor wrote the article. (False)

79. Ken turned his bread into sandwiches.

Question: Ken made sandwiches. (True)

80. Max became the president of the company.

Question: Max works in the company. (True)