Effects of Prosody while Disambiguating Ambiguous Japanese Sentences

in the Brain of Native Speakers and Learners of Japanese:

A Proposition for Pronunciation and Prosody Training

BY

Yuka Naito-Billen

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_____
Chair: Dr. Manuela Gonzalez-Bueno

_____
Co-Chair: Dr. Robert Fiorentino

_____
Dr. Utako Minai

_____
Dr. Paul Markham

_____
Dr. Phil McKnight

Date defended: June 8, 2012

The Dissertation Committee for Yuka Naito-Billen

Certifies that this is the approved version of the following dissertation:

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Chair: Dr. Manuela Gonzalez-Bueno

_____

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Abstract

Recently, the significant role that pronunciation and prosody plays in processing spoken language has been widely recognized and a variety of teaching methodologies of pronunciation/prosody has been implemented in teaching foreign languages. Thus, an analysis of how similarly or differently native and L2 learners of a language use pronunciation/prosodic cues needs to be further investigated, and the learnability of pronunciation/prosodic features should be explored. In this study, the role of prosody in Japanese sentence processing will be specifically explored among native speakers and L2 learners of Japanese whose native language is English. In Experiment 1 and 2, the effect of prosody during Japanese sentence processing was explored among native speakers using a psycholinguistic measurement. In Experiment 3, we compared L2 learners processing and judgment of Japanese sentences utilizing the brain-imaging technique Electroencephalography (EEG) together with a psycholinguistic measurement.

In Experiment 1 and 2, native speakers of Japanese listened to globally ambiguous sentences that can be interpreted in two ways, and temporarily ambiguous sentences that have two different syntactic structures. They either rated how acceptable each sentence is or answered a comprehension question on each sentence. As for the globally ambiguous sentences, the results revealed that overall one type (‘embedded-clause’) of interpretation is preferred over the other type (‘main-clause’) of interpretation at the judgment given time pressure. Prosody guided their interpretations to a certain degree; however, it did not have a deterministic effect, especially for arriving at a ‘main-clause’ interpretation. As for the temporarily ambiguous sentences,

significant effects of prosody in parsing temporarily ambiguous sentences were found, with the results suggesting that while parsing affects processing, its role is not deterministic.

In Experiment 3, native speakers and intermediate- to advanced-level L2 learners of Japanese listened to two types of temporarily ambiguous sentences read with two types of prosody and rated how acceptable each sentence was. Simultaneously, their brain activity was continuously recorded using EEG. The results revealed important similarities and differences among the native speakers and L2 learners' processing of these sentences. Both groups yielded a brain response that indicates the detection of prosodic break, and prosody was utilized at least to some extent. However, the patterns were different among the two groups, and the precise nature of the effects for the learners suggests that they have difficulties with processing non-default-type of structure ('main-clause' structure), and the congruent prosody for that structure ('main-clause prosody').

These results indicate that L2 learners have access to prosodic cues in sentence comprehension. On the other hand, the measurements of processing presented here suggest that these learners are not yet utilizing prosody in a native-like way, suggesting the utility of creating new ways to introduce prosody and its relation with the structure and meaning of Japanese sentences. It is suggested that teaching how to use prosodic cues in comprehending complex sentences with various types of sentence structures may develop L2 learners' ability to develop their oral communication skills.

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Chapter 1

Introduction

Foreign language education has employed many different teaching methods and approaches throughout history, and depending on the methods and approaches, training of pronunciation and prosody, which refers to the rhythm, pauses, accents, amplitude and pitch variations of the language (Steinhauer, Alter, & Friederici, 1999), was at times ignored or given various levels of emphasis. For example, the Audio-Lingual/Oral Method placed pronunciation training at the forefront of instruction in which errors were actively corrected; however, the Direct Method as well as naturalistic approaches considered pronunciation errors as a part of the natural language acquisition process, which should disappear as the learners became more proficient in the target language (Celce-Murcia, Brinton, & Goodwin, 1996).

Today in the U.S., the Communicative Approach, which holds the purpose of developing students' total communication ability, is the dominant method used in foreign language classes. Although this is not an approach which emphasizes pronunciation/prosody training, Celce-Murcia et al. (1996) believe that this approach has brought a new need for teaching pronunciation/prosody. Some studies on nonnative speakers of English have indicated a threshold level of pronunciation/prosody for nonnative speakers; that is, people have communication problems if they fall below the threshold level of pronunciation/prosody regardless of their abilities with grammar and vocabulary (e.g., Hinofotis & Bailey, 1980).

The necessity of teaching pronunciation/prosody for communication purposes has also been pointed out outside the field of teaching English as a second language (TESL). In the field of teaching Japanese as a second language (TJSL), the use of the Communicative Approach has

brought attention to the importance of pronunciation/prosody in communicating meanings. Toda (2006) states that, although pronunciation/prosody has been considered ‘a micro-level’ skill while communication is ‘macro-level’, that does not necessarily mean that pronunciation/prosody training cannot be incorporated in a classroom that uses the Communicative Approach. She reports that many L2 Japanese learners who live in Japan have had communication problems with native speakers of Japanese because of the learners’ inaccurate pronunciation or prosody, and she expresses concern that this deficiency can cause learners to lose their motivation for becoming proficient in Japanese. Pronunciation/prosody is indeed an important sub-skill of speaking ability. Nevertheless, giving pronunciation training to nonnative speakers of Japanese outside Japan (i.e., in the setting of teaching Japanese as a foreign language) is not commonly practiced.

Teaching Japanese as a foreign language (TJFL) outside Japan is challenging for many reasons. Classroom instruction has many limitations, such as: time, resources, and people with whom to practice communicating. Furthermore, there are limited opportunities for students to use Japanese outside the class due to the small number of Japanese speakers and Japanese language situations in countries other than Japan.

For example, it has been reported that teaching Japanese to English speakers is challenging due to the distinct differences that the Japanese language has with English. Christensen and Noda (2002) reported that the Foreign Service Institute (FSI) of the U.S. categorized foreign languages into four different groups according to the time required (Group I taking the shortest time and Group IV the longest time) to reach a certain proficiency level (0 being novice to 5 being proficient as an educated native speaker). The FSI puts Japanese in Group IV along with Chinese, Korean and Arabic, and states that it will take approximately 1320

hours, or eight years of instruction, of an intensive learning environment for Group IV language students to reach only level 2. That being said, Japanese instructors outside Japan must make an effort to teach as efficiently as possible in the limited time of classroom instruction, focusing on what to teach and how to teach it; and under this circumstance, pronunciation and prosody training is often given little attention.

Instruction of prosody (e.g., intonation, accent and rhythm) has been neglected even more than segmental pronunciation in teaching foreign languages for many years. However, recently many researchers (e.g., Canale & Swain, 1980; Hymes, 1981) and foreign language instructors have recognized the important role that it plays in communication. For instance, at the word level, the English word ‘record’ can be a verb or a noun based on the stress position. Also, at the sentence level, a sentence can be interpreted as a statement or as a question based on whether it has a falling or a rising intonation. Prosody plays an important role in communication not only in English, but also in many other languages including Japanese, and the role of prosody has attracted considerable attention from foreign language instructors and students lately. In the case of Japanese, some textbooks on pronunciation and prosody have been published (e.g., Kono, Kushida, Tsukiji, & Matsuzaki, 2004; Tanaka & Kubozono, 1999). Also, prosody training methods using prosody-graphs are being developed (Hirata, 2004; Kono et al., 2004; Matsuzaki, 1995).

However, some critical aspects of the function and usage of prosody in Japanese are still unclear, even for native speakers; thus, it is essential to further investigate what aspects of prosody are important and how an instructor might teach them. Therefore, it is necessary to understand the native-like knowledge and performance of prosodic aspects first, and then compare those data with those of learners at different levels of proficiency in order to give

appropriate teaching suggestions. Once it is found what kind of prosodic features are learnable and important in oral communication, recommendations of prosody instruction can be given to the foreign language education field.

To begin with, it is worthwhile to look into Second Language Acquisition (SLA) theories and language processing research which suggest some ideas about what is learnable and what is difficult to learn when acquiring a second language. Many researchers have pointed out that syntactic properties that interact or interface with the non-linguistic cognitive domain or other linguistic components (e.g., discourse, morphology, semantics and prosody) are more difficult to acquire, and the opposite is true as well (e.g., prosody that interfaces with syntax is difficult to acquire) (e.g., Dekydtspotter, Donaldson, Edmonds, Fultz, & Petrush, 2008; Sorace & Filiaci, 2006; Tsimpli, Sorace, Heycock, & Filiaci, 2004). Thus, testing the prosodic effect among learners will shed light on the syntax-prosody interface, and may give teaching suggestions on how to use prosody effectively in association with mastering the syntactic components of the language. Also, Clahsen and Felser (2006a, 2006b) proposed the Shallow Structure Hypothesis, which says that it is extremely difficult for L2 learners to obtain native-like proficiency in processing syntactic structures in their second language, and that L2 learners rely on other information such as semantic information. If this is the case, prosodic cues may help L2 learners to process complex sentences more effectively.

Misono, Mazuka, Kondo and Kiritani (1997) conducted an experiment on the use of prosodic cues among Japanese listeners in perceiving syntactically ambiguous sentences. In their experiment, participants listened to globally ambiguous sentences and they were asked to choose interpretations from two alternatives shown on a piece of paper. Using an off-line method in which the participants were given sufficient time to analyze two alternatives, they found that the

prosodic cues exert a certain degree of influence on the interpretation of the sentences but their influence is limited. They suspect, however, that prosody might play a dominant role in the initial stages of sentence comprehension, but by the time the participants answered after reading and comparing the two interpretations shown on the paper, the effect of prosody may have decayed. It is possible that the results may differ if the participants are given a limited amount of time to answer, preventing them from trying to compare the stimuli across trials, considering other possible interpretations of the sentence, or using other strategies to come up with their answers.

Furthermore, recent studies on the brain have revealed a new way to probe about incremental language processing. Brain-level investigation can measure how people process language directly as they read or hear it, while the vast majority of other methods cannot measure what people are doing during language processing, but rather test the results of processing, language performance. To illustrate, the Critical Period Hypothesis, which claims that one cannot acquire a language after a certain age, has long been debated by testing native speakers' and L2 learners' language performance in tasks like grammaticality judgment. However, this does not demonstrate whether or not L2 learners use the same brain mechanisms as native speakers during language processing. By employing a neurolinguistic method such as Electroencephalography (EEG), separate brain responses to stimuli, called Event-Related Potentials (ERPs), can potentially indicate what part of the language process has been affected, providing more thorough observations than those found through simply judging performance.

Studies on the brain regarding prosody processing have been conducted recently in European languages, and it has been found that encountering a prosodic boundary evokes an immediate brain activation called Closure Positive Shift (CPS) regardless of the existence of a

pause, grammatical structure or comprehensible words (Kerkhofs, Vonk, Schriefers, & Chwilla, 2007; Meyer, Steinhauer, Alter, Friederici, & von Cramon, 2004; Pannekamp, Toepel, Alter, Hahne, & Friederici, 2005; Steinhauer, 2003; Steinhauer et al., 1999; Steinhauer & Friederici, 2001). In other words, the lengthening and/or tonal features of the boundary yield a CPS brain response. It is also reported that the brain response called N400, which is thought to reflect semantically unexpected linguistic stimuli, and/or P600, the reflection of syntactic reanalysis or integration, are evoked at the disambiguating word when there is a mismatch between prosodic boundary and syntactic break.

If these findings are true of the Japanese language like they are in European languages, native speakers of Japanese should evoke CPS as soon as they perceive a prosodic break, and N400 and P600 should be elicited at the disambiguating word when prosody is incongruent with syntactic structure. Also, as Misono et al. (1997) predicted, it may be observed in an on-line study that prosody plays a more dominant role in processing syntactically ambiguous sentences. Indeed, we as communicators have to analyze sentences instantly in our daily conversation, so it may be beneficial to test how native speakers of Japanese would process prosody in an on-line experiment. Furthermore, in order to argue how and what to teach among the components of prosody in the Japanese classroom, it may be critical to test how learners of Japanese process Japanese prosody, comparing their methods with those of native speakers' of Japanese.

Hence, in the studies reported in this dissertation, temporarily ambiguous Japanese sentences, namely garden-path sentences, as well as globally ambiguous sentences that have two possible interpretations until the end of the sentence were constructed. Garden-path sentences are sentences that require revision of initial analysis, resulting in prolonged reading time (Steinhauer et al., 1999). The following illustrates an English example.

(1a) Since Jay always jogs a mile and a half this seems like a short distance to him.
(1b) Since Jay always jogs a mile and a half seems like a very short distance to him.
(Steinhauer et al., 1999, p. 191)

In the absence of comma or prosodic boundary, "a mile and a half" is initially assumed to be the object of the verb "jogs"; thus, (1a) is processed without difficulty. However, in (1b), as soon as the verb of the main clause "seems" is encountered, the reader or the listener realizes that "a mile and a half" is the subject of the main clause rather than the object of "jogs", so the initial analysis needs to be revised, which yields a garden-path effect. In the current studies, the syntactic structure and prosody of Japanese sentences were manipulated as follows. The (#) mark indicates a prosodic boundary. We call the (#a) boundary the embedded-clause prosody (EP), since it is consistent with the embedded-clause bias sentence (ES) structure, while we call the (#b) the main-clause prosody (MP), since it is consistent with the structure of main-clause bias sentences (MS). The main-clause bias sentence (MS) has a dispreferred structure, and is considered a garden-path sentence, while the embedded-clause bias sentence (ES) has a preferred structure and is not expected to yield a garden-path effect.

(2a) Embedded-clause bias sentence (ES)

ta'kasi-wa (#a)	*[[$Ø_i$]*	*tegami-o (#b)*	*yo'ndeiru*	*atarasi'i*	*sense'e_i-ni]*	*sotto*	*e'syakusita.*
NP1-Top		NP2-Acc	PRED.1		NP3-Dat		PRED.2
Takasi (name)		letter	reading	new	teacher	gently	bowed

"Takasi gently bowed to the new teacher who was reading a letter."

(2b) Main-clause bias sentence (MS)

ta'kasi$_i$-wa(#a)	*tegami-o (#b)[[$Ø_i$*	*$Ø_j$]*	*yo'ndeiru*	*atarasi'i*	*kyooka'syo$_j$-ni]*	*sotto*	*hasa'nda.*
NP1-Top	NP2-Acc		PRED.1		NP3-Dat		PRED.2
Takasi	letter		reading	new	textbook	gently	inserted

"Takasi gently inserted a letter into the textbook that (he was) reading."

The processing of these sentences by native speakers and non-native speakers was analyzed by sentence judgment tasks and simultaneous recording of brain activations, called Event-Related Potentials (ERPs), using Electroencephalography (EEG). By comparing native speakers' and learners' parsing strategies when prosodic information is available, it may be possible to suggest a way for learners to comprehend spoken sentences in a more native-like way. Comparative studies on how prosody is processed between native and nonnative speakers have rarely been conducted in the past; therefore, the data from this study may contribute to the psycholinguistic and neurolinguistic field as well as providing a pedagogical contribution to the field of teaching foreign languages.

1.1. Research Goal

This dissertation aims to explore the nature of auditory sentence processing among native speakers of Japanese, and to examine how the strategies that native speakers and English speaking learners of Japanese employ during auditory sentence processing may differ. Specifically, cross-method psycholinguistic studies on native speakers of Japanese were first conducted utilizing Japanese temporarily and globally ambiguous sentences employing acceptability judgment and comprehension tasks. Then, a neurolinguistic study was conducted on native speakers and learners of Japanese utilizing Japanese temporarily ambiguous sentences employing acceptability judgment tasks. By probing what learners know and what is challenging to acquire regarding prosody and its impact on comprehension, an effective way to incorporate prosodic training in Japanese language teaching may be suggested.

1.2. Definitions of variables

Event-Related Potentials (ERPs):

ERPs are electrophysiological measurements of brain activity recorded at the scalp using EEG (electroencephalography) that are time-locked to the presentation of stimuli. Using ERP measurement, real-time language processing can be measured directly with high temporal resolution. Major ERP components related to this study are as follows:

a) N400:

N400 is a negative-going waveform peaking around 400ms. It is typically observed at the centroparietal region of the scalp when a semantic anomaly or semantically unexpected linguistic stimulus was detected in a sentence. For example, the following sentence 3 will elicit N400 for "socks" in comparison with "butter" at the seventh word:

(3) She spread the warm bread with *socks/butter.
(Kutas & Hillyard, 1980, p. 102)

N400 is also observed when there is a lexical re-access due to the verb's argument structure violation (Steinhauer et al., 1999). In other words, "seems" in sentence (1b) may give N400 as it is reanalyzed as the subject of the main-clause. The sentence is repeated here as (4).

(4) Since Jay always jogs a mile and a half seems like a very short distance to him.
(Steinhauer et al., 1999, p. 191)

b) P600:

P600 is a positive-going waveform that typically appears around 600-900ms, which is obtained in the centroparietal region of the scalp. It is well-known that P600 is elicited when reanalysis of a sentence is needed (i.e., garden-path sentences; see the definition below). It is also observed in complex sentence processing even without reanalysis, such as filler-gap dependencies (Kaan, Harris, Gibson, & Holcomb, 2000). Furthermore, this component is often observed when an earlier component (e.g., N400) is present. Example 4, shown below, elicits P600 at the word 'fell', because at that point the reader has to revise the sentence structure (i.e., (s)he realizes that the word "raced" which was initially assumed as the main verb was not the main verb).

(5) The horse raced past the barn fell.

c) CPS (Closure Positive Shift):

CPS is a positive-going waveform observed right at the prosodic boundary independent of presence or absence of a pause (e.g., Bögels et al., 2010; Kerkhofs et al., 2007; Steinhauer et al., 1999). It is reported that CPS is elicited for Jabberwocky sentences, delexicalized speech, and hummed speech though scalp distributions differ across conditions (Pannekamp et al., 2005). CPS may be observed in reading as well as listening, in the presence of comma (Steinhauer, 2003; Steinhauer & Friederici, 2001).

Garden-Path Sentences:

Garden-path sentences are the temporarily ambiguous sentences that involve reanalysis of syntactic structure. In psycholinguistics, it is reported that when incoming material in a sentence does not fit the semantic and/or syntactic expectations during incremental processing, reanalysis of the sentence is necessary. As for the garden-path effect in Japanese, some researchers (e.g., Frazier, 1983) assume that all sentences that involve reanalysis are garden-path sentences, but others (e.g., Mazuka & Itoh, 1995; Pritchett, 1987) exclude sentences which do not require conscious reanalysis.

Intonational Phrase Boundary (IPh Boundary):

Intonational phrase (IPh) boundary is a synonym for prosodic boundary. IPh has the following characteristics: (1) the last syllable of an IPh has a change in pitch; namely, low or high boundary tone; (2) this last syllable of an IPh is usually longer than the other phrases in the same IPh phrase; (3) there is occasionally a pause after an IPh boundary (Männel & Friederici, 2008).

Pronunciation:

In a broad sense, pronunciation includes both segmental and suprasegmental features although the focus of pronunciation training tends to be segmental features. In this study, unless indicated, pronunciation is used in a broad sense, which includes prosody.

Prosody:

Prosody is one of the suprasegmental features of speech. It is the acoustic properties of speech which may not be predicted by orthography. It includes rhythm, pauses, accents, amplitude and pitch variations of the language (Steinhauer et al., 1999). The current studies focus on boundary information among many prosodic components.

Prosodic Boundary/Break:

Prosodic boundary/break is a boundary between intonational phrases (IPh) in a sentence. There may or may not be a pause at the prosodic break. See *Intonational Phrase Boundary (IPh Boundary).*

Prosodic Disambiguation:

In a particular language, there may be identical words, phrases and/or sentences orthographically, but prosody can provide a bias for them to be interpreted in one way or another. Prosodic disambiguation is the use of prosody to bias the item to one way of meaning. For example, the English word, 'record' is disambiguated as a verb when the second vowel gets an accent, whereas it is disambiguated as a noun when the first vowel is accented. In the sentence level, saying "Go home" with a falling intonation can be an order, while it can be a question with a rising intonation. Also, in complex sentences, a prosodic boundary may suggest the syntactic structure of the sentence.

Second language Acquisition (SLA/ L2acquisition):

L2 is the second language in contrast to L1, which is the first language that one acquires as a child or a native language. In this study, unless it is noted, SLA/ L2 acquisition means an adult's acquisition of a second language after the sensitive period, after their L1 has been established.

Syntactically Ambiguous Sentences:

Syntax is the structure of sentences. Syntactically ambiguous sentences are sentences that have unclear phrase boundaries. There are two types of syntactically ambiguous sentences: (1) globally ambiguous sentences and (2) temporarily ambiguous sentences. While the former refers to sentences that can be interpreted in multiple ways, the latter refers to the ones that are

ambiguous locally but are disambiguated at a certain point to have only one interpretation. Temporarily ambiguous sentences that require reanalysis are called garden-path sentences.

1.3. Summary

Pedagogical interest in teaching prosody is increasing in foreign language instruction. In order to teach it effectively, it may be necessary to understand the mechanism of perception and production of speech of native speakers and learners while they engage in verbal communication. In this study, the perception mechanism of ambiguous Japanese sentence instances in which prosody might play an important role will be analyzed. Specifically, native speakers of Japanese and learners of Japanese whose native language is English will be compared in terms of their behavioral reaction to the stimuli and their brain activation. By understanding the similarities and differences in processing prosodic cues between native speakers and nonnative speakers of Japanese of different proficiency skills, an understanding of the teachability of prosody may be achieved. Pedagogical suggestions may be given on what kind of prosodic training might be meaningful as well as how prosody can be taught in interpreting the meaning of a complex sentence in foreign language.

Chapter 2

Literature Review

This chapter will review the literature concerning second language acquisition theories, foreign language teaching methods, and sentence processing studies in the aspects of pronunciation and prosody, especially on Japanese language. This chapter will be divided into five sections. The first section introduces second language acquisition theories and hypotheses focusing on the acquisition of pronunciation/prosody compared with that of other elements of language. The second section explores various studies of foreign language teaching methods and the instruction of prosody under each methodology. The third section discusses how prosodic cues are utilized during sentence processing and how they are investigated in European languages. The fourth section addresses characteristics of Japanese prosody. The fifth section introduces ambiguous Japanese sentences and examines how native speakers and L2 learners process these sentences.

2.1. SLA Theories and L2 Pronunciation/Prosody Acquisition

Every L2 learner is different, and arrives to the learning process from a different background. There may be some universal stages that all L2 learners follow but there are considerable differences among learners. Therefore, it is essential to take into account who the learners are when designing a curriculum. For example, the learner's age, previous exposure to the language, attitude, and the learner's L1 are important factors to consider.

2.1.1. Age, fluency, and other learner's traits. It has long been argued whether there is a biologically determined period for language acquisition/learning, namely, the Critical Period

Hypothesis (CPH). Lenneberg (1967) claimed that brain lateralization completes around puberty, and the period prior to this, called the Critical Period, is a biologically determined time when language acquisition is maximized. Concerning pronunciation, some researchers also stated that adults were incapable of achieving native-like pronunciation as brain plasticity is lost, after the Critical Period (Krashen, 1973; Scovel, 1969). Related to CPH, Bley-Vroman (1988) proposed the Fundamental Difference Hypothesis (FDH) which suggested that differences in L1 and L2 acquisition may be because adult L2 learners can no longer access Universal Grammar (UG).

Aside from accessibility to UG, researchers agree that there are different perceptive capabilities of children and adults. Eimas, Siqueland, Jusczyk and Vigorito (1971) conducted a study on speech perception of 1-month- and 4-month-old infants, by measuring the sucking rate of a pacifier transmitted to a recording instrument. The infant listened to sounds whose voice-onset time (VOT), which gives distinctions between voiced and voiceless consonants (e.g., /b/ vs. /p/), was manipulated. The results revealed that the infants perceived the differences in VOT categorically at the 30-millisecond boundary like English-speaking adults. Other studies on infants (e.g., Lasky, Syrdal-Lasky & Klein, 1975; Streeter, 1976) revealed that the boundary of the voiced/voiceless distinction is universal regardless of their parents' languages though the specific language environment alters their perception as they develop. It is also reported that the phonemic distinctions that infants have decline as they are exposed to certain languages (e.g., Werker, Gilbert, Humphrey & Tees, 1981). As for adult L2 acquisition, Flege (1986) pointed out the adult learners' limitation of mastering similar but not identical sounds as those in their native language. It was reported that while adult learners were able to produce new sounds that are considerably different from those in their L1 in the native-like manner, similar sounds were

classified as equivalents of their L1 sounds. Thus, it was suggested that the phonetic space is restricted among adults during L2 learning.

Nevertheless, researchers also observed incompatible evidence with CPH (e.g., Flege, Yeni-Komshian, & Liu, 1999; Hakuta, Bialystok, & Wiley, 2003; Johnson & Newport, 1989). Some researchers claimed that CPH overlooks differences between children and adults in terms of "exposure to the target language, linguistic expectations of interlocutors, ego permeability, attitude toward the second language, and type of motivation" (Celce-Murcia et al., 1996, p. 15). For example, adults learning a foreign language tend to receive much less target language input than children. Moreover, since adults have already established their language ego, it is more challenging for them to assimilate to a new culture that uses the target language or to learn a new communication system than it is for children. Consequently, there are factors that make it more difficult for adults to learn a second language other than the reasons that CPH poses. However, regarding pronunciation, it has been pointed out that it is extremely difficult for adults to achieve native-like proficiency, suggesting there may be some kind of age constraint (Flege et al., 1999).

2.1.2. Native language of the learner. Why are some features of a target language more difficult to learn than other features? Many studies have been conducted in terms of L2 compared to L1 acquisition, how L1 affects L2, and whether there are underlying language universals. Whether researchers consider languages different from one another or rather similar due to the sharing of common properties, they recognize some differences between L1 and L2 acquisition and the important role that the native language of the learner plays in SLA. We review some approaches that consider the role of L1 in L2 acquisition below.

First, the Contrastive Analysis Hypothesis (Lado, 1957), or CAH, tries to predict the difficulty of a component of the target language (L2) by comparing the learner's L1and L2; that

is, the features in L2 that are similar to the learner's L1 are easy to acquire, while the features that are different are difficult. Proponents of CAH believe that SLA is filtered through the learner's L1 and that the learners' mistakes in the L2 are due to negative transfer (i.e., interference from the learner's L1). The original (or strong) version of CAH claimed that the learning and success of a learner can be predicted by comparing L1 and L2, but many of the predictions turned out to be incorrect. Then, the weak version was proposed, which starts with what the learner does and tries to reason his or her mistakes on the basis of L1-L2 differences (Gass & Selinker, 2008).

The second approach, Error Analysis (EA), was developed from the weak version of the Contrastive Analysis Hypothesis. In EA, the learner's errors are analyzed in comparison to the target language (L2) while the Contrastive Analysis compared them with the learner's L1. The proponents of this hypothesis found that there are not only interlingual errors which were caused by negative transfer from L1, but also intralingual errors which are due to the L2 being learned independent of L1 (Gass & Selinker, 2008). However, critics have pointed out that focusing on errors does not give a whole picture of SLA. For example, Schachter (1974) found that a group of L2 learners producing few errors in a certain structure did not necessarily indicate that their production was mostly correct, but that they may have avoided using the structure because it was not similar to their L1.

In the third approach, Selinker (1972) proposed the Interlanguage Hypothesis by analyzing different utterances between L2 learners and native speakers trying to convey the same meaning. He considered the differences to be due to different linguistic systems they developed to understand L2, namely, interlanguage. Interlanguage is a unique system that is influenced by the learner's L1 and L2 input. It constantly evolves to be like the grammar of the target language,

though most L2 learners get to a point where they cannot make any more progress; namely, fossilization. Interlanguage has high degrees of variability from moment to moment unlike L1 acquisition, but it has some systematicity among L2 learners of the language regardless of their L1 (i.e., developmental stages that the L2 learners take are similar). Interlanguage Hypothesis also drove many researchers to investigate the universality of phonological acquisition patterns across age and language groups (Ioup & Weinberger, 1987).

The fourth approach, the Markedness Theory, was developed by linguists from the Prague School, such as Trubetzkoy and Jakobson (Celce-Murcia et al., 1996). The theory proposes that, the more basic, neutral, or universal member of the corresponding aspects of two languages ('opposites') is unmarked, while the more specific and less frequent member is marked; and the marked features are more difficult to learn. Eckman (1987) proposed the Markedness Differential Hypothesis applying the Markedness theory, and built a hierarchy of difficulty for phonological acquisition. For example, English allows both voiceless stops /p, t, k/ and voiced stops /b, d, g/ (marked) at the word-final position while German permits only voiceless stops /p, t, k/ (unmarked). This shows that German speakers have a harder time learning to pronounce marked sounds of English than English speakers do learning to only use unmarked sounds of German. In this way, given the L1 and L2 of the learner, the pronunciation/prosodic features that are difficult to learn can be identified (Celce-Murcia et al., 1996).

Finally, proponents of Language Universals focus on common properties that all languages share, and consider surface differences insignificant. They suggest a hierarchy of acquisition of linguistic features across languages, and there seem to be links between language universals and L2 acquisition. For example, Macken and Ferguson (1987) stated, in regard to

phonological acquisition, that stops are acquired before nasals, and nasals before fricatives. Eckman, Moravcsik and Wirth (1989) proposed the Interlanguage Structural Conformity Hypothesis (ISCH) which explained the universal facts about learners' interlanguages regardless of their L1. Eckman (1991) successfully applied ISCH in the phonological domain by combining Interlanguage Theory and Markedness Theory. It has been pointed out, however, that Language Universals alone cannot predict the learners' acquisition patterns thoroughly; the interaction between learners and L2 input have a certain influence on it as well (Celce-Murcia et al., 1996; Macken & Ferguson, 1987).

2.1.3. L2 Pronunciation/Prosody Acquisition. The SLA theories and hypotheses described above predict some parts of the phonological acquisition process. Celce-Murcia et al. (1996) summarized it as follows:

> 1. Native language transfer plays a role in a learner's acquisition of the sounds of the second language, but it is only one piece of the puzzle.
> 2. The extent of influence that negative transfer exerts may differ from learner to learner, and may also vary depending on the type of phonetic structure (e.g., segmental or suprasegmental contrast) being acquired.
> 3. There are some aspects of interlanguage phonology that parallel the first language acquisition of children, indicating the partly developmental and partly universal nature of phonological acquisition.
> 4. There is variation in performance accuracy among learners, depending on whether they are conversing in more formal (i.e., control-facilitating) or informal (i.e., automaticity-facilitating) registers.
>
> (p. 28)

They argued, however, that acquiring phonology is qualitatively different from acquiring syntax and lexicon. For example, people who have native-like pronunciation can be poor at grammar and lexicon, and vice versa. Flege et al. (1999) mentioned that there seems to be an age of acquisition effect in phonological learning unlike in grammar acquisition. Celce-Murcia et al. (1996) also claimed that the younger the adult learner is, the better he or she can learn the

pronunciation/prosody; thus, to obtain intelligible pronunciation is a more realistic pedagogical goal for the vast majority of adult learners than to get a native-like pronunciation. It is also reported that the sociocultural and sociopsychological factors of learners, such as attitude, motivation, and language ego influence how much pronunciation proficiency is achieved.

2.1.4. Neurolinguistic Approaches to Second Language Acquisition

As many neurolinguistic researchers argue, the credibility of the hypotheses such as CPH and FDH can be tested by directly examining neural processes of language since they are hypotheses of how children's and adults' brains process language differently. Sabourin (2009) reported that an increasing number of investigations of neural processes of language have been conducted over the past 10 years, and it is extremely meaningful to use neuroimaging techniques in the field of second language acquisition (SLA). Steinhauer, White and Drury (2009) reviewed Event-Related Potentials (ERP) findings related to late L2 morpho-syntax acquisition, and did not find evidence that supports CPH. ERPs indicated not the age of acquisition, but the proficiency of the learners seemed to predict the brain activity patterns. That is, novice learners yielded no difference in ERP patterns between grammatical and ungrammatical structures, but low to intermediate-level L2 learners yielded responses that are different from native speakers. Then, as they progressed in their ability, the responses approached and attained the native-like pattern.

Reiterer, Pereda and Bhattacharya (2009) also found that L2 proficiency affected brain activation patterns when the age of acquisition was controlled (i.e., the age of onset of L2 learning was 9-years old for both high and low proficiency groups). They gave listening comprehension tasks to high-proficient and low-proficient L2 (English) groups and compared EEG coherence and synchronization by analyzing Gamma-band (high frequency EEG ranges),

which reflects ‘high cognitive phenomena requiring sophisticated integrative thinking processes’ (p. 79). It was revealed that the low proficiency group showed both left and right hemisphere processing, while the high proficiency group showed mostly left hemisphere processing, which is similar to native speakers. While an increasing number of neurolinguistic studies have been conducted on L2 acquisition, few studies focus on pronunciation/prosody (e.g., Herd, 2011) leaving a need for more research in this field of study.

2.2. History of Foreign Language Teaching Methods and Teaching Pronunciation/Prosody

How has pronunciation/prosody been taught in different teaching methods throughout history? There have been a variety of foreign language teaching methods influenced by linguistic theories or educational philosophies, but most of them tend to pay little or no attention to pronunciation/prosody (Celce-Murcia et al., 1996); linguists have studied grammar and vocabulary much longer than pronunciation, and language teachers have long had a much better understanding of grammar than of phonology.

While the grammar-translation method, which neglected the speaking aspect of the language, has a long history traced back to Middle Ages in the study of Greek and Latin (Toda, 2006), instruction of pronunciation/prosody started rather late in the history of language teaching. In the late 1800’s and early 1900’s, the Direct Method gained popularity as opportunities for communication between speakers of different languages increased in Europe (Celce-Murcia et al., 1996; Toda, 2006). This approach was grounded on the way of children acquiring language or adults learning the language in non-classroom settings; thus, pronunciation was not taught explicitly but taught through intuition and imitation.

In 1886, the International Phonetic Alphabet (IPA) was developed to accurately represent the sounds of every language. This brought the Reform Movement in language teaching in 1890's, which emphasized the spoken form of a language and training in phonetics.

In the 1940's and 1950's, the Audio-Lingual Method in the U.S. and the Oral Approach in the U.K., gained popularity. Affected by the Reform Movement, these approaches placed importance on pronunciation, and taught pronunciation explicitly from the start (Celce-Murcia et al., 1996). Theorists of the Audio-Lingual Method believe that one can learn a foreign language by drilling, repetition and habit formation. This method also placed importance on teaching correct pronunciation using pattern practice. However, prosodic factors, such as rhythm and intonation, are not effectively taught because this approach uses minimal pairs of segments to teach pronunciation. Also, it is often criticized that the pronunciation training of the Audio-Lingual Method is mechanical and ignores the meaning or context of a phrase (Toda, 2006).

In the 1980's, the Natural Approach, proposed by Krashen and Terrell (Krashen 1982, 1985; Krashen & Terrell, 1983), and the Communicative Approach (e.g., Canale & Swain, 1980; Hymes, 1981) attracted language educators (Toda, 2006). Krashen believed that it was important for learners to receive slightly more difficult input than they could comprehend (i.e., "i +1" in which the "i" stands for the input that is currently comprehended, and "1" for the next level) in order to become proficient in a language. In the Natural Approach, listening comprehension was supposed to precede production in the beginning stage; as a result, pronunciation and prosody training were not focused on.

The Communicative Approach, which appeared in the 1980's, and is currently the dominant approach, emphasizes training total communication skills rather than focusing on accuracy. For example, Canale and Swain (1980) proposed that learners needed to acquire the

following four competences: (1) grammatical competence: words and rules; (2) sociolinguistic competence: appropriateness; (3) discourse competence: cohesion and coherence; and (4) strategic competence: appropriate use of communication strategies. Focusing on training total communication skills in a meaningful context, this approach was against the decontextualized pronunciation training used in the Audio-Lingual Method. As a result, due to a lack of pronunciation teaching techniques in line with the tenets of the Communicative Approach, pronunciation or prosody training was neglected in this method.

Nevertheless, foreign language researchers and instructors have realized that pronunciation and prosody play a crucial role to making communication successful (Celce-Murcia et al., 1996; Hinofotis & Bailey, 1980; Toda, 2006). That is, the purpose of teaching pronunciation/prosody is not to make learners sound like native speakers but to enable them to communicate with others without interference from inaccurate pronunciation. As a result, the Communicative Approach has given attention to teaching suprasegmental features of language, such as prosody (Celce-Murcia et al., 1996). Under today's Communicative Approach, foreign language researchers and instructors are still searching for the most important aspects of segmental and suprasegmental features and trying to integrate them to meet the communication needs of the learners, which, in most cases, is simply intelligibility.

In regard to teaching methods specifically aimed at training pronunciation/prosody, some techniques are suggested by previous research. The most common technique may be the use of minimal pairs. As is mentioned earlier in this section, minimal pair exercises at the segmental level were widely used in pronunciation training under the Audio-Lingual Method, and its contextualized version (Bowen, 1972, 1975) was practiced under Communicative Approach. Modern computer assisted pronunciation training incorporates minimal pair training as well (e.g.,

Dalby & Kewley-Port, 1999 for English; Hirata, 2004 for Japanese). The main criticisms against the use of minimal pairs are that they are often practiced without context, and real-life situations that require the distinction of the pairs may be rare (e.g., Brown, 1995; Toki, 1989).

However, at the suprasegmental level, contextual minimal pair exercises may be more easily constructed, especially in a longer phrase or a sentence. In fact, many Japanese pronunciation training books and previous studies on pronunciation acquisition include this kind of prosodic training (e.g., Hirano-Cook, 2011; Toda, 2004). Another popular method that is incorporated in recent prosodic training is the use of a *prosody-graph*, a simplified visual pitch contour. That is, the learner's pronounce a word, phrase or sentence by looking at the shape of the prosody-graph. Matsuzaki (1995) reported that the learner's utterance was better when using a prosody-graph than when using an accent symbol.

While the techniques described above mainly focus on training production, perception training may also contribute to pronunciation. VanPatten (1996) and VanPatten and Cadierno (1993) proposed the Input Processing Model on grammar acquisition. According to their model, there are three processes taking place within the learner during acquisition. During the first process, *input* needs to be converted to *intake*, since all of the *input* is not necessarily comprehended. Then, at the second process, *intake* is accommodated and the *developing linguistic system* is restructured. Finally, the third process is the learner being enabled to produce *output* from their *developing system*. The pedagogical application of this model is called Processing Instruction, which focuses on perception training (practice on changing *input* into learners' *intake*), and it has been reported to be effective for not only *intake* but also production. Gonzalez-Bueno and Quintana-Lara (2011) used Processing Instruction in Spanish pronunciation training in the classroom setting, and found some improvement in production, although the

perception data did not yield differences between pre- and post-treatment. Moreover, Wang, Jongman and Sereno (2003) conducted a Chinese tone perception training study, and it was revealed that the perception training improved the L2 Chinese learners' tone perception as well as their production. These results suggest a connection between perception and production in pronunciation/prosody as well.

2.3. Use of Prosodic Cues in Syntactic Disambiguation in European Languages

Communication requires listening as well as speaking; thus, it is also crucial for a learner to acquire an ability to use acoustic information effectively when they are listening. Furthermore, as is mentioned in the previous section, an improvement in perception may possibly contribute to the improvement in production (Gonzalez-Bueno & Quintana-Lara, 2011; Wang et al., 2003).

In fact, researchers outside the language pedagogy field have also claimed that there is a strong relationship between perception and production. Liberman and his colleagues (Liberman, Cooper, Shankweiler & Studdert-Kennedy, 1967, Liberman & Mattingly, 1985) proposed the Motor Theory of Speech Perception, which suggests that the perception of speech relies on vocal tract gestures rather than heard sounds, and the motor system is recruited for speech perception. The recent discovery of mirror neurons, which fire both when one performs and observes an action, supports the strong relationship between perception and production as well (Rizzolatti & Craighero, 2004; Gazzola & Keysers, 2009).

Therefore, understanding how prosodic information is utilized in listening may suggest how to produce accurate prosody. Pronunciation/prosody is not independent of other linguistic features such as syntax and semantics, so the effective use of pronunciation/prosodic information by the speaker may facilitate better communication, especially when speech is long and complex. In this section, the effects of prosody on syntactic processing of speech will be discussed.

It has been reported that prosody may play an important role at the sentence level, namely, as a cue for sentence disambiguation. Psycholinguistic and neurolinguistic studies have shown that people parse a sentence incrementally (i.e. they do not wait to begin processing until the end of the sentence, but process it in real time using the information available at each moment), making predictions (i.e., anticipating aspects of the sentence even in advance of bottom-up information from the sentence) when they read or listen to the sentence (e.g., Marslen-Wilson, 1973, 1975; Mazuka & Itoh, 1995; Steinhauer et al., 1999; Steinhauer & Friederici, 2001). When their prediction turns out to be wrong, the parser needs to reanalyze the sentence, experiencing a so-called garden-path effect. To illustrate, the following classic garden-path sentence is ambiguous until one encounters the verb, "fell," because the word "raced" can be interpreted either as an active past-tense verb or as a passive participle that makes a relative clause.

(6) The horse raced past the barn fell.

However, instead of considering two possibilities, people initially interpret it as an active past-tense verb as they incrementally parse the sentence; as a result, they have to consciously reanalyze the sentence when they get to the word, "fell," causing a garden-path effect. In auditory sentence processing, however, prosodic cues are also available. Can listeners utilize prosody in order to avoid going down the garden path?

It has been pointed out that there is a syntactic bias toward *late closure* (i.e., subordinate clause closes after the object of the verb) over *early closure* (i.e., subordinate clause closes right after the verb) (e.g., Frazier & Rayner, 1982; Frazier, 1983). Kjelgaard and Speer (1999) tested the role of prosody using temporarily ambiguous English sentences which have early closure and late closure syntax. An example set of the sentences are shown below:

(7) [When Roger leaves] the house is dark. (early closure)
(8) [When Roger leaves the house] it's dark. (late closure)
(Kjelgaard and Speer, 1999: p. 156)

These sentences were read with three different types of prosody (cooperating prosody, conflicting prosody, and baseline prosody). In the cooperating prosody condition, the prosodic break was given after *leaves* for (7), and after *the house* for (8). In the conflicting prosody conditions, the positions of the prosodic breaks for (7) and (8) were switched. In the baseline prosody condition, the prosody was neutralized. The results of three types of on-line tasks (speeded phonosyntactic grammaticality judgment task, end-of-sentence comprehension task, and cross-modal naming task) across four experiments revealed that there were no significant differences in judgment scores or RTs in the cooperating condition, while late closure yielded a higher rating and shorter RT than early closure in other conditions. This suggests that congruent prosody indeed diminishes the processing cost of difficult early closure sentences[1].

It has been debated whether other factors like phrase length may intervene and modulate the effect of prosodic boundary. Clifton, Carlson, and Frazier (2006) tested whether listeners treat a prosodic boundary as more syntactically informative when it flanks short constituents than when it flanks longer constituents, using English sentences. For the first set of experiments (Experiments 1A and 1B), they made 64 sentences manipulating noun phrase lengths (long vs. short) and IPh boundaries (i.e., prosodic breaks; early vs. late). The example sentences for their Experiment 1A are as follows:

(9a) (Pat) or (Jay and Lee) convinced the bank president to extend the mortgage.
(9b) (Pat or Jay) and (Lee) convinced the bank president to extend the mortgage.

[1] Previous studies on prosody report varied strengths of prosodic effects. See Carlson (2009) for a review.

(10a) (Patricia Jones) or (Jacqueline Frazier and Letitia Connolly) convinced the bank president to extend the mortgage.
(10b) (Patricia Jones or Jacqueline Frazier) and (Letitia Connolly) convinced the bank president to extend the mortgage.

(Clifton et al., 2006: p. 855)

For Experiment 2, they made 64 sentences manipulating adverb phrase lengths (long vs. short) and IPh boundaries (presence and absence of IPh boundaries). The examples are as follows:

(11a) Susie learned that Bill telephoned last night.
(11b) (Susie learned that Bill telephoned) last night.
(12a) Susie learned that Bill telephoned last night after the general meeting.
(12b) (Susie learned that Bill telephoned) (last night after the general meeting).

(p. 857)

The stimuli for each experiment were divided into four counterbalanced lists along with distracters. The participants listened to one of the four conditions for each target sentence and distracter sentences, and chose between visually presented paraphrases of the sentence as soon as possible.

The results for the first set of experiments revealed that the critical interaction was significant: the percentage difference between those who chose early-break-target choices and late-break-target choices was greater for short names than long names. Also, main effect of early vs. late break position was significant, and the reaction time for the shorter items was significantly shorter than longer items. The results for the second experiment revealed that the critical interaction between presence vs. absence of an IPh boundary before the adverb phrase and length of the adverb phrase was significant. It was found that a long phrase following an IPh

boundary decreased the effect of the boundary, as in Experiment 1. Thus, they concluded that listeners did not interpret prosodic breaks in a context-independent fashion, but may be sensitive to the reasons why speakers produce the properties of the input signal.

Brain imaging studies have recently been employed in the study of prosodic breaks in sentence processing involving closure ambiguity (see Bögels et al., 2011 for a review). Steinhauer, Alter, and Friederici (1999) conducted a study on the use of prosodic cues in processing natural speech in German, employing an on-line neurolinguistic method using electroencephalography (EEG). Their goals were: (1) to test "whether prosodic cues in spoken language are immediately used by the listener to solve syntactic ambiguities that systematically result in initial misunderstandings during reading," and (2) to find out whether the "prosodic influences can be monitored on-line by ERP [Event-related potentials] measures" (p.194). The participants, all native speakers of German, listened to German temporarily ambiguous sentences. Example sentences are as follows (IPh indicates a prosodic break):

(13a) [Peter verspricht Anna zu arbeiten] $_{IPh1}$ [und das Büro zu putzen] $_{IPh2}$
Peter promises Anna to work and to clean the office

(13b) [Peter verspricht] $_{IPh1}$ [Anna zu entlasten] $_{IPh2}$ [und das Büro zu putzen] $_{IPh3}$
Peter promises to support Anna and to clean the office
(Steinhauer et al., 1999: p. 192)

A prosody-syntax mismatch condition (13c) was constructed by combining the first part of sentence (13b) and the last part of sentence (13a) described above:

(13c) [Peter verspricht] $_{IPh1}$ [Anna zu arbeiten] $_{IPh2}$ [und das Büro zu putzen] $_{IPh3}$

The first IPh boundary suggests that *Anna* is not the object of the first verb, *verspricht* ("promised"), but the object of a transitive verb which follows *Anna zu* in the second IPh. However, *arbeiten* ("work") is an intransitive verb, which cannot take *Anna* as its object. Therefore, if the prosody is utilized immediately to build a syntactic structure, it is expected for the listener to be lead down the garden-path.

Results indicated that the brain clearly monitors prosodic cues on-line: the Closure Positive Shift (CPS) was evoked when the IPh boundary (i.e., prosodic break) was perceived, and CPS was present even when the pause was eliminated. The authors stated, "CPS may be associated with processes that serve to structure the mental representation of the speech signal and to prepare the further analysis of subsequent input" (p.195). Also, the syntax-prosody mismatch effect was observed for the third type of the sentences; N400-P600 ERP components were observed at the point where the syntactic disambiguation occurs. The authors suggested that N400 may have reflected a lexical re-access necessary to confirm the violation of the intransitive verb argument structure in condition (c), and P600 may have reflected the syntactic and prosodic revisions. The same pattern was observed when the pause was eliminated. Because the prosodic break came before the syntactic break, it was therefore found that prosody is utilized immediately as it becomes available in sentence processing. Indeed, this study demonstrated that the prosodic boundary can override the preference toward late closure.

Kerkhofs, Vonk, Schriefers and Chwilla (2007) also used EEG to investigate the interactions of discourse context, syntax and prosody in Dutch. Participants were first presented the contexts (i.e., stories that build the expectation for the target sentence) auditorily; then, locally ambiguous target sentences were presented, half of which were with a prosodic break (pause) or without a prosodic break. As they engaged in their listening

tasks, the participants' brain activations were monitored through EEG, but no other tasks were given.

The results revealed that the prosodic break gave rise to CPS in the time window from 400 to 800 ms after the offset of the second NP (i.e., at the beginning of the pause). Moreover, the amplitude of CPS for the identical prosodic break was more positive for the neutral context than the biased context. That is, when the expectation that the discourse context built was congruent with the prosody, the amplitude of CPS was less positive. Therefore, it is inferred that CPS may be an ERP component that reflects immediate interaction between syntax and prosody.

Itzhak, Pauker, Drury, Baum and Steinhauer (2010) conducted an ERP study which examined interactions among/integrations of structural preferences, lexical biases, and prosodic information using English temporarily ambiguous sentences (14a-b). By digitally cross-splicing these sentences and combining the initial portion of (14a) and the final portion of (14b) (found in brackets in the example below), a garden-path sentence (14c) was made. Examples are described below ((#) indicates a prosodic break):

(14a) [While Billy was playing t]he game (#) the rules seemed simple (Late closure)
(14b) While Billy was playing (#) t[he game seemed simple] (Early closure)
(14c) [While Billy was playing the game seemed simple] (Garden path)
(Itzhak et al., 2010: p. 9)

Then, transitivity bias (ratio of transitive over transitive and intransitive occurrences) was calculated using corpus counts, and the sentences were split into two equal-sized groups:

transitively biased (0.66-0.90, mean: 0.77, SD: 0.07) vs. intransitively biased (0.15-0.65, mean: 0.44; SD: 0.16).

They predicted to find a CPS effect for condition (14a) which contains a prosodic break, and P600 in condition (14c), in which no prosodic break should give a garden-path effect, because *the game* is initially treated as the object of the verb *playing* in the absence of the prosodic break. As for the transitivity bias, they predicted uniform CPS effects for both transitive and intransitive conditions unless there are processing interactions between lexically stored structural biases and prosodic boundary information. Finally, they suspected that in condition (14c), the transitivity bias condition, which more likely guides the listener to treat *the game* as the object of the verb *playing*, will give a stronger garden-path effect.

Participants were asked to engage in a sentence-final acceptability judgment task while brain responses were continuously recorded. ERPs were time-locked at the offset of an ambiguous noun phrase (*game* in the example sentences) and analyzed in five consecutive 200 ms windows from 150 to 1150 ms. The first time window (150-350 ms) was used to test for CPS effects, and the latter four (350-550, 550-750, 750-950, and 950-1150) were used for P600, which indicates a garden-path effect.

The behavioral results indicated that the garden-path sentence (14c) is dispreferred compared to (14a) and (14b), suggested by judgment scores and RTs. Also, the sentences with intransitive-biased verbs were overall more highly accepted, especially in condition (14c) although no interaction was found, and yielded longer RTs, suggesting that transitivity biases gave a more severe garden-path effect.

ERP results indicated both the predicted CPS and P600 effects. Moreover, there were striking CPS differences between transitive and intransitive conditions. While the intransitively

biased conditions showed CPS effect only in the condition (14a) relative to (14b) and (14c), the transitively biased conditions yielded CPS-like positive shifts for condition (c), which does not contain a prosodic break, as well as condition (14a). This suggests that a combination of initial parsing preference for late closure and the lexical bias toward transitivity strongly suggested a syntactic boundary that usually coincides with a prosodic break, which yielded a CPS effect. Thus, an immediate interactive mapping of syntactic and prosodic representations is evident. While an overt prosodic break provides the dominant cue which overrides both initial structural preferences and lexical biases, the brain seems to integrate various types of information online and interactively in the absence of an overt prosodic break in closure ambiguities.

Bögels, Schriefers, Vonk, Chwilla and Kerkhofs (2010) tested the effect of prosodic information using Dutch temporarily ambiguous sentences. The sentences contained either one of the control verbs (subject control) and object control)[2] in the matrix clause, and they were disambiguated by a transitive or intransitive verb. The example sentences were shown below:

(15) [subject control + intransitive]
De leerling bekende de leraar te hebben gespiekt tijdens het eerste uur.
the pupil confessed the teacher to have cheated during the first hour
"The pupil confessed (to) the teacher to have cheated during the first hour."

(16) [subject control + transitive]
De leerling bekende de leraar te hebben opgesloten tijdens het eerste uur.
the pupil confessed the teacher to have locked up during the first hour
"The pupil confessed to have locked up the teacher during the first hour."

[2] SC verbs make the subject of the verb take on the function of subject of the following infinitive complement; OC verbs make the indirect object take on the function of subject of the following infinitive complement, See Comrie (1985) for more discussion.

(17) [object control + intransitive]

De chirurg adviseerde de vrouw te slapen voor de zware operatie.
the surgeon advised the woman to sleep before the heavy surgery
"The surgeon advised the woman to sleep"

(18) [object control + transitive]

De chirurg adviseerde de vrouw te ondersteunen voor de zware operatie.
the surgeon advised the woman to support before the heavy surgery
"The surgeon advised to support the woman before the heavy surgery."

(Adapted from Bögels et al., 2010: p. 1038)

In their auditory ERP experiment, those sentences with or without a prosodic break after the matrix verb (third word) were presented. Thirty-six native speakers of Dutch (8 were eliminated due to excessive artifacts) listened to the sentences and brain activations were recorded continuously.

The results revealed a CPS effect almost immediately after pause onset, and it was smaller for SC compared to OC items. At the disambiguating word, SC items yielded a N400 effect for the intransitive condition in both break and no-break conditions. On the other hand, OC items yielded an N400 effect for the intransitive condition only for the with-break condition. Thus, it was found that prosodic breaks may be sufficient to determine the syntactic analysis of a sentence since there was preference toward intransitive verbs for OC items when prosodic information was not available. The authors argue that the N400 effect was caused by a linking problem of arguments and verbs using a model of sentence processing, eADM (Bornkessel & Schlesewsky, 2006). However, the absence of a P600 effect is somewhat puzzling because an N400 is usually accompanied by a P600 in response to argument structure violations, and P600 tends to be considered an indication of structural revision (e.g., Steinhauer et al., 1999). The authors reasoned why no P600 effect was elicited that (1) lack of other prosodic information (e.g., accents) along with prosodic breaks, (2) the scenarios in the study may have focused participants'

attention on the semantics of the sentence instead of syntactic structure, and (3) passive listening without needing to answer comprehension questions might have lessened the need to understand the structure of the sentences, promoting semantic analysis.

Pauker, Itzhak, Baum, and Steinhauer (2011) tested whether mentally deleting existing prosodic boundary is more costly compared to postulating a new one, a hypothesis which they call the Boundary Deletion Hypothesis. They used spoken English temporarily ambiguous sentences described below ((#) indicates a prosodic boundary) (see Steinhauer & Friederici, 2001 for the effect of a comma in written language). Conditions (19c) and (19d) were made by cross splicing at the fricative "th" of the determiner preceding the second noun (*the people*). By splicing at the fricative, the audible artifact could be minimized.

(19a) Late Closure
When a bear is approaching the people (#) the dogs come running.
(19b) Early Closure
When a bear is approaching (#) the people come running.
(19c) A1-B2
When a bear is approaching the people come running.
(19d) B1-A2
When a bear is approaching (#) the people (#) the dogs come running.
(Pauker et al., 2011: p. 2735)

They predicted garden-path effects for both (19c) and (19d), but if the Boundary Deletion Hypothesis holds, there would be smaller P600 for (19c), while there is overall advantage of Late Closure over Early Closure, there would be smaller P600 for (19d).

The participants listened to these sentences and responded whether the sentence was natural or not at the end of each sentence within 5 seconds as their brain activations were monitored using EEG.

The behavioral results revealed that whereas Conditions (19a) and (19b) are equally well-accepted (87.5 % vs. 87.3 %) and did not differ in response times, Condition (19c) was accepted in 53.3% of the trials and Condition (19d) was 28.0%, and it tended to take longer to reject Condition (19c) compared to (19d).

The ERP results revealed CPS effects at every prosodic boundary.[3] Garden-path effects, tested time-locked to the splicing point, yielded a relatively small P600 effect for Condition (19c) compared to Condition (19b), which suggests that a lack of a prosodic boundary in Condition (19c) initially led listeners to follow the Late Closure principle, which needed to be reanalyzed. Furthermore, Condition (19d) elicited a N400 followed by a large P600 effect, which suggests a stronger prosody-syntax mismatch effect compared to Condition (19c). These results support the Boundary Deletion Hypothesis.

Männel and Friederici (2011) conducted a developmental study on the use of prosody during auditory sentence processing of German using ERPs. Participants were 21-month-olds, 3-year-olds and 6-year olds, and they were presented sentences with or without prosodic breaks. The ERP results revealed that 21-month-old toddlers, who have not developed syntactic phrase structure knowledge of the language, did not yield a CPS effect, while obligatory components, which are automatically elicited as the sensory systems detect auditory input after the pause, were observed. This indicates that they detect speech boundaries using low-level acoustic processes. In contrast, 3- and 6-year-olds yielded both obligatory components and CPS, suggesting that they utilize low-level acoustic processes and higher-level

[3] They also observed a pre-CPS negativity in central regions observed for the first boundary in B and D, compared to A and C. They suspect that it may be triggered by syllable lengthening and/or boundary tone. There was also a pre-CPS negativity in frontal regions for A at the second boundary and C, which does not have a boundary. Since the distribution is different than that of B and D, the authors interpreted this effect as an expectancy-related negativity.

perception of combined prosodic boundary cues (i.e., pre-boundary lengthening, pitch change and pause). Thus, prosodic phrase processing is established after the acquisition of syntax, and CPS may be an indicator of prosodic or syntactic structuring abilities, reflecting a highly functional prosody-syntax interface in adult language processing.

Fultz (2009) investigated the role of prosody in lexical and syntactic disambiguation among L2 learners of French whose native language is English. She developed four types of ambiguous sentences with different levels of complexity, which were read in two distinct prosodic phrasings. She found that the learners utilized prosodic information in an easy task like lexical disambiguation, but did not utilize it in a rather difficult task like relative clause ambiguity.

The findings from European language studies raise a question whether the cues that the listeners use and brain activations elicited by the cues are similar across different languages including non-European languages such as Japanese, and whether L2 learners of these languages can utilize them. It may be practical, however, to understand the system of Japanese pronunciation and prosody before further discussing this matter in regards to the Japanese language. The next section addresses the characteristics of Japanese pronunciation and prosody, and the following section deals with prosodic cues in Japanese ambiguous sentences.

2.4. Characteristics of Japanese Pronunciation and Prosody

More and more instructors in the Japanese language classroom have realized the important role that pronunciation/prosody plays, and an increasing number of studies on pronunciation/prosody training have been conducted recently. Toda (2006) reported that many learners have had difficulty in communicating with Japanese people due to their pronunciation

and prosody problems, and therefore they were eager to correct and improve their pronunciation and prosody.

Beckman and Pierrehumbert (1986) reported that there are similarities and differences between English and Japanese intonational features, but the differences are rather minor compared to their similarities. First, English and Japanese are similar in that both have pitch accents, though Japanese uses them to contrast lexical items and English uses them to contrast different intonational meanings. Hirata (2004) gives an illustration of the phonemic distinctions in duration and pitch that Japanese has. For example, the combination of four segments, K-A-T-A, can mean six different things: /kata/ with high and low tones means ‘shoulder’; /kata/ with low and high tones mean ‘form’; /kat:a/ with a geminate consonant and high-low tone means ‘won,’ past tense of ‘win’; /kat:a/ with low-high tone means ‘bought’; /ka:ta:/ with two long vowels and high-low tones means ‘Carter,’ an English name; and /kat:a:/ with a geminate and a long vowel with high-low tone means ‘box-cutter’.

Second, both English and Japanese have hierarchical prosodic structures, “from the grouping of tones into pitch accents at local level to the choice of phrase-terminal tones and the manipulation of pitch range over larger domains” (Beckman & Pierrehumbert, 1986, p. 305), but because of the lexical origin differences, the intonational patterns in a sentence vary: the range of possible intonational variation is substantially smaller in Japanese than in the English system. In other words, a sentence is not merely the combination or sequence of word accents and non-accents, but the sentence as a whole forms an intonational contour; prosody or intonational structure plays an important role.

Although Beckman and Pierrehumbert (1986) claimed that the differences are rather minor, these micro-level differences may be a great challenge for English speakers trying to

learn Japanese prosody. It has been reported that native English speakers have difficulty learning phonemic contrasts among lexical items (e.g., Hirata, 2004; Toda, 2006). Aoki (2005) described the difficulty of mastering the Japanese prosody of the sentence final particle '*ne*' when it is used in isolation. She reported that the prosody usage of a learner with three-year instruction of Japanese in the US was far from the standard use of the Japanese native speaker's, while that of the learner with three-year instruction and five-year living experience in Japan was mostly good, though not perfect. This may suggest that learning Japanese prosodic features is possible for English speakers; thus, effective prosody teaching methods would compensate for the lack of extended exposure in the foreign language classroom.

2.5. Use of Prosodic Cues in Japanese Ambiguous Sentences

Many researchers (e.g., Inoue, 2003; Inoue & Fodor, 1995; Mazuka & Itoh, 1995; see Miyamoto, 2008 for a review) have reported that Japanese sentences pose more ambiguity than the sentences in head-initial languages, such as English. Japanese is a left-branching, head-final language; that is, the word that determines the syntactic category of the phrase comes at the final position. While a head-initial language like English presents a disambiguating word at the initial position of a phrase, a head-final language like Japanese gives a disambiguating word at the end of the phrase. Because the sentence is temporarily ambiguous until the disambiguating word appears, sentences in head-final languages contain more ambiguity. Also, the fact that Japanese allows scrambling of arguments and adjuncts, and productive occurrence of zero pronouns (i.e., pronouns are occasionally dropped) adds further ambiguity.

Nevertheless, Inoue and Fodor (1995) claimed that the parsing mechanism for Japanese is exactly the same as that of English. That is, Japanese parsing is serial without delay (i.e., it is processed as information and becomes available without considering two or more parsing

options at the same time), and many revisions that need to be made due to the false hypotheses adopted by the parser in Japanese processing are (almost) cost-free (i.e., no Garden-Pass effect).

Mazuka and Itoh (1995) also argued that Japanese temporarily ambiguous sentences were not necessarily costly enough to cause the garden-path effects in the narrow definition, that is, conscious reanalyses of the sentence. They claimed that due to the ambiguous nature of Japanese sentence structures, in order to elicit conscious garden-path effects, both subject and object noun phrases (NPs) have to be reanalyzed unless the sentence involves lexical ambiguity. For example, (20a) causes conscious a garden-path effect, but (20b) does not:

(20a) Yakuza-no kanbu-ga wakai kobun-o sagasi-dasita kenzyuu-de
gang-Gen leader-Nom young member-Acc found gun-with
utikorosite simatta.
shot to death
'The leader of the gang shot the young member to death with the gun he found.'

(20b) Yakuza-no kanbu-ga wakai kobun-o sagasi-dasita otoko-ni
gang-Gen leader-Nom young member-Acc found man-Dat
rei-o itta.
thanked
'The leader of the gang thanked the man who found the young member of the gang.'

(Mazuka & Itoh, 1995: p. 306)

Previous studies on Japanese prosody have shown some effects of prosody on parsing and interpreting sentences. Venditti and Yamashita (1994) compared the use of prosody in a simplex sentence as in (21) and three complex sentences as in (22-24) shown below. A female native speaker of Japanese was recorded speaking these sentences and the acoustic analysis of the segment *mari ga yonda* showed that she used different prosodies (i.e., lengthening and lowering of pitch) when producing a clause that comprised the entire simplex sentence compared to the same clause in a complex sentence. This illustrates that some syntactic distinctions are

conveyed by prosody in Japanese speech production. However, there was no difference among complex sentences. This suggests that existence of *pro*[4] or *t*[5] does not affect the prosody where the syntactic boundaries are the same.

(21) Mari-ga yonda.
Mari-Nom read
'Mari read (it).'

(22) [Mari-ga t_i yonda] hakusyo$_i$-wa omokatta.
Report-Top was heavy
'The report which Mari read was heavy.'

(23) [Mari-ga t_i *pro* yonda] hanare$_i$-wa kurakatta.
Room-Top was dark
'The room in which Mari read (it) was dark.'

(24) [Mari-ga *pro* yonda] handan$_i$-wa tadasikatta.
Decision-Top was correct
'The decision due to Mari's reading (it) was correct.'

(Venditti & Yamashita, 1994: p. 376)

Segments (21) through (24) were used for their perception experiments. Following an off-line end-of-the-segment judgment experiment testing whether the segment *mari ga yonda* was a part of simplex or complex sentence, which yielded an accuracy rate greater than 94%, they employed a *gating paradigm* in Experiment 2 to test at what point listeners identify the structure. In this paradigm, the segments were divided into individual mora[6] (6 morae/gates) and were presented in intervals which progressively increased by one mora. That is, listeners heard the first mora, /ma/, then the first and second morae together, /mari/, then, first three morae

[4] *pro* refers to a dropped pronoun.
[5] *t* refers to a trace, which displays the original position of a moved element in a syntactic structure.
[6] Japanese is a mora-based language whose native speakers divide words into basic rhythmic units that are smaller than syllables, namely, morae. The mora has three types of realizations: (a) (C)V, (b) the first part of long consonant or geminate, or (c) syllable-final or moraic /n/. Mora is a temporal unit where each mora is supposed to bear approximately the same length of time, though there are some disagreements. See Tsujimura (2007) for more discussion.

together, /mariga/, and so on until the whole segment was presented. The listeners were asked to answer whether the presented mora/morae are a part of a simplex or complex sentence and how confident they were in their answers after each mora/morae presentation. The results showed that the point at which the listeners changed their answer from wrong to right response and the point when the confidence level became greater than 50% were around the fifth mora, where the lengthening and pitch lowering effects emerged in the acoustic analysis. This correlation between production and perception results suggests that the native listeners also use those prosodic cues online as they become available to differentiate complex sentences from simplex ones. Their study revealed evident utilization of prosody in distinguishing simplex and complex sentences, but the prosodies were rarely different among complex sentences that had the same syntactic boundary. These findings leave open the question of how prosody is used to distinguish among complex sentences with different syntactic boundaries.

Azuma (1997) studied prosodic features of a syntactically ambiguous sentence. A male Tokyo speaker elicited the following sentence to give meanings of (a) and (b).

(25)	Nara-de	(#)	taoreta	yooji-o	hakonda.
	NP1-Loc		Pred.1	NP2-Acc	Pred.2
	in Nara		fell	little child	carried

(Adapted from Azuma, 1997: p. 23)

a. ‘In Nara, (I) carried a child who fell.’
b. ‘(I) carried a child who fell in Nara.’

In the acoustic analysis, the elicitation for interpretation (25a), had a pause at (#), and a pitch reset was observed. However, the elicitation for interpretation (25b) had no pause at (#) and a pitch reset was barely observed.

Then, he manipulated the prosodic features of the sentence and tested how native speakers of Japanese interpreted the sentence. Specifically, after eliminating the pause at (#), he manipulated (1) the fundamental frequency (F_0) contours of the first and second segments (raising or dropping the segment to make it similar to the elicitation for the other interpretations), and (2) the pause (inserting 100 to 700 ms pause at (#)). The results revealed that the manipulation of F_0 yielded more opposite interpretations. On the other hand, although it shifted the participants' interpretations to some extent, the pause did not give as strong an influence as F_0. Therefore, the authors concluded that F_0 is the most important indicator of the syntactic boundary, and it plays a more important role than the pause. Nevertheless, since he used only one syntactically ambiguous sentence whose topic or subject was dropped, it may be necessary to test more sentences that have a topic or subject to prove the effects of pauses and F_0.

Kang, Speer and Nakayama (2004) examined the processing of both temporarily and globally ambiguous Japanese sentences in the same context with and without a prosodic boundary at (#) as follows. The relative clause for each interpretation is indicated by the brackets, and the subscripts at the opening and closing positions of the relative clause correspond to each interpretation:

(26) Takashi-ga (#) [nyuuin shiteiru oba]-o nagusameta
Takashi-nom was hospitalized aunt-acc consoled
'Takashi consoled the aunt who was hospitalized.'

(27) Takashi-ga (#) nyuuin shiteiru byooin -o sagashita
Takashi-nom was hospitalized hospital-acc looked for
a. [Takashi-ga nyuuin shiteiru byooin]-o sagashita
'(Someone) looked for the hospital where Takashi was hospitalized.'
b. Takashi-ga [nyuuin shiteiru byooin]-o sagashita
'Takashi looked for the hospital where (someone) was hospitalized.

(Kang et al., 2010: p. 3025)

Sentence (26) and (27) are minimally different from each other only with respect to the alternating nouns (*oba* 'aunt' in (26): *byooin* 'hospital' in (27)) in the same position, and are identical until one sees/hears the disambiguating second NP *oba-o* (aunt-acc) in (26) or *byooin-o* (hospital-acc) in (27). While, sentence (26) has only one interpretation at the disambiguating word (i.e., it is a temporarily ambiguous sentence), (27) has two possible interpretations even at the end of the sentence (i.e., it is a globally ambiguous sentence).

As for the temporarily ambiguous sentence (26), they demonstrated that the mismatch of prosodic and syntactic boundaries caused processing difficulty, reflected by lower accuracy rates and longer Reaction Times (RTs) for the mismatch condition. The globally ambiguous sentence (27) showed interesting results. The visual presentations of globally ambiguous sentences revealed a preference toward interpretation (27a), although there was a clear awareness of its ambiguity. When these globally ambiguous sentences were presented auditorily, the condition without a boundary, which is consistent with interpretation (27a), yielded marginally shorter RTs. Interpretation results revealed that the presence or absence of a prosodic boundary was used to assign syntactic constituency and to guide the listener to a specific interpretation. Interpretation (27a) was chosen significantly more in the without-boundary condition compared to the with-boundary condition, and the opposite tendency was found for interpretation (27b). Although the proportion of interpretation (27a) was higher overall (without-boundary condition: 60.2%; with-boundary condition: 33.7%) compared to interpretation (27b) (without-boundary condition: 15.4%; with-boundary condition: 40.4%), the authors believe that it was because positing an empty pronoun for the subject of an embedded predicate without any preceding context is pragmatically unnatural, and the fact that prosody could shift the listeners' interpretation from (27a) to (27b) in the with-boundary condition is remarkable. This poses the question of whether

prosody would give a deterministic effect on the interpretation of 'neutral' globally ambiguous sentences which do not contain a pragmatic bias and have two equally plausible interpretations.

Misono, Mazuka, Kondo and Kiritani (1997) conducted an off-line study on the effects of prosodic and semantic biases on the interpretation of Japanese globally ambiguous sentences by native speakers of Japanese. They created globally ambiguous sentences which were given three types of semantic biases: (i) embedded-clause bias, (ii) main-clause bias, and (iii) neutral. In the neutral sentence, the probability of the target action ([PRED.1] in the example sentences below) being performed by the matrix subject or the matrix object is semantically equal; whereas in the embedded-clause-bias and main-clause-bias sentences, there is a semantic bias toward the matrix object and matrix subject, respectively. Those sentence examples are shown in (28-30) below. The possible prosodic boundaries which lead to interpretations (a) and (b) respectively are indicated as (#a) and (#b) below. The relative clause for each interpretation is marked with brackets.

(28) Embedded-clause bias sentence

Haha-wa	(#a)	benkyoo-ni akite	(#b)	terebi-o	mite-iru	otooto-o	shikaritsuketa.
NP1-Top		NP2-PRED.1		NP3-Acc	PRED.2	NP4-Acc	PRED.3
mother		study of getting tired		TV	watching	younger brother	scolded

a. Embedded-clause interpretation
   Haha-wa [benkyoo-ni akite terebi-o mite-iru otooto]-o shikaritsuketa.
   'Mother scolded small brother that was watching TV, getting tired of studying.'
b. Main-clause interpretation
   Haha-wa benkyoo-ni akite [terebi-o mite-iru otooto]-o shikaritsuketa.
   'Mother, being tired of studying, scolded small brother who was watching TV.'

(29) Main-clause bias sentence

Chichioya-wa (#a)	yopparatte (#b)	nete-iru	akanboo-o	ofuro-ni	ireyoo to shita.
NP1-Top	PRED.1	PRED.2	NP2-Acc	NP3-GOAL	PRED.3
father	drunken	sleeping	baby	bath into	put

a. Embedded-clause interpretation
   Chichioya-wa [yopparatte nete-iru akanboo]-o ofuro-ni ireyoo to shita.
   'The father tried to bathe the baby that was drunk and sleeping.'
b. Main-clause interpretation
   Chichioya-wa yopparatte [nete-iru akanboo]-o ofuro-ni ireyoo to shita.
   'The father, being drunk, tried to bathe the sleeping baby.'

(30) Neutral sentences

Shoonen-wa (#a)	zubunure-ni natte (#b)	kakemawaru koinu-o	oikaketa.
NPl-Top	PRED.l	PRED.2	NP2-Acc	PRED.3
boy	drenched become	run around	puppy	ran after

a. Embedded-clause interpretation
   Shoonen-wa [zubunure-ni natte kakemawaru koinu]-o oikaketa.
   'The boy ran after the puppy that was drenched and running around.'
b. Main-clause interpretation
   Shoonen-wa zubunure-ni natte [kakemawaru koinu]-o oikaketa.
   'The boy, becoming drenched, ran after the running puppy.'

(Misono et al., 1997: pp. 232-233)

In embedded-clause bias sentences as in (28), the subject of the first predicate (PRED.1) *benkyoo-ni akite* ('being tired of studying') could structurally be either NP1 *haha* ('mother') or NP4 *otooto* ('younger brother'); however, it is more plausible, semantically, that a younger brother is the agent of being tired of studying rather than a mother. This yields a semantic bias towards assigning a representation in which *otooto* ('younger brother') serves as the agent of *benkyoo-ni akite* ('being tired of studying'), resulting in coming up with a structure where the phrase *benkyoo-ni akite terebi-o mite-iru* constitutes a relative clause modifying *otooto*, i.e., an embedded phrase --- hence, this is called an embedded-clause bias sentence. On the other hand,

in main-clause bias sentences as in (29), the semantic bias is yielded differently; the subject of the PRED.1 *yopparatte* (‘being drunken’) is much likely to be NP.1, *chichioya* (‘father’) rather than NP 2, *akamboo* (‘baby’). This results in biasing to posit a structure where the phrase PRED.1 *yopparatte* (‘being drunken’), having *chichioya* (‘father’) as the phrasal subject, serves as a clausal modifier associated with the matrix predicate *ofuro-ni ireyoo to shita* (tried to bathe…). In neutral sentences as in (30), neither of the semantic biases is observed; thus, there is no semantic bias toward positing either of the two structures.

These sentences were read with two types of prosodies: (a) embedded-clause and (b) main-clause prosodies. They examined how the prosodic congruency would affect the resolution of the structural ambiguity when biasing semantic information was also present. Neutral sentences, however, do not have a semantic bias, and the authors suspected that the prosodic manipulation would lead the listeners to select an interpretation congruent with the prosody. Examples of these sentences are shown above (prosodic boundaries are indicated by (#) for each interpretation). Interpretations are presented as (a) embedded-clause interpretation and (b) main-clause interpretation. The interpretations in parentheses are possible but dispreferred interpretations.

Participants were directed to listen to a sentence and choose one of the two interpretations printed on an answer sheet that they thought best matched the interpretation of the heard sentence. Their results revealed that when prosody was congruent with semantic bias, almost all the participants chose the target interpretations. However, when they were incongruent, prosody actually shifted 18% to 23% of their interpretations toward the alternate interpretations. Nevertheless, when the semantic bias was neutral, where the listeners’ interpretations were suspected to be primarily based on the prosodic cues, as much as 9% (embedded-clause prosody

condition) to 29% (main-clause prosody condition) of the answers were the opposite of what the prosody suggested. Thus, they concluded that prosody has some influence, but it is limited at the point when the listeners make their judgments. They suspected, however, that the influence of prosody may be stronger at earlier stages of sentence processing, and suggested the necessity of conducting on-line studies to better understand the role of prosody in Japanese sentence processing.

Eda, Naito and Hirano (2009) used similar stimuli and an off-line method similar to Misono et al. (1997) and tested how native speakers of Japanese and intermediate and advanced level L2 learners use prosodic cues when they process ambiguous sentences. The findings were, first, that native speakers' results showed very similar tendencies as Misono et al.'s results. That is, when semantic bias and prosodic bias were incongruent, they tended to use semantic cues in interpreting sentences. Second, that advanced-level L2 learners' results showed that their usage of semantic and prosodic cues were almost half and half when they were incongruent. In other words, they relied on prosodic information more than the native speakers. However, other tendencies were similar to the native speakers'. Third, the intermediate-level L2 learners' results were rather different from the other two groups'. They did not seem to use semantic information of sentences effectively, but they somewhat relied on the prosodic cues. To illustrate, the proportions of choosing the main-clause bias interpretations for the sentences read with embedded-clause prosody were 45% and 48% for embedded-clause bias sentences and main-clause bias sentences respectively, while the ones read with main-clause prosody were 63% and 81%. It was suspected that intermediate-level learners had difficulty building the syntactic structure of embedded-clause bias sentences online. Eda et al. (2009) suggested that teaching

how to use prosodic cues to build syntactic structures might help the learners to achieve advanced-level proficiency.

Recently, Wolff, Schlesewsky, Hirotani and Bornkessel-Schlesewsky (2008) conducted an ERP study on word order effects and Japanese prosody (Ex.1). They made a canonical Subject-Object-order sentence type and a scrambled Object-Subject-order sentence type. Since the prosodic boundary after Object in Object-Subject-order-type sentences is reported to signal a scrambled word order (Hirotani, 2005), prosody was also manipulated in two ways: with or without prosodic boundary after the first argument ("hanzi-ga/o"). Prosodic boundaries are indicated by (#), and critical prosodic differences are underlined in the example sentences (31-34) below:

(31) Subject-object-order, No prosodic boundary:
nisyuukanmae (#) hanzi-ga daizin-o manekimasita
two weeks ago judge-NOM minister-ACC invited
"Two weeks ago, the judge invited the minister."

(32) Object-subject-order, No prosodic boundary:
nisyuukanmae (#) hanzi-o daizin-ga manekimasita
two weeks ago judge-ACC minister-NOM invited
"Two weeks ago, the minister invited the judge."

(33) Subject-object-order, Prosodic boundary:
nisyuukanmae (#) hanzi-ga <u>(#)</u> daizin-o manekimasita
two weeks ago judge-NOM minister-ACC invited
"Two weeks ago, the judge invited the minister."

(34) Object-subject-order, Prosodic boundary:
nisyuukanmae (#) hanzi-o <u>(#)</u> daizin-ga manekimasita
two weeks ago judge-ACC minister-NOM invited
"Two weeks ago, the minister invited the judge."

(Adapted from Wolff et al., 2008: p.136)

Japanese native speakers listened to these sentences and answered comprehension questions as quickly as possible within 5500 ms by pressing yes/no buttons after each sentence

presentation. The behavioral results indicated that object-initial sentences yielded higher error rates and longer RTs than subject-initial counterparts, but the presence of a prosodic boundary reduced this difficulty.

As for the ERP, the authors hypothesized to find (a) a *scrambling negativity* (i.e., ERP for scrambled word order; see Schlesewsky et al., 2003) at the position of the first case marker only when there was a prosodic boundary after the first argument, (b) an N400 effect for the SO-type of sentences compared to scrambled OS-type sentences at the position of the second argument due to a semantic prediction regarding the transitivity of the event (see Bornkessel, Fiebach & Friederici, 2004 for this effect in German), and (c) a CPS effect for a condition with a prosodic boundary. The results essentially supported all of the hypotheses although the latency of scrambling negativity was short (120-240 ms) compared to the previous literature on other languages. The fact that a CPS is observed for non-European language like Japanese confirms that ERP is a promising tool to investigate the prosodic effect in Japanese auditory sentence processing, and similar studies using Japanese complex sentences should be conducted.

In sum, previous studies have demonstrated a clear effect of prosody in sentence processing of Japanese, which is a head-final language where the prosodic boundary typically coincides with opening positions of syntactic phrases rather than closing positions as in head-initial languages. It is worth investigating, however, the effect of prosody using Japanese globally ambiguous sentences whose semantic biases are systematically manipulated when processed under time pressure, in order to understand the nature of earlier effects of prosody (cf., Misono et al., 1997), since previous studies tended to incorporate untimed, off-line methods. Furthermore, ERP studies on the effect of prosody on Japanese complex sentences that involve relative clauses have yet to be conducted. While many neurolinguistic and psycholinguistic

studies on European languages (e.g., Kjelgaard & Speer, 1999; Pauker et al., 2011; Steinhauer et al., 1999) have demonstrated that prosody is monitored and utilized online, and prosodic representation might determine the initial syntactic structure of an utterance in a head-initial language, it has not been investigated if this also is the case for Japanese, a head-final language. Among Japanese sentences, which hold 'opening ambiguity', in contrast with 'closure ambiguity' in head-initial languages[7] (Hirose, 2003), it has been reported that late opening structure is more costly than early opening structure (Inoue & Fodor, 1995; Hirose, 2003; Mazuka & Itoh, 1995) just like early closure structure is more costly than late closure structure in a head-initial language. Thus, it is meaningful to investigate whether congruent prosody would diminish the dis-preference toward the late opening structure.

Moreover, L2 learners' detection and utilization of prosody is in question. Männel and Friederici (2011) reported that a CPS was not elicited for the child before the syntactic development (21-month-olds). Would a low-level adult L2 learner have a similar problem detecting prosodic boundaries? Eda et al. (2009) demonstrated that advanced-level Japanese learners tended to rely on prosodic information more when there is prosody-semantics mismatch, and even intermediate-level Japanese learners yielded differences in two types of prosodies although the prosody did not necessarily guide them to the correct interpretation. This raises a few questions: Would the L2 learners' prosody detection mechanism be the same as native speakers'? How do L2 learners utilize prosody in auditory sentence processing of Japanese? Comparing the detection and utilization mechanism of native speakers of Japanese and L2 learners may shed light on Japanese pronunciation training and Japanese pedagogy in general.

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[7] Mazuka & Itoh (1995) used the terms, "subject reanalysis" and "subject-object reanalysis" for "early opening" and "late opening" respectively.

2.6. Current Study

The aim of this dissertation is twofold. The first aim is to understand the nature of auditory sentence processing among native speakers of Japanese utilizing psycholinguistic experiments that collect multiple measures employing multiple types of sentences. In particular, Misono et al. (1997) was extended by adding time pressure, and by acquiring both judgment and reaction times to detect prosodic effects on processing when other linguistic information is absent and present, in order to contrast the findings regarding global ambiguity with the untimed, offline findings from Misono et al. (1997). Moreover, temporary ambiguity was tested in the same experimental context, modeling after Kang et al. (2004). Kang et al. (2004) was extended by adding late opening sentences together with early opening sentences, so as to test whether congruent prosody can diminish the processing cost of difficult late opening sentences. In addition, in order to gain a fuller picture of the effects of prosody in the processing of ambiguous sentences, they were assessed not only in a sentence comprehension task but also in an acceptability judgment task. This series of experiments is reported in Chapter 3.

The second aim is to compare the L2 learners' auditory sentence processing with native speakers' utilizing neurolinguistic ERP measures combined with psycholinguistic tasks. Specifically, the same temporarily ambiguous sentences described above were employed using the timed acceptability judgment task, while brain activity was continuously monitored. ERP studies on the effects of prosody on syntactic processing in L2 learners have yet to be conducted in any language; thus, the current study will shed light in the field of second language acquisition and processing. The experiment is described in detail in Chapter 4.

2.7. Summary

Many SLA theories have demonstrated that there is L1 influence on L2 acquisition, and yet there is some universality in L2 acquisition among different languages. There may not be a critical period of language acquisition, but it has been pointed out that the younger the better for adult L2 learners to acquire L2 pronunciation/prosody. Phonological acquisition is qualitatively different and may be more challenging than acquiring other SLA properties since the learner's language ego and psychological and socio-cultural features influence it in a complex way.

There have been quite a few foreign language teaching methods throughout history. Some put emphasis on pronunciation at the word level while others did not, but not many teaching methods have paid attention to prosodic aspects of language. However, recently, it has been argued in the paradigm of The Communicative Approach, that intelligible pronunciation is necessary to make communication successful. Thus, effective ways of teaching pronunciation/prosody should be further explored.

It may also be important to investigate how people process auditory speech, since communication requires speaking and listening. Syntactically ambiguous sentences are useful in testing what kind of roles prosody plays in sentence processing. Many psycholinguistic and neurolinguistic studies have been conducted to test the use of prosodic cues among native speakers of different languages, and it has been found that prosody has some effect on their sentence interpretation. However, there are few studies on non-European languages and non-native speakers on this topic.

The Japanese language uses prosodic cues in many different ways; thus, learning prosody is crucial to making communication that is free of misunderstanding. Although an increased number of studies have been conducted on Japanese prosody, and its teaching methods have

been advanced recently, more research is required to pursue efficient instruction methods and to further understand problems that learners have in learning Japanese.

Therefore, the studies reported in this dissertation aim to examine how native speakers of Japanese and native speakers of English learning Japanese process prosodic cues in auditory sentence processing. Comparisons of the detection and utilization mechanism between native speakers and learners may shed light on Japanese pronunciation training and Japanese pedagogy in general.

Chapter 3

Psycholinguistic Studies on L1 Japanese Listeners' Auditory Sentence Processing

It is necessary to understand how native speakers of Japanese (*native speakers* will henceforth be referred to as L1) use prosody in auditory sentence processing in order to investigate how similar or different L2 learners of Japanese do. In fact, there are few studies that dealt with L1 Japanese listeners' use of prosody during sentence processing. In this chapter, experiments investigating the effects of prosody during ambiguity resolution in Japanese using a cross-method, psycholinguistic approach, building upon the design and approach of Kang et al. (2004) and Misono et al. (1997) are reported. In particular, Misono et al.'s (1997) study was extended by adding time pressure, and acquiring both judgment and reaction times to detect prosodic effects on processing when other linguistic information is absent or present, in order to contrast the findings regarding global ambiguity with the untimed, offline findings from Misono et al. (1997). Moreover, temporary ambiguity is tested in the same experimental context, in a study modeling after Kang et al. (2004). Kang et al.'s (2004) study was extended by adding late opening sentences together with early opening sentences, so as to test whether congruent prosody can diminish the processing cost of difficult late opening sentences. In addition, in order to gain a fuller picture of the effects of prosody in the processing of ambiguous sentences, the effects of prosody were assessed not only in a sentence comprehension task but also in an acceptability judgment task.

3.1. Experiment 1: Globally Ambiguous Sentences

The experiment reported in this section extends the offline study of the effects of prosody in Japanese globally ambiguous sentences by Misono et al. (1997), testing acceptability judgments with time pressure, and adding time pressure to the auditory comprehension task that was used in Misono et al. (1997). It was hypothesized that if prosody has a stronger effect given time pressure, interpretations of neutral sentences will be typically determined based on the prosodic information; and interpretations of main-clause bias sentences and embedded-clause bias sentences will be shifted toward the other interpretations when prosody is incongruent with the semantic bias. However, if prosody has little to no effect given time pressure, interpretations of neutral sentences will be neutral regardless of the prosody, and interpretations of main-clause bias sentences and embedded-clause bias sentences will not be shifted toward the other interpretations even when prosody is incongruent with the semantic bias. Thirdly, if the effect of prosody is constant across offline tasks and tasks with time pressure which are more likely to reflect earlier stages of online processing, the pattern of results will be expected to replicate those in Misono et al. (1997).

3.1.1. Stimuli. Twenty-eight triplets of globally ambiguous sentences (embedded-clause bias sentences (ES), main-clause bias sentences (MS), and neutral sentence (NS)) were constructed to serve as target sentences for Experiment 1. As in Misono et al., (1997), neutral sentences were created in a way that the first predicate (underlined in the examples 35-37) can be interpreted equally as the action of either the matrix subject or the matrix object (*Kenta* or *friend* in the examples), while embedded-clause bias and main-clause bias sentences have semantic bias toward the matrix object and the matrix subject to be the agent of the action, respectively.

Example sentences are shown below (35-37), and the two possible syntactic structures are displayed in Figure 1 using NS as an example.

(35) NS: Kenta-wa (#E) terebi-o mitumenagara (#M) benkyoositeiru tomodati-ni
Kenta(name)-Top TV-Acc watch while studying friend-Dat
oogoede donatta.
loudly yelled

a. Embedded Interpretation
"Kenta loudly yelled at his friend who was studying while watching TV."

b. Main Interpretation
"Kenta, while watching TV, loudly yelled at his friend who was studying."

(36) ES: Kenta-wa (#E) eewajiten-o hikinagara (#M) benkyoositeiru tomodati-ni
Kenta(name)-Top dictionary-Acc consult while studying friend-Dat
oogoede donatta.
loudly yelled

a. Embedded Interpretation
"Kenta loudly yelled at his friend who was studying while consulting a dictionary."

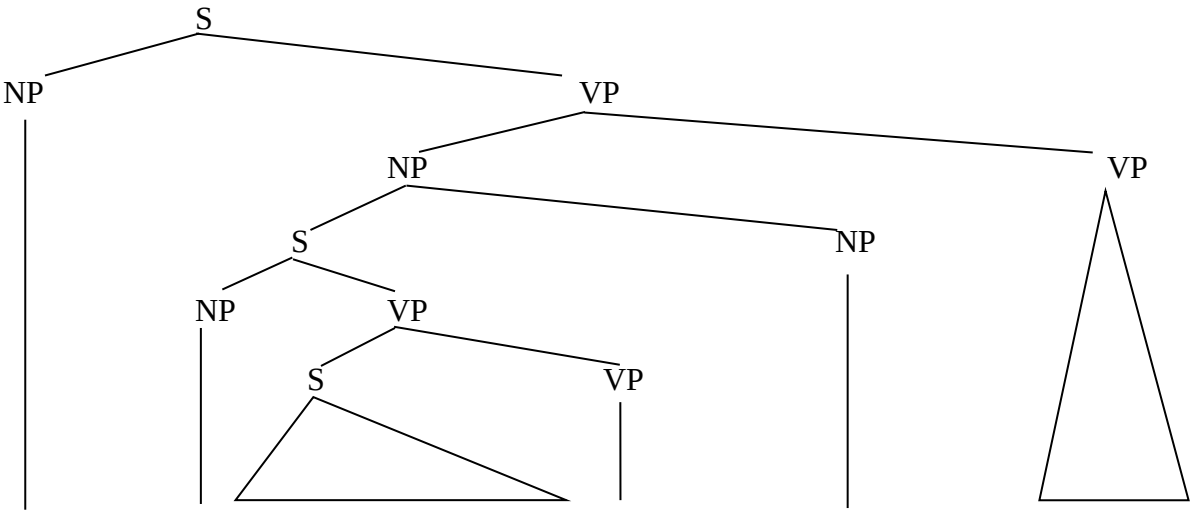
b. Main Interpretation
"Kenta, while consulting a dictionary, loudly yelled at his friend who was studying."

(37) MS: Kenta-wa (#E) shawaa-o abinagara (#M) benkyoositeiru tomodati-ni
Kenta(name)-Top shower-Acc taking while studying friend-Dat
oogoede donatta.
loudly yelled

a. Embedded Interpretation
"Kenta loudly yelled at his friend who was studying while taking a shower."

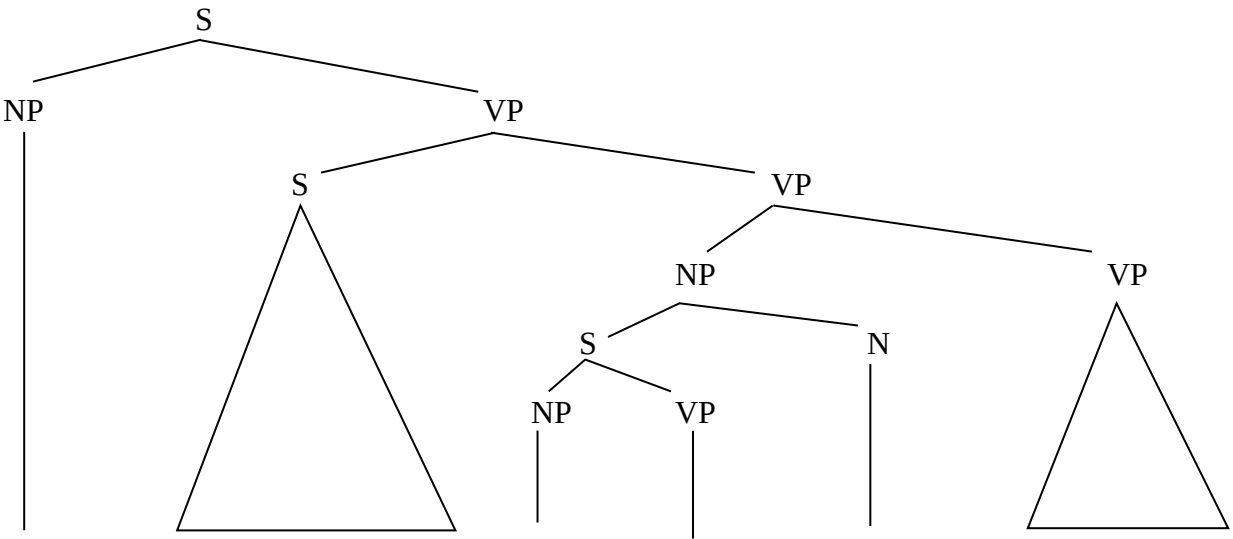
b. Main Interpretation
"Kenta, while taking a shower, loudly yelled at his friend who was studying."

[Embedded-clause interpretation]



Kenta$_i$-wa Ø$_j$ Ø$_j$ terebi-o mitumenagara benkyoositeiru tomodati$_j$-ni oogoede donatta
Kenta-TOP TV watch while studying friend-DAT loudly yelled
"Kenta loudly yelled at his friend who was studying while watching TV."

[Main-clause interpretation]



Kenta$_i$-wa Ø$_i$ terebi-o mitumenagara Ø$_j$ benkyoositeieru tomodati$_j$-ni oogoede donatta.
Kenta-TOP TV watch while studying friend-DAT loudly yelled
"Kenta, while watching TV, loudly yelled at his friend who was studying."

Figure 1. Syntactic structures of Globally Ambiguous Sentences (NS).

As shown in example (35), both interpretations are equally plausible in the neutral condition. An embedded-clause bias can be induced by replacing the "watching TV" with "consulting a dictionary" (example (36)), because it is more natural to consult a dictionary while studying than yelling. A main-clause bias can be induced by replacing "watching TV" with "taking a shower" (example (37)), since studying while taking a shower is not very likely. A female native speaker of Japanese who has a Tokyo accent read these sentences and they were recorded through a microphone (Electro-Voice RE20) into a solid-state recorder (Marantz PMD671) in a sound-proof room. She read each sentence with two different prosodies (embedded-clause prosody (EP): with a prosodic break at the point indicated as (#E) in the examples above; and main-clause prosody (MP): with a prosodic break at the point indicated as (#M) in the examples above), which yielded 168 sentences. 336 temporarily ambiguous sentences and 168 ungrammatical sentences were also created to serve as fillers, half of which were read with EP and the other half with MP by the same speaker.

3.1.1.1. Visual pretest of stimuli. In order to test whether the stimuli are interpreted according to the targeted semantic bias, each sentence was tested visually. Thirty-six native speakers of Japanese (29 women; age: 19 years 4.7 months to 33 years 5.1 months, mean: 21 years 7.4 months) who were undergraduate students in universities in Japan filled out a paper-pencil survey. Participants were provided a 5-page packet that had instructions and a small number of short biographical questions on the first page, followed by 28 triplets of globally ambiguous sentences. The order was randomized for each participant. Participants filled out gender, date of birth and native language(s) for the biographic section. Then, they were asked to read each sentence carefully and mark who the agent of the target action (words 2 and 3) was, using 1 for the matrix subject (main-clause interpretation), 5 for the matrix object (embedded-

clause interpretation), and 3 for either one of them (neutral interpretation). They also marked their confidence level of their answers using the scale of 1 (not confident at all) to 5 (very confident). The proportions of answers 1 (main-clause interpretation), 3 (neutral), and 5 (embedded-clause interpretation) were calculated for each sentence type. The results are summarized in Table 1.

Table 1
Visual Pretest Results of Globally Ambiguous Sentence Interpretations

		Semantic Bias		
		Embedded	Neutral	Main
Interpretation	Embedded	**58%**	25%	7%
	Neutral	29%	**51%**	13%
	Main	13%	24%	**80%**

a. Each column shows the mean proportion of each interpretation for 28 sentences across 36 participants within the same semantic bias.
b. Bold numbers show the proportion of the target interpretation of each semantic bias.

Then paired *t*-tests were conducted to examine whether the proportion of the target answer was different from the other answers for each condition. For the ES, embedded-clause interpretation (58%) was significantly greater than neutral interpretation (29%) ($t(35) = 4.29$, $p < .001$) or main interpretation (13%) ($t(35) = 7.27$, $p < .001$), and neutral interpretation (29%) was also greater than main interpretation (13%) ($t(35) = 3.36$, $p = .002$). For the MS, the proportion of main-clause interpretation (80%) was significantly greater than neutral interpretation (13%) ($t(35) = 15.18$, $p < .001$) or embedded-clause interpretation (7%) ($t(35) =$

19.52, $p < .001$), and that of neutral interpretation was greater than embedded-clause interpretation (7%) ($t(35) = 2.07$, $p = .046$) as well.

As for the NS, neutral interpretation (51%) was greater than embedded-clause interpretation (25%) ($t(35) = 4.60$, $p < .001$), and greater than main-clause interpretation (24%) ($t(35) = 4.03$, $p < .001$). An additional *t*-test was conducted between embedded interpretation and main interpretation of this type of sentences in order to test if the bias toward embedded or main interpretation would be greater. The result showed that there was no difference between these interpretations (25% - 24%) ($t(35) = .05$, $p = .96$). These results altogether show that the stimuli for each condition have intended semantic biases when they were presented visually.

3.1.1.2. Acoustic Analyses of Globally Ambiguous Sentences. Acoustic analyses of the stimuli were conducted to test whether acoustic features of the stimuli were properly controlled. The pitch contours of an example sentence read with two prosodies are shown in Figure 2. Following Misono et al. (1997), the total length of the sentences, duration of the pause at the prosodic break of each type of sentences, and the peak F_0s of the first NP ($F_0$1), first predicate ($F_0$2), and the second predicate ($F_0$3) were measured. The mean lengths of the whole sentence and pauses and pitch differences of the peak F_0s are summarized in Table 2.

An ANOVA was conducted for phonetic differences between embedded-clause bias, main-clause bias, and neutral sentence triplets. The results on the pitch peak differences between the first NP and the first predicate ($F_0$2-$F_0$1) showed that there was a main effect of prosody ($F(1, 27) = 67.84$, $p < .001$), indicating that the pitch drop between the first NP and first predicate was significantly smaller for the sentences read with EP compared to the sentences read with MP. This shows that there was a pitch reset at the prosodic boundary of the sentences read with embedded-clause prosody, while there was no reset for the sentences read with main-clause

prosody at the same position. There was no main effect of sentence type ($F(2, 54) = 1.73$, $p = .19$) or interaction ($F(2, 54) = 1.31$, $p = .28$). The paired *t*-test results between item pairs with the same structure but different prosodies confirmed that sentences read with embedded-clause prosody had pitch resets, while those with main-clause prosody did not (ES-EP vs. ES-MP: $t(27) = 4.29$, $p < .001$; MS-EP vs. MS-MP: $t(27) = 6.24$, $p < .001$; and NS-EP vs. NS-MP: $t(27) = 3.34$, $p = .002$). There were also marginal differences between ES-EP and MS-EP ($t(27) = -1.91$, $p = .07$) and MS-EP and NS-EP ($t(27) = 1.92$, $p = .07$), but other conditions that had the same prosody but different semantic biases yielded no differences.

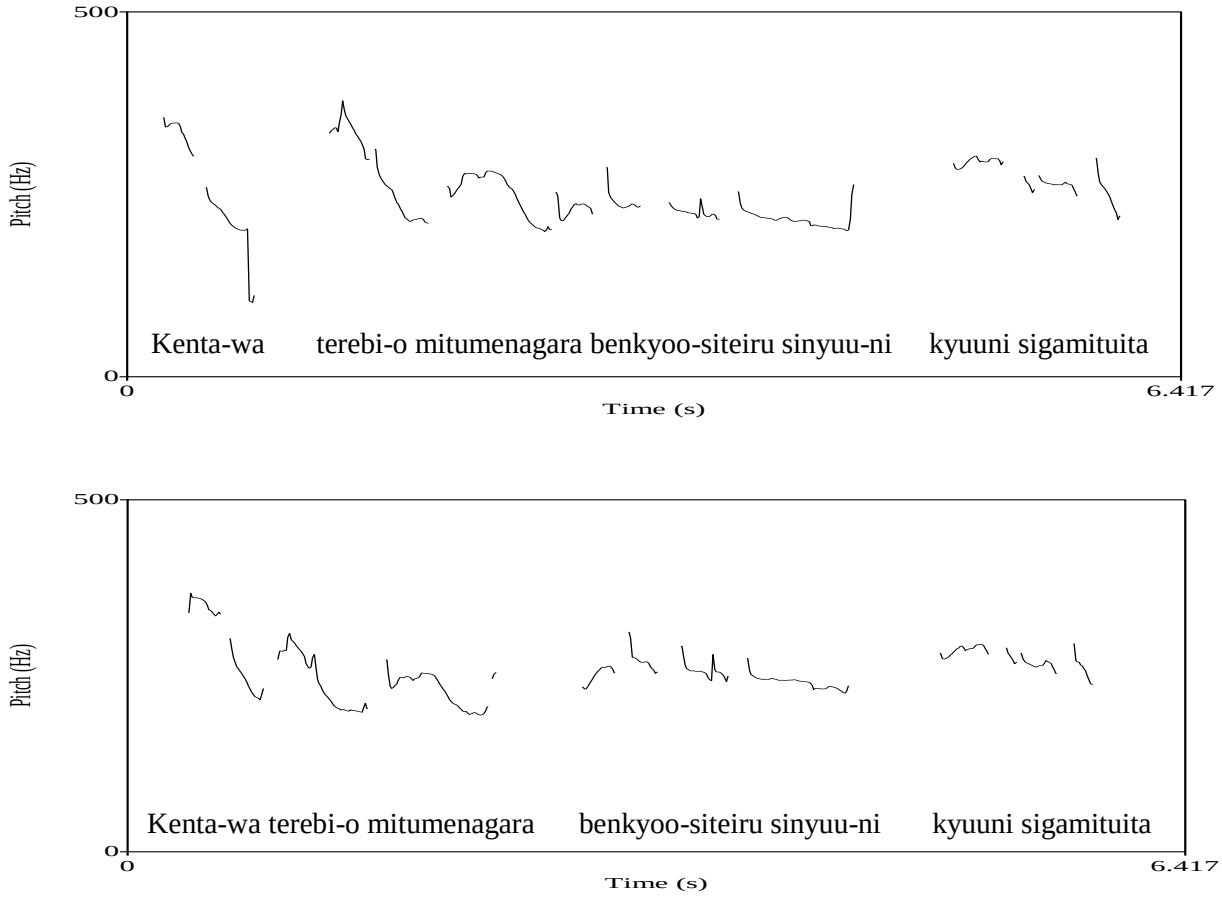


Figure 2. F_0 pattern of embedded-clause bias sentence (top) and main-clause bias sentence (bottom) read with congruent prosody.

Table 2
Summary of Total Duration, Pause Duration, and F_0 for the Globally Ambiguous Sentences

Semantic bias	Prosodic bias: Length (s)		Prosodic bias: Pause (s)		$F_0$2-$F_0$1 (Hz)		$F_0$3-$F_0$2 (Hz)	
	Main	Embd	Main	Embd	Main	Embd	Main	Embd
Main	5.78 (0.41)	5.80 (0.40)	0.63 (0.09)	0.42 (0.09)	-10.85 (40.09)	18.33 (38.80)	-8.4 (30.05)	-58.23 (26.21)
Embd	5.88 (0.30)	5.85 (0.37)	0.64 (0.07)	0.43 (0.09)	-21.11 (33.91)	-0.12 (35.94)	-21.51 (32.35)	-59.36 (24.81)
Neutral	5.86 (0.34)	5.86 (0.36)	0.63 (0.08)	0.44 (0.09)	-21.37 (39.71)	-2.38 (40.94)	-15.41 (27.02)	-58.67 (22.27)

a Numbers in parentheses are standard deviations for 28 sentences.
b Pauses for the sentences with main-prosody were measured after the second word, and those with embedded-prosody were measured after the first word.
c $F_0$1 was the peak F_0 for the first NP that ended with the topic marker *-wa,* $F_0$2 the peak $F_0$for the first predicate that ended with *-nagara,* and $F_0$3 the peak F_0 for the second predicate that ended with *-teiru.*

Similarly, the pitch peak differences between the second predicate and the first predicate ($F_0$3-$F_0$2) were compared using ANOVA. The results revealed that there was a main effect of prosody ($F(1, 27) = 146.66$, $p < .001$). This indicates, at this position, the pitch drop for the sentences read with MP was significantly smaller compared to those read with EP ($F(1, 27) = 146.66$, $p < .001$). There was no main effect of semantic bias ($F(2, 54) = .62$, $p = .55$) or an interaction ($F(2, 54) = 1.71$, $p = .19$). Paired *t*-test results among pairs with the same semantic bias but different prosodies confirmed the existence of pitch resets for sentences read with MP but not for the ones with EP (ES-EP vs. ES-MP: $t(27) = -6.00$, $p < .001$; MS-EP vs. MS-MP: $t(27) = -12.30$, $p < .001$; and NS-EP vs. NS-MP: $t(27) = -7.48$, $p < .001$). There were no differences among pairs that have the same prosodies (all $t < 1.70$, all $p > .10$).

The visual pretest and the acoustic analyses of the stimuli revealed that the semantic biases and prosodies were properly controlled to test the role of prosody during auditory processing of globally ambiguous sentences in Experiment 1.

3.1.2. Experiment 1A: Auditory acceptability judgment study.

In Experiment 1A, the role of prosody on Japanese globally ambiguous sentence processing among native speakers was tested under time pressure. The task employed in this portion of Experiment 1 was an acceptability judgment task.

3.1.2.1. Methods.

Participants. Twenty-four native speakers of Japanese (18 women; age: 18 years 3 months to 21 years 3.1 months, mean: 21 years 1.6 months) who were undergraduate students in Japan participated in this study. All of them were monolingual speakers of Japanese, and their exposure to other languages was minimal. They read and signed written informed consent form prior to the experiment, and they received 1,000 Japanese yen (approximately 10 USD) upon the completion of the experiment.

Materials. The auditory stimuli were 28 sextuplets (3 semantic biases x 2 prosodies) of globally ambiguous target sentences, 84 quadruplets of temporarily ambiguous sentences, and 28 sextuplets of ungrammatical sentences, of which the temporarily ambiguous sentences and ungrammatical sentences served as fillers. The target sentences are repeated here:

(38) NS: Kenta-wa (#E) terebi-o mitumenagara (#M) benkyoositeiru tomodati-ni
Kenta(name)-Top TV-Acc watch while studying friend-Dat
oogoede donatta.
loudly yelled

a. Embedded Interpretation
"Kenta loudly yelled at his friend who was studying while watching TV."
b. Main Interpretation
"Kenta, while watching TV, loudly yelled at his friend who was studying."

(39) ES: Kenta-wa (#E) eewajiten-o hikinagara (#M) benkyoositeiru tomodati-ni
Kenta(name)-Top dictionary-Acc consult while studying friend-Dat
oogoede donatta.
loudly yelled

a. Embedded Interpretation
"Kenta loudly yelled at his friend who was studying while consulting a dictionary."
b. Main Interpretation
"Kenta, while consulting a dictionary, loudly yelled at his friend who was studying."

(40) MS: Kenta-wa (#E) shawaa-o abinagara (#M) benkyoositeiru tomodati-ni
Kenta(name)-Top shower-Acc taking while studying friend-Dat
oogoede donatta.
loudly yelled

a. Embedded Interpretation
"Kenta loudly yelled at his friend who was studying while taking a shower."
b. Main Interpretation
"Kenta, while taking a shower, loudly yelled at his friend who was studying."

Recordings of the target and filler sentences were transferred digitally to a PC and they were divided into four equivalent lists; thus, each list consisted of 168 sentences. A Latin Square Design was employed, in which the same sentences with different prosodies were put in different lists, sentences were randomized within each block, and the blocks were presented in two

different orders. These sentences in each list were further divided into four equivalent blocks. Orders of blocks were organized in eight different ways and were counterbalanced.

Procedure. Stimulus presentation and data collection were done using the experiment control software, *Paradigm* (Perception Research Systems). Participants sat in front of a computer screen in a quiet room wearing headphones, placed their right hand on the computer mouse, and listened to 168 sentences (42 targets and 126 fillers) across four blocks. The headphones and the computer mouse were connected to a laptop computer, and the participants' answers and reaction times (RTs) were recorded directly onto the computer.

Each trial started with the presentation of a cross at the center of the screen, followed by the auditory presentation of a sentence. As soon as a sentence was played, a rating scale (1- very bad to 5- very good) was presented on the computer screen, and they clicked the number as quickly as possible within a 3-second time limit using the mouse. The participants' responses and reaction times (RTs) were recorded directly onto the computer. Upon their answer or a 3-second timeout, the rating scale was replaced by the centered cross, and the next trial began. They were encouraged to take breaks between the blocks, and each participant's total visit was approximately 40 minutes. This procedure was approved by the Institutional Review Board at the University of Kansas.

3.1.2.2. Results. Judgment and RT results for Experiment 1A are shown in Table 3, and a full report of all statistical analyses are summarized in Appendix A.

Repeated measures ANOVA were conducted on the acceptability rating data and RTs separately, with Semantic Bias (ES, MS and NS) and Prosody (EP and MP) as within-subjects factors. The results of the acceptability judgment score revealed that there was a main effect of semantic bias, a main effect of prosody only by items, and an interaction between prosody and

semantic bias. The main effects reflect a preference toward ES and EP, but the interaction suggests that prosodic congruency also influenced responses. For the RTs, only a main effect of prosody was observed, reflecting a shorter reaction time for the embedded-clause prosody[8].

Table 3
Results of Acceptability Judgment Task for Globally Ambiguous Sentences

		Acceptability Judgment		**Reaction Time (ms)**	
		Embedded-clause prosody	Main-clause prosody	Embedded-clause prosody	Main-clause prosody
Semantic Bias	Embedded	4.10 (0.52)	3.82 (0.74)	1285 (328)	1349 (363)
	Neutral	3.87 (0.71)	3.75 (0.58)	1259 (399)	1435 (362)
	Main	2.77 (0.88)	3.43 (0.73)	1357 (300)	1357 (408)

a. Acceptability Judgment scores show the mean scores of 28 sentences (*1: very bad* to *5: very good*) across 24 participants.
b. Reaction Times are the mean RTs of 28 sentences across 24 participants.
c. Numbers in parentheses are standard deviations for 24 participants.

Planned direct comparisons using paired *t*-tests were conducted among (a) items whose semantic bias and prosody are congruent and incongruent respectively (MS-MP vs. ES-EP and

[8] In order to test for the effect of prosodic congruency, an additional repeated measures ANOVA was conducted excluding NS. The acceptability judgment results revealed that there was a critical interaction ($F_1(1, 23) = 37.62$, $p < .001$; $F_2(1, 27) = 13.16$, $p < .001$), reflecting that conditions with congruent prosodies were rated significantly higher than incongruent prosodies. There was also a main effect of semantic bias ($F_1(1, 23) = 70.13$, $p < .001$; $F_2(1, 27) = 46.43$, $p < .001$), and a main effect of prosody only by items ($F_1(1, 23) = 2.87$, $p < .1$; $F_2(1, 27) = 7.01$, $p < .001$). These effects suggest that ES is preferred compared to MS, and prosodic congruency gives a significant effect although the size of the effect is not the same for ES and MS: it is stronger for dispreferred MS. The RT results did not yield any main effects or interaction ($F_1(1, 23) < .83$, $p > .1$; $F_2(1, 27) < 2.10$, $p > .1$).

MS-EP vs. ES-MP), (b) items that have the same prosody (MS-EP vs. ES-EP and ES-MP vs. MS-MP), and (c) the items that had the same semantic biases (MS-EP vs. MS-MP and ES-MP vs. ES-EP).

a. Effects of structure within the same prosodic congruency conditions

First, we compared the items whose syntactic structure that the semantic bias suggests and prosody were congruent. The ratings of ES-EP (4.10) were significantly higher than those of MS-MP (3.43). However, RTs did not yield a significant difference (1285 ms vs. 1357 ms). Second, incongruent conditions were compared. The rating results showed that ES-MP scores (3.82) were significantly higher than MS-EP (2.77); however, the RTs were not different (1349 ms vs. 1357 ms). These results suggest that embedded-clause structure is more preferred than main-clause structure even when both of the prosody and semantic bias suggest the same interpretation.

b. Effects of semantic bias within the same prosody conditions

Among the items with the embedded-clause prosody, congruent ES-EP (4.10) was scored significantly higher than incongruent MS-EP (2.77) in rating, and neutral NS-EP (3.87) yielded a higher score than incongruent MS-EP (2.77). In contrast, among sentences with main-clause prosody, congruent MS-MP (3.43) was scored lower than incongruent ES-MP (3.82) or NS-MP (3.75). These opposite tendencies of EP and MP conditions suggest that acceptability of the sentence depends more on the semantic bias of the sentence than prosodic congruency. The RT results revealed no significant differences.

c. Effects of prosody within the same semantic bias conditions

Among the items with the same semantic biases, MS-MP (3.43) had a significantly higher rating than MS-EP (2.77), while ES-EP (4.10) yielded a marginally higher score

compared to ES-MP (3.82), only by participants. There were no RT differences between ES conditions or MS conditions. As for the NS, there was no difference in the ratings; however, RTs yielded a significant difference (NS-EP: 1259 ms vs. NS-MP: 1435 ms), reflecting NS-EP was responded faster than NS-MP, which suggests the difficulty of arriving at the main-clause interpretation even when the semantic bias is neutral. Taken together, the judgment and RT data demonstrated a preference toward congruent prosody as well a preference for the embedded-clause interpretation.

3.1.3. Experiment 1B: Auditory Comprehension Study

In Experiment 1B, the role of prosody on Japanese globally ambiguous sentence processing among native speakers was tested under time pressure employing a comprehension task. While the task is the same as that used by Misono et al. (1997), participants were asked to respond under time pressure, and both judgment and RT data were recorded.

3.1.3.1. Methods.

Participants. Twenty four native speakers of Japanese (all women; age: 18 years 3.5 months to 24 years 5.2 months, mean: 19 years 4.1 months) who were undergraduate students in Japan participated in this study. All of them were monolingual speakers of Japanese, and their exposures to other languages were minimal. No participants who took part in Experiment 1A or the visual pretest also participated in this study. They read and signed a written informed consent form prior to the study and they received 1,000 Japanese yen upon the completion of the experiment.

Materials. The stimuli were exactly the same as the ones used in Experiment 1A.

Procedure. The procedure is exactly the same as Experiment 1A except the participant's task is not acceptability judgment but to answer yes/no comprehension questions provided after

the stimulus sentence presentation. Each trial started with a presentation of a cross at the center of the computer screen followed by auditory sentence presentation. As soon as the sentence was finished, a comprehension question about the heard sentence was visually presented at the center of the screen, asking whether a particular person was the agent of a particular action. Participants were instructed to answer the question as quickly as possible using 'Yes' and 'No' buttons marked on the mouse within a 5-second time limit. Upon their response or 5-second timeout, the question was replaced by a centered cross, and the next trial began. The stimuli were presented across four blocks and each participant's total visit was approximately 40 minutes. Both judgments and reaction times were recorded for each trial. This procedure was approved by the Institutional Review Board at the University of Kansas.

3.1.3.2. Results. Judgment and RT results for Experiment 1B are shown in Table 4, and a full report of all statistical analyses is summarized in Appendix B. Two-way Repeated ANOVA was conducted on the proportion of main-clause interpretation and RTs separately, with Semantic Bias (ES, MS and NS) and Prosody (EP and MP) as within-subjects factors. The proportion of main-clause interpretation revealed main effects of semantic bias and prosody, reflecting sentences with main-clause bias or main-clause prosody yielded more main-clause interpretation. There was no interaction among these two factors. These results illustrate that both ES and EP suggest embedded-clause interpretation and MS and MP suggest main-clause interpretation steadily, while NS shows the same tendency as ES. The reaction time results similarly showed main effects of semantic bias and prosody, reflecting that ES and EP conditions were responded more quickly than MS and MP. These main effects in both the accuracy and RT results showed that both semantic bias and prosody significantly contribute to the interpretation of the sentence. There was also an interaction between prosody and semantic bias in the RTs for

the comprehension questions. This interaction suggests that RT differences in MS conditions with EP vs. MP are not equivalent to those of ES or NS conditions[9].

Table 4
Results of Comprehension Task for Globally Ambiguous Sentences

		Main-Clause Interpretation		**Mean Reaction Time (ms)**	
		Embedded-clause prosody	Main-clause prosody	Embedded-clause prosody	Main-clause prosody
Semantic Bias	Embedded	4% (7)	51% (23)	1415 (335)	1751 (400)
	Neutral	9% (14)	58% (27)	1500 (578)	1686 (355)
	Main	34% (33)	76% (22)	1722 (572)	1756 (458)

a. Data in the left column show the mean proportion of main-clause interpretation for 28 sentences across 24 participants.
b. Reaction Times are the mean RTs of 28 sentences across 24 participants.
c. Numbers in parentheses are standard deviations for 24 participants.

[9] In order to test for an interaction between semantic bias and prosodic congruency, an additional repeated measures ANOVA was conducted on the proportion of the prosody-based interpretation between MS and ES with embedded-clause and main-clause prosodies. The prosody-based interpretation results showed a critical interaction of semantic bias and prosody ($F_1(1, 23) = 57.57$, $p < .001$; $F_2(1, 27) = 144.00$, $p < .001$), which reflects the asymmetry of two prosodic conditions in ES and MS: the difference between congruent and incongruent prosody conditions is significantly bigger for ES compared to MS. There was also a main effect of semantic bias ($F_1(1, 23) = 13.73$, $p < .001$; $F_2(1, 27) = 22.66$, $p < .001$), but no effect of prosody ($F_1(1, 23) = 1.41$, $p > .1$; $F_2(1, 27) = .57$, $p > .1$). The RT results also showed a critical interaction ($F_1(1, 23) = 5.40$, $p < .05$; $F_2(1, 27) = 6.96$, $p < .05$), as well as main effects of semantic bias ($F_1(1, 23) = 10.34$, $p < .05$; $F_2(1, 27) = 9.22$, $p < .05$) and prosody ($F_1(1, 23) = 9.48$, $p < .001$; $F_2(1, 27) = 6.96$, $p < .001$). This interaction came from the RT differences in ES congruent and incongruent conditions, while RTs of MS congruent and incongruent conditions were both long and did not differ significantly. RT results also reflect the asymmetry of embedded-clause and main-clause interpretations.

Paired *t*-tests were conducted among (a) items whose semantic bias and prosody are congruent and incongruent respectively (MS-MP vs. ES-EP and MS-EP vs. ES-MP), (b) items that have the same prosody (MS-EP vs. ES-EP and ES-MP vs. MS-MP), and (c) the items that had the same semantic biases (MS-EP vs. MS-MP and ES-MP vs. ES-EP).

a. Effects of structure within the same prosodic congruency conditions

As for the congruent condition, the proportion of embedded-clause interpretation for the ES-EP condition (96%) was significantly higher compared to main-clause bias interpretation for MS-MP condition (76%). Even when semantic bias and prosody suggested the same interpretation, there seemed to be a difficulty in arriving at the main-clause interpretation. RT results were consistent with the judgment results with shorter RTs for ES-EP (1415 ms) compared to MS-MP (1756 ms), indicating preference toward embedded-clause interpretation. As for the incongruent condition, although the incongruent prosodies shifted the interpretations toward the other ones, the proportion of semantic-bias-based interpretation was higher for ES-MP condition (51%) compared to MS-EP (34%). This suggests that when semantic bias and prosody are incongruent, the embedded interpretation is more easily taken, implying a strong structural bias toward embedded-clause bias sentences. The RTs did not yield differences.

b. Effects of semantic bias within the same prosody conditions

Proportions of the prosody-based interpretations were compared between conditions that had the same prosodies. When EP was used, the congruent condition yielded significantly higher rates of prosody-based interpretation than the incongruent condition (ES-EP: 96% vs. MS-EP: 66%), and shorter RTs (ES-EP: 1415 ms vs. MS-EP: 1722 ms). Also, the neutral condition (NS-EP) yielded higher prosody-based interpretation (i.e., embedded-clause interpretation; 91%) compared to the incongruent main-clause bias condition (MS-EP) (66%), but the neutral

condition (NS-EP: 91%) did not yield a significant difference compared to the congruent embedded condition (ES-EP) (96%). Results for RTs showed similar tendencies: the embedded congruent condition (ES-EP: 1415 ms) was responded significantly faster than the incongruent condition (MS-EP: 1722 ms), and the neutral condition (NS-EP: 1500 ms) was faster than the incongruent condition (MS-EP: 1722 ms), while there was no difference between the embedded congruent condition and the neutral condition (ES-EP: 1415 ms vs. NS-EP: 1500 ms). Thus, the congruent ES-EP is interpreted more accurately and quickly compared to the incongruent MS-EP, and NS-EP yielded similar tendencies to the congruent ES-EP.

When MP was used, the proportion of choosing the prosody-based interpretation was significantly higher for the congruent condition (MS-MP: 76%) compared to the incongruent condition (ES-MP: 51%), just like the EP congruent vs. incongruent conditions (96% vs. 66%). However, the neutral condition yielded a significantly lower main-clause interpretation rate (58%) compared to the congruent MS-MP condition (76%), and a marginal difference compared to the incongruent condition only by subjects (51%). RTs did not reveal any differences among three conditions when they were read with main-clause prosody. These non-parallel results between the embedded-clause prosody and main-clause prosody conditions also indicate the structural preference toward the embedded-clause interpretation.

c. Effects of prosody within the same semantic bias conditions

The proportion of semantic-bias-based interpretation was compared among the conditions with the same semantic biases. Embedded congruent condition (ES-EP) yielded a significantly higher semantic-bias-based interpretation (96%) compared to the incongruent condition (ES-MP: 51%). This tendency is also evident in the RT results, showing faster RTs for the ES-EP (1415 ms) compared to ES-MP conditions (1751 ms). MS conditions also yielded significantly higher

semantic-bias-based interpretation (main-clause interpretation) for the congruent condition (MS-MP: 76% vs. MS-EP: 34%); however, the RTs did not yield differences (1756 ms vs. 1722 ms). Overall, the RTs were the longest for the main-clause bias sentences, suggesting the interpreting difficulty of main-clause bias sentences. Furthermore, neutral condition with two different prosodies (NS-EP and NS-MP) yielded similar significant differences as ES conditions, showing more embedded-clause interpretation for NS-EP (91% vs. NS-MP: 40%). RTs for NS-EP (1500 ms) were also shorter than NS-MP (1686 ms).

3.1.4. Discussion

Experiment 1A showed that the semantic bias affected the listener's acceptability rating of the sentences, while the types of prosody (EP or MP) did not. However, prosodic congruency influenced listeners' acceptability judgments greatly: congruent conditions (ES-EP and MS-MP) were more favored compared to incongruent conditions (ES-MP and MS-EP), although the RTs did not yield differences. Also, it was found that the listeners favored embedded-clause interpretation over main-clause interpretation, indicated by higher ratings for ES conditions compared to MS conditions. The results of the neutral conditions also support this tendency: there were no rating differences between the two prosodies, but the RTs for the sentences read with EP were significantly shorter than those read with MP, which suggests the difficulty of arriving at the main-clause interpretation.

Experiment 1B showed that both semantic bias and prosody contributed to the listener's interpretation of the sentences. The interpretations of ES and MS sentences were significantly different, and incongruent prosodies shifted interpretations away from the interpretations suggested by the semantic biases. Furthermore, the effect of prosody seems stronger under time pressure in the current study compared to without time pressure in Misono et al. (1997),

especially for the incongruent conditions. Moreover, embedded-clause interpretations are overall more easily arrived upon. This tendency was evident in the following: (1) the proportion of main-clause interpretation in the MS-MP congruent condition (76%) was much smaller than that of embedded-clause interpretation in the ES-EP congruent condition (96%); (2) the proportion of embedded-clause interpretation in neutral conditions read with EP (91%) was equivalent to ES-EP (96%), while the proportion of main-clause interpretations when read with MP was only 58%, which falls between ES-MP and MS-MP, but closer to ES-MP (51%) than MS-MP (76%); and (3) the RTs for ES-EP (1415 ms) and NS-EP (1500 ms) are much shorter compared to MS sentences (MS-MP: 1756 ms; MS-EP: 1722 ms) or ES and NS sentences read with MP (ES-MP: 1751 ms; NS-MP: 1686 ms).

Just like Misono et al. (1997), our results did not reveal deterministic effects of prosody. However, our study showed that the effect of prosody under time pressure was somewhat stronger than when it was untimed, especially for the incongruent conditions. In contrast, the semantic effect does not appear to be as strong in judgments under time pressure compared to untimed judgments. Moreover, in addition to the effects of semantic bias and prosody, a third factor, structural preference, emerged with time pressure. That is, overall the listeners arrived more easily at the embedded-interpretation than the main-clause interpretation, implying a preference toward embedded structure regardless of semantic or prosodic bias. This preference was not evident in the visual pretest, which showed that there was no preference toward embedded-clause interpretation when readers were given the same sentences without time pressure: the interpretations of neutral sentences were completely neutral (1/4 of the time, the embedded-clause interpretation was chosen, 1/4 of the time, the main-clause interpretation was chosen, and the other half of the time, ‘either’ was chosen), and the proportion and confidence

level of choosing main-clause interpretation of main-clause bias sentences were significantly higher than those of embedded-clause interpretation for embedded-clause bias sentences. This suggests that the preference for embedded structure may be a reflection of the initial processing of the sentence, detected using judgments under time pressure but not in an untimed judgment task. Why was embedded-clause interpretation preferred when the auditory tasks were given under pressure? It may be explained by 'expel' operations (Fodor & Inoue, 1994; Inoue & Fodor, 1995; Miyamoto, 2003). Let us first consider a neutral sentence as an example here. In reading (without overt prosody), the most natural process would be that the parser initially interprets the fragment *kenta-wa terebi-o minagara benkyoo-siteiru* as a single clause, giving an interpretation of 'Kenta is studying while watching TV'. However, when it encounters the head noun *tomodati* ('friend') which comes right after the fragment, the parser has to reanalyze the fragment and 'expel' one or more constituents from that. An earlier example (35) is repeated as (41) below, and two possible interpretations for (41) are given as (41a) and (41b) respectively:

(41) Kenta-wa (#E) terebi-o mitumenagara (#M) benkyoositeiru tomodati-ni oogoede
Kenta(name)-Top TV-Acc watch while studying friend-Dat loudly
donatta.
yelled

a. Embedded-clause interpretation
Kenta-wa [terebi-o mitumenagara benkyoositeiru] tomodati-ni…
Kenta-Top TV-Acc watch while studying friend-Dat
"Kenta (did something to) the friend who was studying while watching TV.

b. Main-clause interpretation
Kenta-wa terebi-o mitumenagara [benkyoositeiru] tomodati-ni…
Kenta-Top TV-Acc watch while studying friend-Dat
"Kenta, while watching TV, (did something to) the friend who was studying."

Interpretation (41a) accompanies an ‘expelling’ operation of one NP (Kenta-Top) to the outer clause, while (41b) requires an ‘expelling’ operation of two NPs and one VP (Kenta-Top, TV-acc, watching while), which suggests that (41b) is more costly (see Inoue & Fodor, 1995; Fodor & Inoue, 1998; Frazier, 1990, 1995; Miyamoto, 2003). Thus, the preference towards embedded-cause interpretation observed in Japanese speakers’ processing might be attributed to the labor needed to ‘expel’ extra phrases when reanalyzing the clause.

In listening, this parsing preference and prosody should interact. When embedded-clause prosody was used, both embedded-clause prosody and embedded structural bias led the parser to the embedded interpretation, but when the main-clause prosody was used, incongruent structural bias prevented the prosody from shifting the interpretation to the main-clause interpretation. This suggests that the prosodic effect is not strong enough to overcome the structural preference at this ‘early’ stage of sentence interpretation with time pressure, just like a ‘late’ stage of interpretation without time pressure, reported by Misono et al. (1997).

Now let us also consider the sentences that have semantic biases. Earlier examples (36) and (37) are repeated as (42) and (43) below:

(42) Embedded-clause bias sentence
Kenta-wa (#E) eewajiten-o hikinagara (#M) benkyoositeiru tomodati-ni oogoede
Kenta-Top dictionary-Acc consult while studying friend-Dat loudly
donatta.
yelled

a. Embedded-clause interpretation
Kenta-wa [eewajiten-o hikinagara benkyoositeiru] tomodati-ni…
Kenta-Top dictionary-Acc consult while studying friend-Dat
“Kenta (did something to) the friend who was studying while consulting dictionary.”

b. Main-clause interpretation
Kenta-wa eewajiten-o hikinagara [benkyoositeiru] tomodati-ni…
Kenta-Top dictionary-Acc consult while studying friend-Dat
"Kenta, while consulting a dictionary, (did something to) the friend who was studying."

(43) Main-clause bias sentence
Kenta-wa (#E) shawaa-o abinagara (#M) benkyoositeiru tomodati-ni oogoede donatta.
Kenta-Top shower-Acc taking while studying friend-Dat loudly yelled

a. Kenta-wa [shawaa-o abinagara benkyoositeiru] tomodati-ni…
Kenta-Top shower-Acc taking while studying friend-Dat
"Kenta (did something to) the friend who was studying while taking a shower."

b. Kenta-wa shawaa-o abinagara [benkyoositeiru] tomodati-ni…
Kenta-Top shower-Acc taking while studying friend-Dat
"Kenta, while taking a shower, (did something to) the friend who was studying."

Both of the sentences will be initially parsed in the same way as the neutral example without prosody. That is, the parser will process *Kenta-wa eewajiten-o hikinagara benkyoositeiru* ('Kenta is studying as he is consulting a dictionary') and *Kenta-wa shawaa-o abinagara benkyoositeiru* ('Kenta is studying as he is taking a shower') as one clause respectively. For the embedded-clause bias sentence (42), the parser will get to the semantically preferred interpretation (42a) by expelling one NP; thus, structural bias and semantic bias match without prosody. When embedded-clause prosody is used, it is congruent with both structural and semantic biases; thus, getting to the embedded-clause interpretation would be the most natural consequence. On the other hand, when main-clause prosody is used, it contradicts with the other two biases (structural and semantic biases); thus, it is questionable how much the main-clause prosody shifts the interpretation of ES-MP toward the main-clause interpretation. In fact, the embedded-clause bias sentences were made in the way that first two VPs have strong

connections; however, there is no contradiction when separating them using main-clause prosody; thus, it may be the case that embedded-clause sentences were initially parsed just like neutral sentences[10].

For a main-clause bias sentence (43), in order to get to the interpretation that the semantic bias suggests, the parser needs to expel two NPs and one VP (Kenta-Top, shower-Acc, taking while), instead of one NP (Kenta-Top). Even when the prosody is congruent with the main-clause semantic bias, structural preference is the opposite; thus, it should not be as easy to arrive at the main-clause interpretation compared to arriving at embedded-clause interpretation even in the congruent condition. This is evident in our target interpretation and RT results (MS-MP: 76% and 1756 ms. vs. ES-EP: 96% and 1415 ms). When the incongruent (embedded) prosody was used, the prosody together with the structural bias should have gone against the main-clause semantic bias; thus, it would be even more difficult. However, even in this case, MS semantic bias kept a quite strong effect (i.e., 35% chose MS interpretation), which could be explained by the semantic relationship between the first two VPs. Among MS, to connect the first and second VPs is semantically awkward (e.g., studying while taking a shower); thus the parser may face processing difficulty at the second VP and be compelled to expel 2 NPs and a VP. On the other hand, ES does not posit this processing difficulty whether to connect or separate these two VPs (consulting a dictionary and studying (ES), or watching TV and studying (NS)); thus, expelling 1 NP is sufficient. Figure 3 illustrates these expel operations in detail.

[10] The interpretations of ES-EP and NS-MP as well as ES-MP and NS-MP were only marginally different (EP: $t_1(23) = -1.69$, $p < .1$; $t_2(27) = -1.69$, $p < .1$; MP: $t_1(23) = -2.30$, $p < .1$; $t_2(27) = 1.11$, $p > .1$) .

Examples of Neutral and Embedded-clause bias and Main-clause bias sentences (NS, ES & MS)

NS:	Kenta-wa	terebi-o mitumenagara	benkyoositeiru	tomodati-ni…
	Kenta(name)-Top	TV-Acc watch while	studying	friend-Dat
ES:		eewajiten-o hikinagara		
		dictionary-Acc consult while		
MS:		shawaa-o abinagara		
		shower-Acc take while		

Initial analysis:

- NS: [Kenta-wa terebi-o mitumenagara benkyoositeiru]…
  "Kenta is studying while watching TV."
- ES: [Kenta-wa eewajiten-o hikinagara benkyoositeiru]…
  "Kenta is studying while consulting a dictionary."
- MS: [Kenta-wa shawaa-o abinagara benkyoositeiru]…
  "Kenta is studying while taking a shower."

(i) Expel operation 1 to get to Embedded-clause interpretation (preferred operation):

Expel 1 NP

Kenta-wa [terebi-o mitumenagara benkyoositeiru tomodati]-ni…
eewajiten-o hikinagara
shawaa-o abinagara

NS: "Kenta (did something to) the friend who was studying while watching TV.
ES: "Kenta (did something to) the friend who was studying while consulting a dictionary."
MS: "Kenta (did something to) the friend who was studying while taking a shower."
➔ Interpretation of MS is semantically awkward, while the other two are fine.

(ii) Expel operation to get to Main-clause interpretation (dispreferred operation):

Expel 2 NPs and 1 VP

Kenta-wa terebi-o mitumenagara [benkyoositeiru tomodati]-ni…
Kenta-wa eewajiten-o hikinagara
Kenta-wa shawaa-o abinagara

NS: "Kenta, while watching TV, (did something to) the friend who was studying."
ES: "Kenta, while consulting a dictionary, (did something to) the friend who was studying."
MS: "Kenta, while taking a shower, (did something to) the friend who was studying."
➔ Interpretation of MS is semantically natural, while the other two are also possible.

Figure 3. Illustrations of 'Expel' Operations of Globally Ambiguous Sentences.

In sum, at this ‘earlier’ stage of judgment under time pressure, both semantic and prosodic bias have effect on interpreting sentence meaning, as does a strong structural bias which was not clearly identified at a ‘later’ stage of judgment without time pressure in Misono et al. (1997). Nevertheless, this study is not an on-line study which monitors the parsing decisions moment-by-moment during sentence processing. Effects of each type of bias and the interactions among them during sentence processing should be investigated in the future by implementing more on-line methods.

3.2. Experiment 2: Temporarily Ambiguous Sentences

In Experiment 1, we tested globally ambiguous sentences which have more than one possible interpretation at the end of the sentence, though semantic bias may suggest one interpretation over the other in the cases of embedded-clause bias and main-clause bias sentences. Temporarily ambiguous sentences, on the other hand, have only one interpretation by the end of the sentence; thus, investigating temporary ambiguity provides another test case of whether and how prosody may affect listeners’ final judgment when only one interpretation is possible. Finding effects of prosody in this environment would provide strong evidence for the recruitment of prosodic information during sentence comprehension.

3.2.1. Stimuli

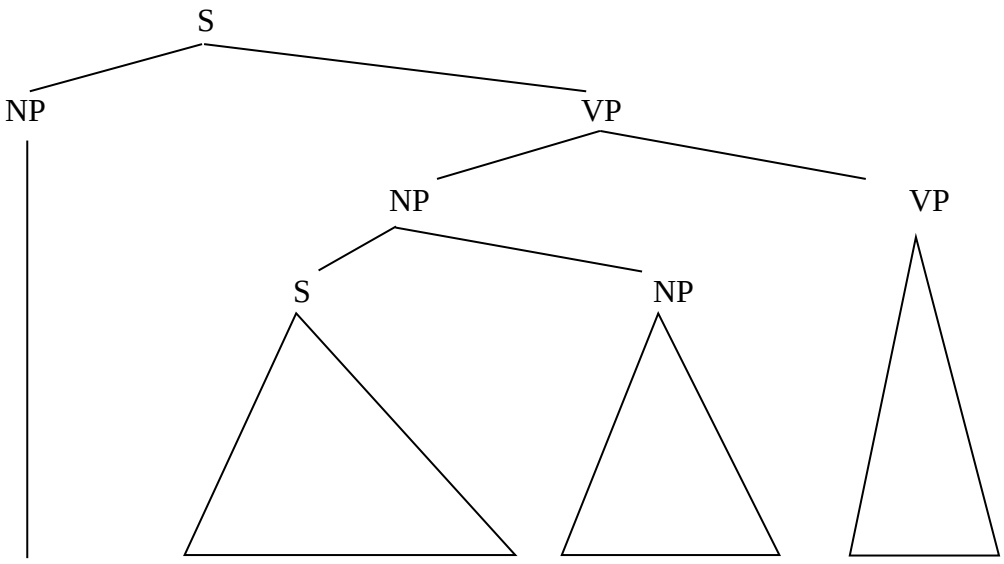
Eighty-four pairs of temporarily ambiguous sentences (embedded-clause structure sentences (ES) and main-clause structure sentences (MS)) were constructed to serve as target sentences for Experiment 2. Examples of sentences are shown in examples below and the structures are displayed in Figure 4.

(44) ES: Takasi-wa (#E) [tegami-o (#M) yondeiru atarasii sensee$_i$]-ni sotto esyakusita.
Takasi (name)-Top letter-Acc reading new teacher-Dat gently bowed
"Takashi gently bowed to the new teacher who was reading a letter."

(45) MS: Takasi$_i$-wa (#E) tegami$_j$-o (#M) [yondeiru atarasii kyookasyo]-ni sotto hasanda.
Takasi (name)-Top letter-Acc reading new textbook-Dat gently inserted
"Takashi gently inserted the letter into the new textbook that he was reading."

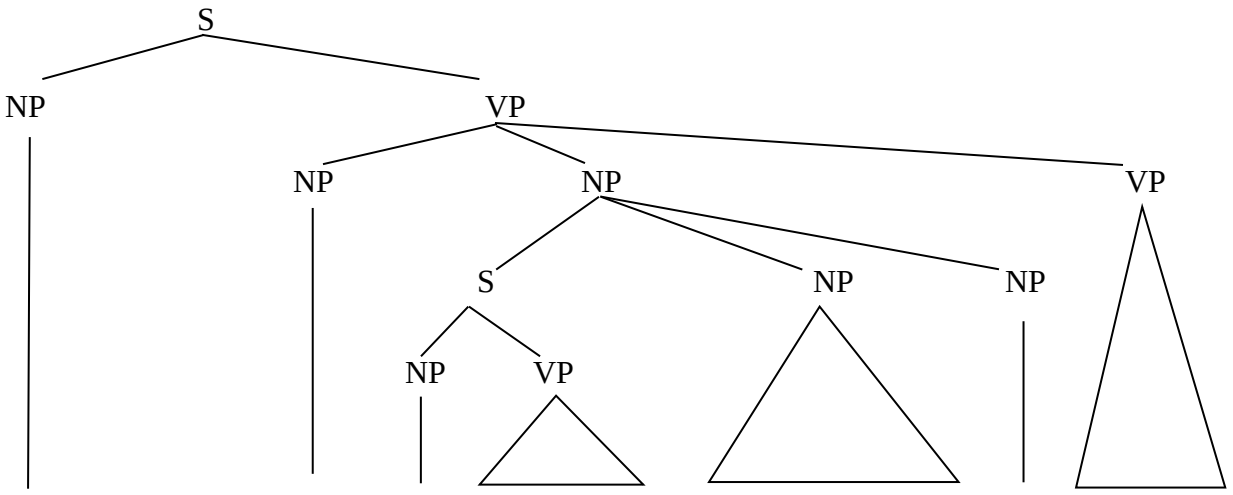
The same female native speaker of Japanese who recorded the globally ambiguous sentences for Experiment 1 read these sentences. She read each sentence with two different prosodies (embedded-clause prosody (EP): prosodic break at (#E); and main-clause prosody (MP): prosodic break at (#M)), which yielded 336 sentences. The embedded-clause-structure sentence is a typical Japanese sentence that has a relative clause, which only requires subject reanalysis. On the other hand, the main-clause-structure sentence requires both subject and object reanalyses, which is considered costly (Miyamoto 2008, Mazuka & Itoh, 1995). Moreover, its word order is scrambled; that is, NP-Acc is followed by NP-Dat, while NP-Dat is typically followed by NP-Acc in a canonical order sentence (Hoji, 1985; Saito, 1985). Therefore, it is predicted that readers will have a harder time interpreting MS without a prosodic cue supporting this structure, and this experiment aimed to assess whether prosody would guide the parser to even build the dispreferred syntactic structure as well as the default structure. To this end, we developed the following hypotheses on the processing of the auditorily-presented temporarily ambiguous sentences in Experiment 2.

[Embedded-clause interpretation]



Takasi-wa Ø$_j$ tegami-o yondeiru atarasii sensee$_i$-ni sotto esyakusita
Takasi-TOP letter-ACC reading new teacher-DAT gently bowed
"Takasi gently bowed to the new teacher who was reading a letter."

[Main-clause interpretation]



Takasi$_i$-wa tegami$_k$-o Ø$_i$ Ø$_j$ yondeiru atarasii kyookasyo$_j$-ni t$_k$ sotto hasanda
Takasi-TOP letter-Acc reading new textbook-DAT gently inserted
"Takasi gently inserted his letter into the new textbook that he was reading."

Figure 4. Syntactic structures of Temporarily Ambiguous Sentences.

First, concerning the effect of prosodic congruency, if prosody affects the parsing of temporarily ambiguous sentences, prosody-structure congruent conditions will be preferred over incongruent conditions. Second, regarding the effect of sentence structure, if prosody has a deterministic effect on parsing, there should be differences in sentence processing ease between prosody-structure congruent and incongruent conditions. Specifically, in congruent conditions, there will be no processing difference between sentences with the preferred structure (ES) and those with dis-preferred structure (MS), whereas in prosody-structure incongruent conditions, there will be processing differences between sentences with the preferred structure (ES) and those with dis-preferred structure (MS). On the other hand, if prosody does not have a deterministic effect on parsing, there will be processing differences between sentences with the preferred structure (ES) and those with dispreferred structure (MS) regardless of prosody-structure congruency.

3.2.1.1. Visual pretest of stimuli. An untimed visual pretest was conducted in order to test whether a preference toward embedded-clause structure compared to main-clause structure is evident. Twenty native speakers of Japanese (15 women; age: 19 years 4.7 months to 33 years 5.1 months, mean: 22 years 9.4 months) who are undergraduate students in Tokyo filled out a paper-pencil survey. The 84 pairs of temporarily ambiguous sentences were divided into two lists which contain the same number of ES and MS sentences. No sentences that were members of the same pair were on the same list. The sentences were randomized for each participant.

Participants were provided a 5-page packet that had instructions and short biographical questions on the first page, followed by 84 randomized temporarily ambiguous sentences. They filled out gender, date of birth and native language(s) for the biographic section. Then, they were asked to read each sentence and rate how good each sentence is, using a scale of 1 (very bad) to

5 (very good). There was no time limit for answering each question. Results are summarized in Table 5.

Table 5
Visual Pretest Results of Temporarily Ambiguous Sentence Acceptability Judgment

		Acceptability Judgment
Structural Bias	Embedded	3.96 (0.65)
	Main	2.21 (0.76)

a. Acceptability Judgment scores show the mean scores of 84 sentences (*1: very bad* to *5: very good*) across 24 participants.
b. Numbers in parentheses are standard deviations for 20 participants.

Paired t-test results showed that native speakers of Japanese rated embedded-clause sentences significantly higher than main-clause sentences ($t_1(19) = 7.21$, $p < .001$; $t_2(83) = 25.66$, $p < .001$). These results established that the stimuli have expected bias toward embedded-clause interpretation even when sufficient time is given to analyze each sentence.

3.2.1.2. Acoustic Analyses of Temporarily Ambiguous Sentences. Acoustic analyses of the stimuli were conducted to test whether acoustic features of the stimuli were properly controlled. The lengths of entire sentences, pause durations of critical prosodic breaks, and F_0 peaks of the first, second and third words were measured for the quadruplets of the temporarily ambiguous sentences. An example of the pitch contours of a quadruplet of sentences is shown in Figure 5, and the summary of the measurements is shown in Table 6.

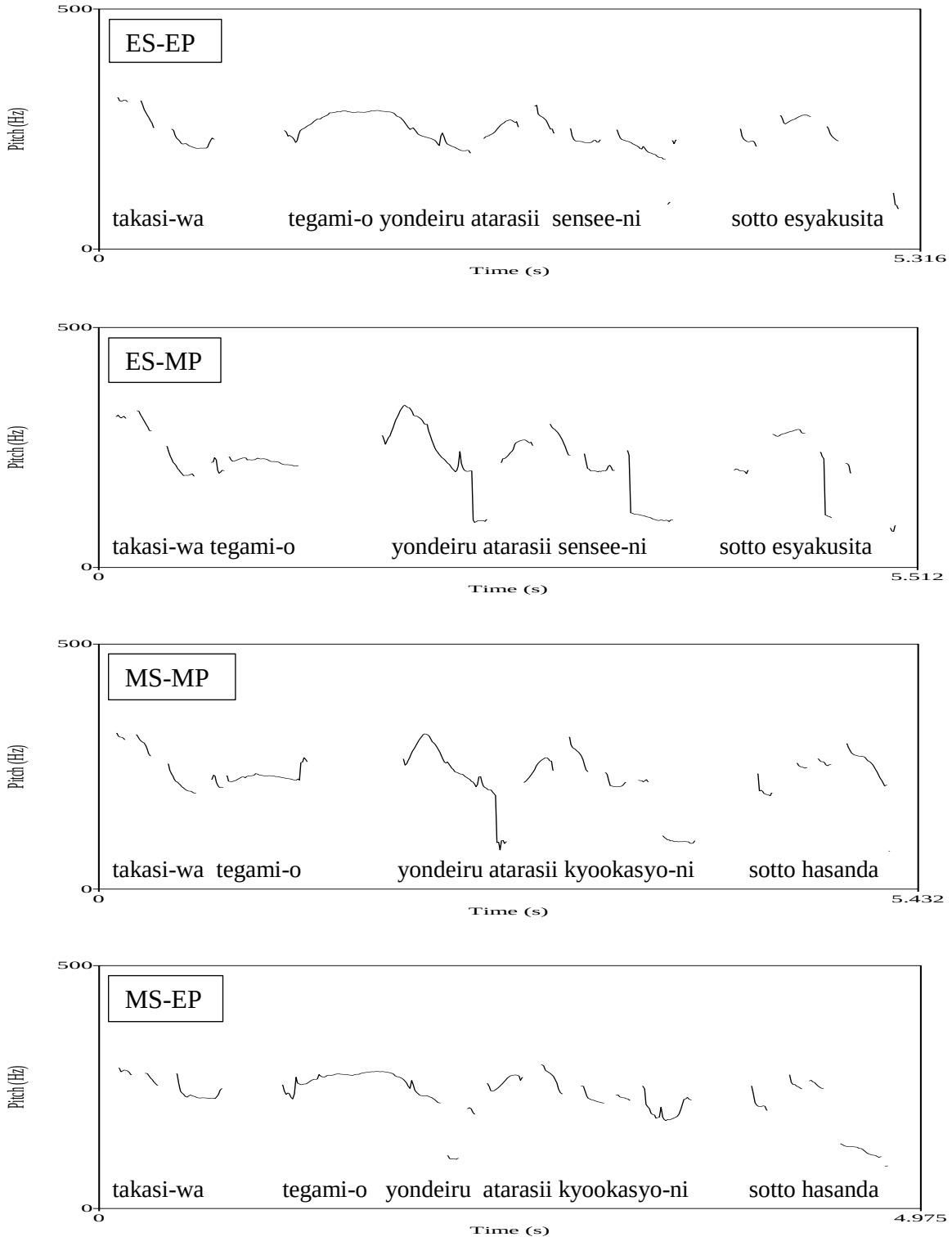


Figure 5. F_0 pattern of embedded-clause-structure sentences read with congruent and incongruent prosodies and main-clause-structure sentences read with congruent and incongruent prosodies.

Table 6
Summary of Total Duration, Pause Duration, and F_0 for the Temporarily Ambiguous Sentences

	Prosodic bias							
	Length (s)		Pause (s)		$F_0$2-$F_0$1 (Hz)		$F_0$3-$F_0$2 (Hz)	
Structure	Main	Embd	Main	Embd	Main	Embd	Main	Embd
Main	5.40	5.56	0.57	0.38	-39.40	0.27	30.51	-40.49
	(0.42)	(0.36)	(0.11)	(0.08)	(43.73)	(39.27)	(36.30)	(36.88)
Embd	5.62	5.33	0.57	0.37	-41.53	-2.44	26.53	-48.50
	(0.41)	(0.38)	(0.28)	(0.08)	(46.19)	(40.28)	(39.68)	(40.92)

a Numbers in parentheses are standard deviations for 84 sentences.
b Pauses for the sentences with main-prosody were measured after the second word, and those with embedded-prosody were measured after the first word.
c $F_0$1 was the peak F_0 for the first word that ended with the topic marker -*wa*, and $F_0$2 the peak F_0 for the second word that ended with the accusative marker -*o*.

The sentences read with EP have the prosodic break right after the first word, while the sentences read with main-clause prosody have the prosodic break right after the second word. The pauses in Table 6 were measured at these locations.

An ANOVA was conducted for phonetic differences between embedded-clause-structure and main-clause-structure sentence pairs. ANOVA on F_0 peak differences between the first and second words revealed that there was a main effect of prosody ($F(1,83) = 208.18$, $p < .001$), showing the pitch drop from the first to second word for the sentences read with MP is significantly bigger than embedded-clause prosody sentences' drop at the same position. Paired *t* tests also revealed that the pitch drop at the ES-MP (mean = -41.53) was bigger than ES-EP (mean = .27) ($t(83) = 13.47$, $p < .001$), and MS-MP (mean = -39.40) was bigger than MS-EP (mean = -2.44) ($t(83) = 10.79$, $p < .001$). These results suggest that there was a pitch reset after the first word in the sentences read with EP, while there was no reset for sentences read with MP.

Another ANOVA on F_0 peak differences between the second and third words revealed that there was a main effect of prosody ($F(1, 83) = 468.21$, $p < .001$), a main effect of sentence structure ($F(1, 83) = 10.05$, $p = .002$), but no interaction ($F(1, 83) = 1.22$, $p = .27$). The prosody effect shows that the pitch drop from the second to the third word for the sentences read with EP is significantly bigger (mean = -44.50 Hz) than those read with MP (mean = 28.52 Hz) at the same position. Paired *t* test results revealed that the pitch drop for the ES-EP (mean = -46.86) was bigger compared to ES-MP (mean = 26.52) ($t(83) = -18.77$, $p < .001$), and MS-EP (mean = -40.49) was bigger than MS-MP (mean = 30.50) ($t(83) = -19.35$, $p < .001$). In fact, the sentences read with MP had a higher peak for the third word compared to the second word, which suggests that there was a pitch reset after the second word in the sentences read with MP, while there was no reset for sentences read with EP. The pitch drop for ES-EP (mean = -46.86) was also bigger than MS-EP (mean = -40.49) ($t(83) = -3.65$, $p < .001$).

3.2.2. Experiment 2A: Auditory Acceptability Judgment Study

In Experiment 2A, the role of prosody on Japanese temporarily ambiguous sentence processing among native speakers was tested under time pressure employing an acceptability judgment task. In this section it was investigated how much prosody shifted the dispreference observed in the visual pretest.

3.2.2.1. Methods.

Participants. Twenty-four native speakers of Japanese who participated in Experiment 1A also completed this task.

Materials. The auditory stimuli were 84 quadruplets of temporarily ambiguous target sentences, 28 sextuplets of globally ambiguous sentences described in Experiment 1, and 28 sextuplets of ungrammatical sentences, of which the globally ambiguous and ungrammatical

sentences served as fillers. Recordings of the target and filler sentences were transferred digitally to a PC and they were divided into four equivalent lists; thus, each list consisted of 168 sentences. The example sentences are repeated here:

(46) ES: Takasi-wa (#E) [tegami-o (#M) yondeiru atarasii sensee$_i$]-ni sotto esyakusita.
Takasi (name)-Top letter-Acc reading new teacher-Dat gently bowed
"Takashi gently bowed to the new teacher who was reading a letter."

(47) MS: Takasi$_i$-wa (#E) tegami$_j$-o (#M) [yondeiru atarasii kyookasyo]-ni sotto hasanda.
Takasi (name)-Top letter-Acc reading new textbook-Dat gently inserted
"Takashi gently inserted the letter into the new textbook that he was reading."

A Latin Square Design was employed, in which the same sentences that have different prosodies were put in different lists, sentences were randomized within each block, and the blocks were presented in two different orders. These sentences in each list were further divided into four equivalent blocks. Orders of blocks were organized in eight different ways and they were counterbalanced.

Procedure. The procedure of Experiment 2A was the same as Experiment 1A.

3.2.2.2. Results. Judgment and RT results for Experiment 2A are shown in Table 7, and a full report of all statistical analyses is provided in Appendix C.

Table 7
Results of Acceptability Judgment Task for Temporarily Ambiguous Sentences

		Acceptability Judgment		**Mean Reaction Time (ms)**	
		Congruent Prosody	Incongruent Prosody	Congruent Prosody	Incongruent Prosody
Structural Bias	Embedded	4.36 (0.56)	3.39 (0.72)	1279 (286)	1412 (261)
	Main	3.01 (0.86)	1.83 (0.53)	1419.66 (256)	1470 (390)

a. Acceptability Judgment scores show the mean scores of 84 sentences (*1: very bad* to *5: very good*) across 24 participants.
b. Reaction Times are the mean RTs of 84 sentences across 24 participants.
c. Numbers in parentheses are standard deviations for 24 participants.

Two-way repeated-measures ANOVA were conducted on the acceptability judgment scores and RTs separately, with Sentence Structure (ES and MS) and Prosodic Congruency (Congruent and Incongruent) as within-subjects factors. Results of the acceptability judgment scores revealed that there were main effects of sentence structure and prosodic congruency, reflecting that embedded-clause-structure sentences were significantly rated higher than main-clause-structure sentences, and congruent conditions were also rated significantly higher than incongruent conditions. The reaction time ANOVA results also revealed the same tendency: main effects of sentence structure and prosodic congruency, reflecting a preference toward embedded-clause structure and congruent conditions. These results indicate that structural bias and prosodic congruency have effects on sentence comprehension of temporarily ambiguous sentences.

Paired comparisons were conducted to test (a) the effect of the sentence structure within the same prosodic congruency conditions, and (b) the effect of prosodic congruency within the same sentence structure conditions.

a. Effects of structure within the same prosodic congruency conditions

When the congruent conditions were compared, ES-EP yielded significantly higher scores (4.36) compared to MS-MP (3.01), and shorter RTs (ES-EP: 1279 ms vs. MS-MP: 1420 ms). When incongruent conditions were compared, ES-MP (3.39) was scored significantly higher than MS-EP (1.83), but no difference was found in the RTs (ES-MP: 1412 ms vs. MS-EP: 1470 ms). These results suggest that the ES structure is overall preferred over MS structure.

b. Effect of prosodic congruency within the same structure conditions

The paired *t*-test results between the sentences with congruent and incongruent prosodies within the same structure revealed that both embedded-clause and main-clause structures with the congruent prosody had significantly higher rating scores than those with incongruent prosody, both by-participants and by-items (ES-EP: 4.36 vs. ES-MP: 3.39). When we examine whether these effects were also evident in RTs, RTs for the ES-EP (1279 ms) were also significantly shorter than ES-MP (1412 ms) sentences both by participants and by items; however, RTs for the MS-MP (1420 ms) and MS-EP sentences (1470 ms) were not different. It was observed that RTs for MS sentences were overall the longest regardless of the prosody. Nevertheless, the results of judgments and RTs together suggest that prosody affects sentence processing for both sentence structures.

3.2.3. Experiment 2B: Auditory Comprehension Study

In Experiment 2B, the role of prosody on Japanese temporarily ambiguous sentence processing among native speakers was tested under time pressure employing a comprehension

task. It was tested whether prosody-structure congruency aided the comprehension of the sentence.

3.2.3.1. Methods.

Participants. Twenty-four native speakers of Japanese who participated in Experiment 1B also took part in this task.

Materials. Both target and filler stimuli were the same as those used in Experiment 2A.

Procedures. The procedure is exactly the same as Experiment 1B.

3.2.3.2. Results. Judgment and RT results for Experiment 2B are shown in Table 8, and a full report of all statistical analyses is provided in Appendix D. Two-way repeated-measures ANOVA were conducted on the accuracy rate of the comprehension questions and RTs with Sentence Structure (ES and MS) and Prosodic Congruency (Congruent and Incongruent). Results for the accuracy rate revealed that there was a main effect of sentence structure (ES > MS) and prosodic congruency (congruent > incongruent). There was also a significant interaction between structure and congruency, reflecting that incongruent prosody particularly lowered the sentence comprehension accuracy for the main-clause-structure sentences, compared to embedded-clause-structure sentences.

Table 8
Results of Comprehension Task for Temporarily Ambiguous Sentences

		Accuracy Rate		**Mean Reaction Time (ms)**	
		Congruent Prosody	Incongruent Prosody	Congruent Prosody	Incongruent Prosody
Structural Bias	Embedded	94% (5)	91% (11)	1455 (278)	1723 (441)
	Main	76% (12)	52% (10)	2068 (438)	2326 (552)

a. Accuracy Rates are the mean of 84 sentences across 24 participants.
b. Reaction Times are the mean RTs of 84 sentences across 24 participants.
c. Numbers in parentheses are standard deviations for 24 participants.

The reaction time results for this task also revealed that there were main effects of sentence structure and prosodic congruency, reflecting the shorter RTs for embedded-clause-structure sentences and congruent conditions.

Both accuracy rate and RT results indicate that the structural bias and prosody-structure congruency have strong effects on sentence comprehension. The interaction suggests the ease of arriving at the embedded-clause interpretation even when the prosody is incongruent with the structure, and the difficulty of arriving at the main-interpretation when difficult MS has an incongruent prosody. The longer RTs for the MS also support this tendency.

Paired comparisons were conducted to test (a) the effect of the sentence structure within the same prosodic congruency conditions, and (b) the effect of prosodic congruency within the same sentence structure conditions to further assess the effects of prosodic congruency and structural bias.

a. Effects of structure within the same prosodic congruency conditions

When different sentence structures were compared within the same prosodic congruency, there were significant differences both in the accuracy rate (ES-EP: 94% vs.MS-MP: 76%) and the RTs (ES-EP: 1455 ms vs. MS-MP: 2068 ms) in the congruent conditions. In the incongruent conditions, there were also significant differences in both the accuracy rate (ES-MP: 91% vs. MS-EP: 52 %) and the RTs (ES-MP: 1723 ms vs. MS-EP: 2326 ms). Similar to Experiment 2A, it was evident that embedded-clause structure was preferred over main-clause structure regardless of the prosodic congruency.

b. Effects of prosodic congruency within the same structure conditions

The comparison of the effect of prosodic congruency within the same sentence structures revealed that MS-MP accuracy rate (76%) was significantly higher than MS-EP (52%), and RT for the MS-MP (2068 ms) was also significantly shorter than its incongruent counterpart, MS-EP (2326 ms). On the other hand, the accuracy rate for ES-EP (94%) was not significantly higher than ES-MP (91%). It should be noted that ES sentences yielded high accuracy rates regardless of the prosodic congruency. Although the judgment data did not yield differences for ES conditions, RT did yield a difference: ES-EP (1455 ms) was significantly shorter than its incongruent counterpart ES-MP (1723 ms), indicating the smaller processing cost of the congruent condition. These particular ES condition comparisons, for which the RT data revealed differences among sentence types that were judged similarly, demonstrate the advantage of acquiring multiple measures to understand the nature of language processing.

3.2.4. Discussion

Experiment 2A showed that prosody-structure congruent conditions were preferred compared to incongruent conditions. There was also a strong preference toward ES compared to

MS, and the structural bias was evident even in the prosody-structure congruent conditions. These tendencies were evident in the acceptability judgment rating scores and much shorter RTs for the ES-EP condition compared to other conditions. Similarly, Experiment 2B results revealed a strong effect of prosodic congruency and strong bias toward embedded-clause interpretation suggested by higher comprehension question accuracy rates and faster RTs. Like Experiment 2A, even among congruent conditions, the accuracy rate of ES-EP was significantly higher than that of MS-MP, and RTs were shorter for ES-EP than for MS-MP. Furthermore, the accuracy rates of the ES congruent and incongruent conditions were high and did not differ, suggesting the ease of comprehending ES sentences, although RTs were shorter for the congruent condition.

Both Experiments 2A and 2B revealed a preference toward prosody-structure congruent conditions over incongruent conditions. However, a strong preference toward ES structure was also evident; that is, analyzing the NP-acc as a part of the embedded-clause is favored compared to analyzing it as a part of the main-clause, regardless of the prosodic congruency. These results revealed that prosody indeed modulates the processing of temporarily ambiguous sentences, which ultimately yield only one interpretation; however, prosody alone is not strong enough to cancel out the effect of structure as assessed by judgments under time pressure.

Kjelgaard and Speer (1999) showed that prosody can neutralize the effects of dispreferred structure in English, as congruent prosody removed the otherwise-apparent processing differences between early-closure and late-closure sentences. Their example sentences are repeated below:

(48) English Late Closure Sentence
[When Roger leaves the house] it's dark.

(49) English Early Closure Sentence
[When Roger leaves] the house is dark.

In contrast, the current study did not show a similarly strong effect of prosody on the parsing of the dispreferred (late opening) structure in Japanese, a head-final language. Our Experiment 2 example sentences are repeated below:

(50) Japanese Embedded-Clause-Structure Sentence

ta'kasi-wa	*[[Ø$_i$]*	*tegami-o*	*yo'ndeiru*	*atarasi'i*	*sense'e$_i$-ni]*	*sotto*	*e'syakusita.*
NP1-Top		NP2-Acc	PRED.1		NP3-Dat		PRED.2
Takasi (name)		letter	reading	new	teacher	gently	bowed

"Takasi gently bowed to the new teacher who was reading a letter."

(51) Japanese Main-Clause-Structure Sentences

ta'kasi$_i$-wa	*tegami-o*	*[[Ø$_i$ Ø$_j$]*	*yo'ndeiru*	*atarasi'i*	*kyooka'syo$_j$-ni]*	*sotto*	*hasa'nda.*
NP1-Top	NP2-Acc		PRED.1		NP3-Dat		PRED.2
Takasi	letter		reading	new	textbook	gently	inserted

"Takasi gently inserted a letter into the textbook that (he was) reading."

However, we have to consider carefully the differences between their stimulus design and ours. We have drawn parallels among early closure (dispreferred)/late closure (preferred), and early opening (preferred)/late opening (dispreferred) structures, but there also seem to be quite a few differences among the English and Japanese constructions.

First, the Japanese sentence pair (50-51), in contrast with the English sentence pair (48-49), is syntactically more complex due to the empty category insertions that Japanese sentences involve. Moreover, within the Japanese sentence pair, (51) is more complex and harder to parse

than (50) because of the scrambling and an extra '*expel*' operation (i.e., phrases that are initially treated as a clause are pushed out of the clause) with an extra empty category insertion.

Second, the reanalyses in English closure ambiguity and Japanese opening ambiguity involve different operations (see Figure 6). The difficulty in English early closure sentences compared to late closure is due to the '*steal*' operation (i.e., a phrase that is initially assigned as the object of the verb of the subordinate clause is 'stolen' to be the subject of the main clause) (Fodor & Inoue, 1994; Inoue & Fodor, 1995). On the other hand, the difference between early opening and late opening in our study is the number of phrases to be 'expelled' (see theoretical models and frameworks in Inoue & Fodor, 1995; Fodor & Inoue, 1998; Frazier, 1990, 1995; and Miyamoto, 2003). To illustrate, for the English sentences, *the house* would be initially analyzed as the direct object. When it is followed by *it's*, there is no problem for the parser (late closure); however, when it is followed by *is*, this verb needs to have its subject, which causes the parser to find what is initially treated as an argument of the first clause. As a consequence, *the house* would be 'stolen'. On the other hand, the difference in Japanese sentences is that while embedded-clause-structure sentences require only one NP 'expel', main-clause-structure sentences require two NPs to be 'expelled'; thus, no 'steal' operation is involved.

Steal Operation: English Early Closure Sentence

When Roger leaves the house is dark.

Initial analysis:
[When Roger leaves the house]…

Steal Operation:

[When Roger leaves] the house is dark

Expel Operation: Japanese Embedded- and Main- clause-structure Sentence (ES & MS)

ES: Takasi-wa tegami-o yondeiru atarasii sensee$_i$-ni sotto esyakusita.
Takasi-Top letter-Acc reading new teacher-Dat gently bowed
"Takashi gently bowed to the new teacher who was reading a letter."

MS: Takasi$_i$-wa tegami$_j$-o yondeiru atarasii kyookasyo-ni sotto hasanda.
Takasi-Top letter-Acc reading new textbook-Dat gently inserted
"Takashi gently inserted the letter into the new textbook that he was reading."

Initial analysis:

- ES: [Takasi-wa tegami-o yondeiru]…
  "Takasi is reading a letter."
- MS: [Takasi-wa tegami-o yondeiru]…
  "Takasi is reading a letter."

(i) Expel operation 1 to get to Embedded-clause interpretation (preferred operation):

Takasi-wa [tegami-o yondeiru atarasii sensee]-ni…
*kyookasyo

ES: "Takasi (did something to) the new teacher who was reading a letter."
MS: "Takasi (did something to) the new textbook that was reading a letter." → ✘

(ii) Expel operation to get to Main-clause interpretation (dispreferred operation):

Takasi-wa tegami-o [yondeiru atarasii *sensee]-ni…
kyookasyo

ES: "*Takasi (did something with) the letter to the teacher that he was reading." → ✘
MS: "Takasi (did something with) the letter to the textbook that he was reading."

Figure 6. Illustrations of 'Steal' and 'Expel' Operations.

In sum, the results have shown that prosody-structure congruency modulates the comprehension of auditory sentences, especially when the structure is not a default type. Although prosody does not yield a decisive effect on judgments even under time pressure in Japanese, the results provide evidence for the utilization of prosody in the parsing of the head-final language Japanese, as revealed by the examination of ambiguity resolution. The fact that prosody affected processing despite other information actually disambiguating the sentence before it was concluded provides strong evidence that prosodic information affects sentence comprehension. These findings motivate future research investigating at what point prosody begins to affect sentence processing and how it interacts with other information sources in the sentence during incremental sentence processing.

3.3. General Discussion

We have examined the effect of prosody in Japanese sentence processing utilizing both acceptability and comprehension tasks with time pressure, employing two types of ambiguous sentences: globally and temporarily ambiguous sentences. As for the globally ambiguous sentences, we tested to what extent prosody and semantic bias would affect sentences that can otherwise have two interpretations even at the end of the sentence. Then, we investigated the role of prosody in the parsing of temporarily ambiguous sentences to examine whether effects of prosody would be evident in the processing of a sentence for which other information sources ultimately disambiguate the sentence, yielding only one interpretation by the end of the sentence, a particularly strong test case for demonstrating prosodic effects in sentence comprehension.

The results were broadly consistent across the tasks and ambiguity types, showing that (1) congruent prosody was preferred over incongruent prosody, especially for dispreferred structures, and (2) embedded-clause-structure sentences were preferred compared to main-

clause-structure sentences regardless of prosody when judged under time pressure. The fact that neutral semantic-bias sentences used in the global ambiguity experiment (Experiment 1) tended to be processed as embedded rather than main-clause bias sentences further underscores this second point. Thus, we can conclude that prosody indeed affects Japanese sentence processing, but it does not have a deterministic effect on parsing; in our experiments, structural biases most strongly guided parsing decisions regardless of prosodic congruency in judgments under time pressure.

As we have mentioned earlier, our stimuli for both experiments are Japanese sentences that require an 'expel' operation. From the results of Experiment 1, it can be inferred that even when the number of dropped pronouns and insertions of empty categories are the same, the number of 'expelled' phrases contributes to parsing difficulty: the fewer operations, the easier the parse. While prosody influences the parsing of these structures, it does not have a deterministic effect for these sentences under time pressure. Misono et al. (1997) suspected that the prosodic effect has decayed in their off-line experiment; however, our timed study did not reveal a particularly strong effect of prosody either. The two sentence structures in Experiment 2 are also different from each other in the numbers of 'expelled' items as well as structural complexity (i.e., word order and the number of dropped pronouns and empty category insertion). The results showed a strong structural preference toward embedded-clause-structure sentences, and again the prosodic congruency did not have a deterministic effect on deciding interpretations; that is, congruent prosody did not cancel out the structural preference. Nevertheless, it was also found that prosody did modulate the interpretation of the sentences, an effect that was most evident in the difficult main-clause-structure sentences.

In this study, both an acceptability judgment test and a comprehension test were conducted, and participants' judgments of the sentences as well as RTs were collected. Overall, the results of each experiment arrived at similar conclusions; however, the combination of judgment and RT data provided a fuller picture of the role of prosody than could have been gained by relying on only one of these measures. Recall that in Experiment 1A, no rating score difference was found between neutral sentences read with two different prosodies. One could have concluded that neutral sentences had been equally easily resolved with each of the two different interpretations; RTs, however, revealed that the neutral sentences read with main-clause prosody engendered significantly longer response times than those with embedded-clause prosody. These results, together with the interpretation results in Experiment 1B, made clear the existence of a structural bias toward embedded-clause interpretation. Furthermore, Experiment 2B showed that there were no differences in comprehension accuracy rate among embedded-clause-structure sentences with embedded or main prosodies. This could have led us to the conclusion that embedded-clause-structure sentences were so easy to parse that prosodic congruency would not matter. It was the RT differences between these two conditions that indicated that prosodic congruency matters even for the easy embedded-clause-structure sentences. Together with the results of Experiment 2A, these findings provided a fuller picture of the scope of prosodic congruency effects. These findings underscore the methodological benefit of employing a cross-method approach, toward gaining a more complete picture of the effects of prosody in sentence processing. This calls for further research regarding how prosodic information is utilized *during* sentence processing in Japanese. Thus, in the next chapter, we turn to the investigation of on-line processing of Japanese sentences utilizing a brain-imaging method, EEG.

3.4. Summary

Effects of prosody among native speakers in parsing of ambiguous sentences in Japanese, a head-final language, employing a cross-method approach were examined using two ambiguity test cases: global ambiguity and temporary ambiguity. While prosody did not have a deterministic effect on the parsing of globally ambiguous or temporarily ambiguous sentences as measured by judgments under time pressure, prosody did robustly modulate both judgments and the response times associated with these judgments. Moreover, a strong effect of structural bias was particularly evident in these judgments made under time pressure, which was not evident in Misono et al.'s (1997) untimed study. Further research needs to look into the effect of prosody *during* sentence processing of Japanese.

Chapter 4

ERP Investigation of L1 and L2 Japanese Listeners' Auditory Sentence Processing

The psycholinguistic studies (Experiments 1 and 2) on native speakers described in the previous chapter suggested that prosody plays a role in the judgment of Japanese sentences. Also, the effect of structural preference was evident with time pressure, but not reported in a previous study without time pressure (Misono et al., 1997). Although it is typically believed that the judgment data are the reflection of processing, it is not clear at what point of the sentence processing these effects emerge and how strong they are. In this chapter, a neurolinguistic study (Experiment 3) is reported, in which an on-line brain-imaging tool, EEG, is employed to measure moment-by-moment brain responses to auditory Japanese sentences in native speakers and L2 learners. Data obtained using EEG will reveal when and how prosody is detected and utilized in auditory sentence processing in native speakers and adult learners of Japanese.

4.1. Methods

4.1.1. Participants. The Japanese native speakers (n = 18)[11] that were recruited were born and grew up as monolingual speakers of Japanese in Japan and were, at the time of the experiment, studying at the University of Kansas or living in Lawrence, Kansas and the Greater Kansas City area. Eight of the participants were female, and their ages were 19 to 32 (mean: 22 years 8.5 months). Intermediate to advanced-level Japanese learners (n = 18)[12] were also recruited in the second-, third- and fourth-year Japanese classes and through word-of-mouth in

[11] Nine additional native speakers were also recruited but excluded from the analysis due to excessive artifact.

[12] Four additional L2 learners were also recruited but excluded from the analysis due to excessive artifact.

Lawrence, Kansas and the Greater Kansas City area. Ten of the L2 participants were female. The L2 participant ages ranged from 18 to 32 (mean: 24 years 4.4 months). As each learner was recruited, a vocabulary list that contains all the critical verbs used in the experiment was distributed to the potential non-Japanese-speaking participants, and they were asked to study the words on the vocabulary list. All participants had normal hearing and had no reading or learning disabilities, and all participants but one L2 learner (ambidextrous) were right-handed according to the Edinburgh Handedness Inventory (Oldfield, 1971). The participants read and understood the informed consent form which has been approved by The Human Subject Committee in Lawrence (HSCL) of the University of Kansas.

A preliminary session was held for non-native speakers of Japanese in order to assess their listening proficiency level and their language background, as well as to test their vocabulary knowledge of the critical verbs. Non-Japanese participants who were taking third- and fourth-level-Japanese at the University of Kansas received extra credit from Japanese instructors for their participation in this preliminary session, and were paid 5 dollars per 30 minutes for the main session in which EEG experiment was held. Other participants were paid five dollars per 30-minute session for their participation upon their completion of the whole experiment.

Survey. A survey was administered to all participants. The survey solicited demographic data with respect to gender, age, nationality, place of birth, general and language education background, and daily language usage.

Language testing. The vocabulary test on the verb list given at the recruitment was developed using the experiment control software *Paradigm*, and was given to ensure that the non-native Japanese speaking participants were familiar with the critical verbs used in the experiment. They heard each verb and were asked to choose the correct meaning for each word

among three choices presented on the computer screen. Those who achieved an accuracy level of 90 percent or higher participated in the EEG experiment. Then, the participants were given the listening portion of Japanese Language Proficiency Test (JLPT) to determine their listening proficiency level. Their scores ranged from 33% to 100%, and the average was 77%.

4.1.2. Stimuli. Eighty-four pairs of temporarily ambiguous sentences, as described in Chapter 3, served as target sentences. Acoustic analyses of the target sentences are summarized in Table 6 in the previous chapter. The examples are repeated here:

(52) ES: Takasi-wa (#E) [tegami-o (#M) yondeiru atarasii sensee$_i$]-ni sotto esyakusita.
Takasi (name)-Top letter-Acc reading new teacher-Dat gently bowed
"Takashi gently bowed to the new teacher who was reading a letter."

(53) MS: Takasi$_i$-wa (#E) tegami$_j$-o (#M) [yondeiru atarasii kyookasyo]-ni sotto hasanda.
Takasi (name)-Top letter-Acc reading new textbook-Dat gently inserted
"Takashi gently inserted the letter into the new textbook that he was reading."

The (#) indicates a prosodic break, and either (#E) or (#M) was used for each sentence. Embedded-clause prosody (#E) was a congruent prosody for Embedded-clause structure, and (#M) was Main-clause prosody, which was a congruent prosody for Main-clause structure. This made 336 target sentences. 168 globally ambiguous sentences and 168 ungrammatical sentences whose prosodies were also manipulated in two ways served as fillers. These sentences were divided into two equivalent lists employing a Latin Square Design, and each list was further divided into eight equivalent blocks. The order of the blocks was arranged in eight ways, and the stimuli within a block were set to present in a random order each time.

4.1.3. Procedure. The EEG signals were recorded continuously as the participant engaged in the acceptability judgment task described in the previous chapter. They were seated

in a dark room in front of a computer screen wearing non-metal earphones compatible with EEG (Etymotic ER-3A Insert Earphones). In each trial, participants were asked to close their eyes when a cross was presented at the center of the computer screen. About two seconds after the cross was presented, an auditory sentence was presented for 3.2 to 5.9 seconds (mean: 5.48 sec.) through the earphones, using a Sound Blaster Audigy 2 ZS Internal Sound Card (Creative Technology, Ltd.) at a comfortable level of volume. As soon as the sentence was finished, the center cross was replaced by a rating scale, and the participants rated how acceptable each sentence was by clicking the number on the rating scale (1: very bad to 5: very good) presented on the computer screen. Participants were asked to blink their eyes between the trials and to try not to move their eyes while they were closed during the auditory stimuli presentation.

Participants were encouraged to take a short break between blocks. Total participant time for one lab visit was approximately three hours including EEG setup (~30~60 minutes). This procedure was approved by the Institutional Review Board at the University of Kansas.

4.1.4. EEG Recording. A Neuroscan Synamps2 EEG system (Compumedics Neuroscan, Inc.) was used to record participants' brain activity continuously during the auditory sentence processing task. Participants were fitted with an electrode cap (Electro-Cap International, Inc.), containing 29 sintered Ag/AgCl scalp electrodes arrayed in a modified 10-20 layout (midline: FPZ, FZ, FCZ, CZ, CPZ, PZ, OZ; lateral: F7/8, F3/4, FT7/8, FC3/4, T3/4,C3/4, TP7/8, CP3/4, T5/6, P3/4, O1/2). Six additional electrodes were placed on the left and right outer canthus, and above and below each eye, to monitor eye-blinks and eye-movements, and a reference electrode was placed on the left mastoid, respectively. One of the mastoid electrodes was the online reference and the other was recorded as a regular active electrode. Electrode AFZ served as

ground. Impedances for each electrode were kept below 5 kΩ. The recordings were amplified with a bandpass of 0.01 to 100 Hz and digitized at a sampling rate of 1kHz.

4.1.5. EEG Variables. EEG components that are expected to be found are CPS, N400, and P600 (see Chapter 1 *Definitions of Variables* for more explanation). CPS is known to be elicited when a prosodic boundary is detected; thus the presence of CPS is tested at each prosodic boundary. N400 is known to be sensitive to the semantic anomaly; thus, encountering an inanimate word when an animate word is expected, or vice versa, is expected to elicit N400. P600 is known to be elicited when there is a reanalysis of a sentence structure. Thus, the elicitation of N400 and P600 are tested at the disambiguating word. In this study, it is tested whether L1 and L2 listeners detect prosodic boundaries, and how prosody can change the L1 and L2 listener's expectation of the sentence structure by monitoring the modulation of these ERPs.

4.1.6. Data Analysis. Behavioral data (ratings and response times) were analyzed using three-way mixed ANOVA with Sentence Structure (ES and MS) and Prosodic Congruency (Congruent and Incongruent) as within-subjects factors and Group (L1 and L2) as a between-subjects factor. Specifically, the participants' ratings and RTs of each sentence heard were analyzed. Follow-up paired *t*-tests were conducted within the same groups (Japanese L1 Listeners and L2 learners) to analyze whether the prosody gives at least some effect, and if so, whether the effect is strong enough to neutralize the structural bias. Congruent conditions and incongruent conditions were compared within the same structures (ES-MP vs. ES-EP; MS-EP vs. MS-MP) to test the former case, and the congruent conditions (MS-MP vs. ES-EP) were compared to test the latter case.

ERP data were analyzed as follows. The raw data were re-referenced offline to average of both mastoids, epochs were made with a time window starting at -1000 ms to 3000 ms time

locked at the offset of the first word (onset of pause for EP conditions), offset of the second word (onset of pause for MS conditions), and the onset of the disambiguating fifth word. Then, non-ocular artifacts were manually rejected, followed by the application of ICA decomposition (Makeig, Bell, Jung, & Sejnowski, 1995) in order to remove ocular artifacts, implemented in *EEGLAB* (Delorme & Makeig, 2004), and the remaining artifacts were manually rejected. Then, baseline-correction, 30 Hz Low-pass Filter and averaging were performed. ERPs were quantified via mean amplitudes and latencies by time window, relative to a 200-ms pre-stimulus baseline interval. The time windows were chosen based on the visual inspection of the waveforms. When the visual inspection did not clearly suggest particular time windows, 7 subsequent 200 ms time windows from 200 ms after the time locking point until 1600 ms were individually analyzed.

ERPs were compared separately for midline electrodes and four lateral regions of interest (ROIs). Midline electrodes included FZ, FCZ, CZ, CPZ, and PZ. As for the lateral regions, left anterior electrodes included F3, FC3, and FT7; left posterior electrodes included P3, TP3, and CP7; right anterior electrodes included F4, FC4, and FT8, and right posterior electrodes included P4, TP4, and CP8.

For the lateral electrodes, the following four factors were analyzed using ANOVA: structure (ES and MS) × prosody/prosodic congruency (EP and MP for CPS; Congruent and Incongruent for the effects at the disambiguating word) × anteriority (anterior and posterior) × laterality (left and right) for each group. For the midline, three-way repeated measures ANOVA were conducted across structure (ES and MS) × prosody/prosodic congruency (EP and MP for CPS; Congruent and Incongruent for the effects at the disambiguating word) × anteriority (FZ, FCZ, CZ, CPZ and PZ) for each group of participants. Follow-up comparisons will be done if the global ANOVA reveals a significant main effect or an interaction with the factor condition.

4.1.7. Predictions. To this end, the following predictions were made in terms of the detection and utilization of prosody:

1. CPS is an ERP that is elicited upon the detection of prosodic boundary. Thus, if prosodic boundary is immediately detected in the brain, there will be a CPS at every prosodic break (e.g., Bögels et al., 2010; Steinhauer et al., 1999; Wolff et al., 2008).
2. If prosodic boundary guides the listener to build a syntactic structure, incongruent prosody will generate an incorrect prediction regarding what the learner will hear at the disambiguating word. Thus, there will be an N400-P600 effect (surprise for the unexpected word followed by structural revision) for the incongruent conditions at the disambiguating word (e.g., Steinhauer et al., 1999). Behaviorally, prosody-structure congruent conditions will be preferred over incongruent conditions (e.g., Kjelgaard & Speer, 1999; also see Chapter 3 of this dissertation).
3. If prosody has an immediate strong enough effect to neutralize the structural bias, the preference toward embedded-clause structure will disappear when prosody is congruent. Thus, there will be an N400-P600 effect for MS, only in the incongruent condition. On the other hand, if prosody does not neutralize structural effects, MS will be dispreferred either way, showing N400-P600 effects for both congruent and incongruent conditions (e.g., Steinhauer et al., 1999). Behaviorally, ES-structure will be preferred, only in the comparison of incongruent conditions for the former case, and in both conditions for the latter case (e.g., Kjelgaard & Speer, 1999; also see Chapter3 of this dissertation).

4.2. Results

4.2.1. Behavioral Results. Judgment and RT results for Experiment 3 are shown in Table 9, and a full report of all statistical analyses is summarized in Appendix E.

Table 9
Behavioral Results of Native Speakers (L1) and L2 Learners

		L1 Acceptability Judgment		**L1 Reaction Time (ms)**	
		Congruent Prosody	Incongruent Prosody	Congruent Prosody	Incongruent Prosody
Structural Bias	Embedded	4.16 (0.49)	3.51 (0.63)	1494 (240)	1562 (248)
	Main	2.74 (0.47)	1.83 (0.43)	1691 (278)	1655 (278)
		L2 Acceptability Judgment		**L2 Reaction Time (ms)**	
		Congruent Prosody	Incongruent Prosody	Congruent Prosody	Incongruent Prosody
Structural Bias	Embedded	3.28 (0.54)	3.08 (0.35)	2189 (258)	2217 (267)
	Main	2.91 (0.31)	2.86 (0.27)	2275 (349)	2269 (283)

a. Acceptability Judgment scores show the mean scores of 84 sentences (*1: very bad* to *5: very good*) across 18 participants for each group.
b. Reaction Times are the mean RTs of 84 sentences across 18 participants for each group.
c. Numbers in parentheses are standard deviations for 18 participants for each group.

A three-way mixed ANOVA was conducted on the acceptability rating data and RTs separately, with Sentence Structures (ES and MS) and Prosody (EP and MP) as within-subjects factors and Group (L1 and L2) as a between-subjects factor. The accuracy rate results revealed there was no main effect of group. There was a significant main effect of structure, reflecting

that embedded-clause is preferred over main-clause structure, and a significant main effect of prosodic congruency, suggesting that the congruent prosody is preferred over incongruent prosody. Also, there was a significant interaction between group and structure, reflecting that the preference difference between the embedded-clause structure and main-clause structure for native speakers is greater than that of L2 learners; and there was a significant interaction between group and prosodic congruency, reflecting that the preference difference between the congruent and incongruent conditions for native speakers is greater than that of L2 learners. The interaction among group, structure and prosodic congruency was also significant, $F(1, 34) = 6.50$, $p = .016$, reflecting that the use of prosody for the two structures is not the same for native speakers and L2 learners.

As for the reaction times (RTs), there was a main effect of groups, reflecting that the L2 learners took a significantly longer time to respond compared to native speakers. There was also a significant main effect of structure, reflecting shorter RTs for embedded-clause structure compared to main-clause structure. However, the effect of prosodic congruency was not significant in RTs. There was a significant interaction between group and structure, reflecting that the difference between embedded-clause structure and main-clause structure is greater for L1 compared to L2. There was also an interaction between structure and prosodic congruency, reflecting that embedded-clause structure was responded to more quickly than main-clause structure in the comparison of congruent conditions than in the comparison of incongruent conditions.

Follow-up *t*-tests were conducted within the groups to test the effect of structure and prosody respectively. The native speakers' group showed that the condition with congruent prosody was rated higher for both structures (ES and MS); and they responded faster only for the

embedded-clause structure comparison. Also, the embedded-clause structure was rated higher for the comparisons of both congruent conditions and incongruent conditions; and they responded faster regardless of the prosody for both comparisons. L2 learners' results revealed that the condition with congruent prosody was rated higher than incongruent prosody only in the comparison of embedded-clause conditions, and the embedded-clause condition was rated higher regardless of prosodic congruency. RT results only indicated a significant difference in the comparison of congruent conditions.

Overall, both native speakers' and L2 learners' results suggested that the congruent conditions were preferred compared to incongruent conditions, and the embedded-clause condition was preferred over the main-clause condition. It was also found that L2 learners took a longer time to respond to the stimuli though their responses were quite similar to those of the native speakers. One remarkable difference may be that while the native speakers rated the congruent condition higher than the incongruent condition for main-clause structure sentences, L2 learners did not show differences. This may indicate that L2 learners have difficulty analyzing 'difficult' main-clause-structure sentences, and they may not be able to use prosodic information for the analysis of this type of sentence.

4.2.2. ERP Results.

4.2.2.1. Detection of prosodic boundary. In order to test whether native speakers and L2 learners of Japanese detect the prosodic boundary immediately, the presence of CPS was tested by calculating ERPs time-locked at the offset of the first word and second word. The visual inspection of the waveforms suggested that a CPS response emerged in the time window of 200-800 ms; thus, the statistical analyses were done for that time window. Two separate ANOVA were performed for lateral regions and midline electrodes. A full report of all statistical analyses

for the first prosodic boundary is summarized in Appendix F, and those for the second prosodic boundary in Appendix G.

Figure 7 shows waveforms at the first prosodic boundary, plotted at a selection of representative electrodes, for both native speakers and L2 learners. The native speakers' ANOVA results for lateral regions revealed a significant main effect of prosody, reflecting that the waveforms for embedded-clause prosody were more positive. A main effect of anteriority reflected the positivity in anterior regions. There was a significant interaction between prosody and anteriority, reflecting that anterior positivity was much stronger for conditions read with embedded-clause prosody.

A separate ANOVA was conducted for midline electrodes. There was a significant main effect of prosody, reflecting a positivity for the conditions with embedded-clause prosody. There was also a main effect of anteriority, reflecting an anterior positivity. There was a significant interaction between prosody and anteriority, which reflects the degree of anterior positivity is greater for the conditions with embedded-clause prosody. Thus, CPS was confirmed by statistical analysis for conditions with embedded-clause prosody at the first prosodic break in the broad anterior region.

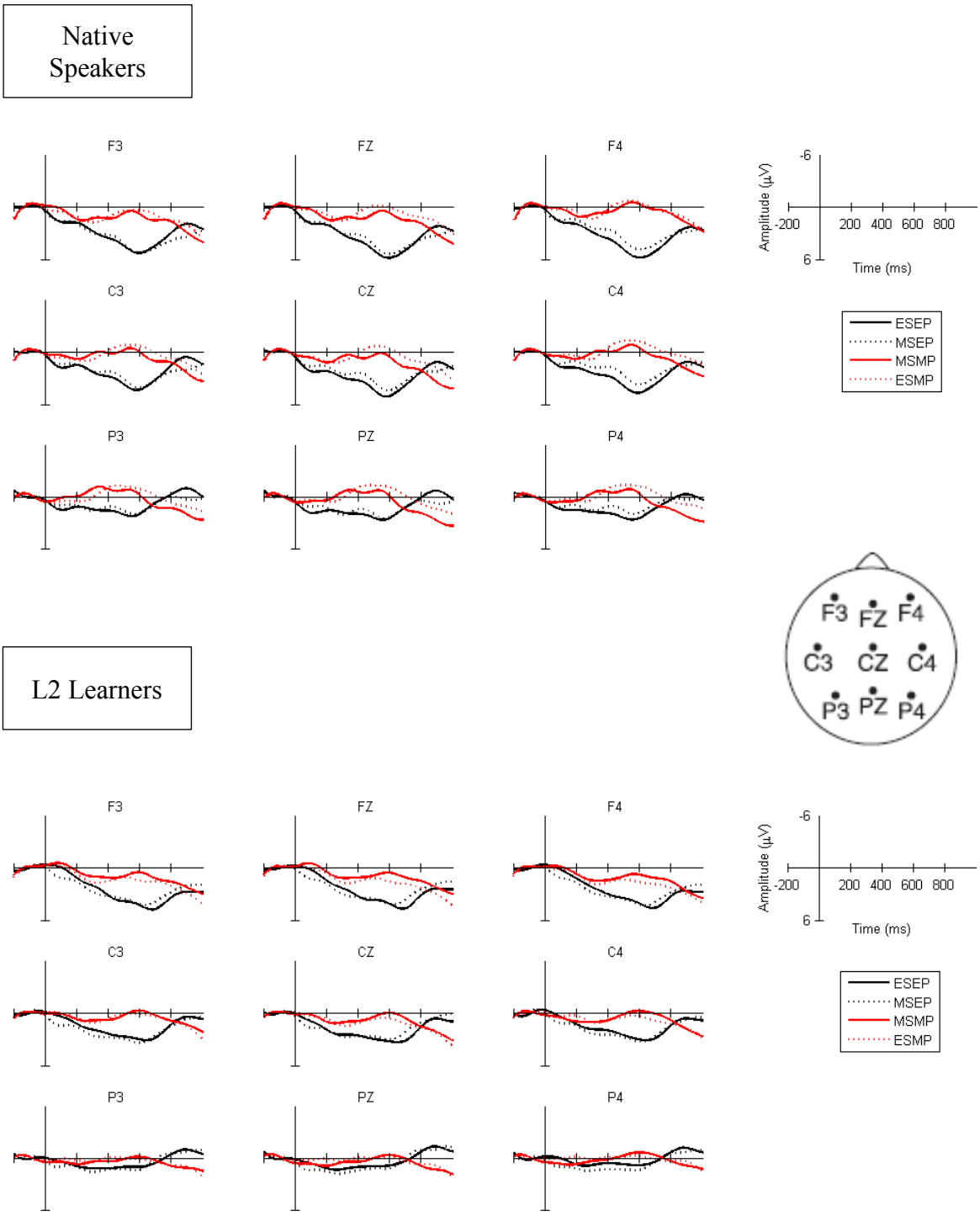


Figure 7. CPS effects at the first prosodic boundary. The data were filtered using a 5Hz low-pass-filter for plotting purposes only. Black lines represent embedded-clause prosody, and red lines represent main-clause prosody.

L2 learners showed the same pattern of effects at the first prosodic boundary. An ANOVA for the lateral electrodes revealed that there was a significant main effect of prosody, reflecting that the waveforms for embedded-clause prosody were more positive, and a main effect of anteriority, reflecting a positivity in the anterior region. There was also an interaction between prosody and anteriority, reflecting a greater positivity for the conditions with embedded-clause prosody.

An ANOVA for midline electrodes revealed that there was a significant main effect of prosody, reflecting that the waveforms for embedded-clause prosody were more positive. There was also a main effect of anteriority, suggesting that the anterior electrodes were more positive. There was a significant interaction between prosody and anteriority, reflecting that the degree of positivity in the anterior region is much stronger for the conditions with embedded-clause prosody. Therefore, the L2 learners also yielded CPS for the conditions with embedded-clause prosody in broad anterior regions.

The same analyses were performed for the second prosodic boundary. Figure 8 shows waveforms at the second prosodic boundary, plotted at a selection of representative electrodes for both native speakers and L2 learners. As for the native speakers, an ANOVA for the lateral electrodes revealed that there was a significant main effect of prosody, reflecting that the conditions with main-clause prosody were more positive. There was also a main effect of anteriority, reflecting that the anterior regions were more positive. There was an interaction between prosody and anteriority, reflecting that anterior positivity was only observed for the waveforms for main-clause prosody.

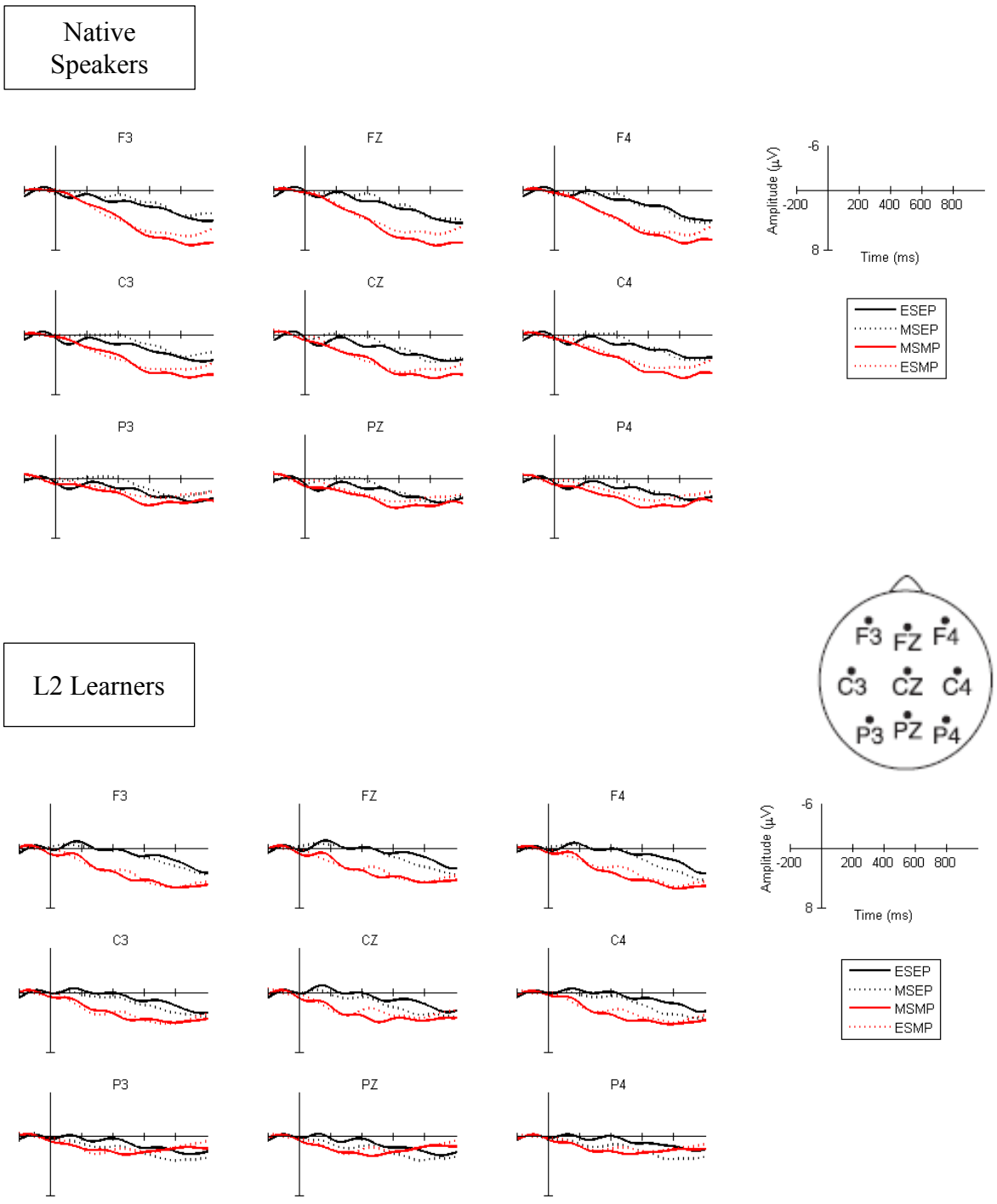


Figure 8. CPS effect at the second prosodic boundary. The data were filtered using a 5Hz low-pass-filter for plotting purposes only. Black lines represent embedded-clause prosody, and red lines represent main-clause prosody.

Another ANOVA was performed for midline electrodes. There was a significant main effect of prosody, reflecting that the waveforms for main-clause prosody were more positive than those for embedded-clause prosody; and a main effect of anteriority, reflecting that the anterior electrodes were more positive. There was also an interaction between prosody and anteriority, reflecting that anterior positivity was significantly greater for the conditions with main-clause prosody.

As for L2 learners, an ANOVA for the lateral regions revealed a main effect of prosody, reflecting that the conditions with main-clause prosody are more positive; there is also an interaction between prosody and anteriority, reflecting that only main-clause prosody showed anterior positivity.

A separate ANOVA for the midline electrodes revealed that there was a main effect of prosody, reflecting that the waveforms for main-clause prosody were more positive. There was also an interaction between prosody and anteriority, which reflects that the positivity in the anterior region was only found for the conditions with main-clause prosody.

To summarize the effect at the second prosodic boundary, the CPS effect for the conditions with main-clause prosody was evident for both native speakers and L2 learners although a main effect of anteriority was not evident for L2 learners. However, this non-effect of anteriority was due to the lack of positivity in the anterior regions for the conditions with embedded-clause prosody, which did not have a prosodic boundary there; thus, the CPS was still observed in the similar regions for L2 learners as for native speakers.

Therefore, the CPS effects observed at the first and second prosodic boundaries together suggest that native speakers and L2 learners of Japanese detect prosodic boundaries immediately, and there was no qualitative difference in their detection of prosody.

4.2.2.2. Utilization of Prosody. It was found that prosody is immediately detected in the brain for both native speakers and L2 learners. However, is the prosody immediately utilized to disambiguate sentence meaning? In order to test whether prosody is utilized to analyze sentence meaning, the presence of N400-P600 effects were tested.

If the prosody is utilized to build the sentence structure like in European languages, an incongruent prosody should yield a garden-path effect right at the disambiguating fifth word. More specifically, if the embedded-clause prosody generates a prediction of finding an animate object as the fifth word of the embedded-clause structure sentence, and main-clause prosody generates a prediction of finding an inanimate object as the fifth word of the main-clause structure sentence, the incongruent prosody should yield N400-P600 effect at the disambiguating word (e.g., Steinhauer et al., 1999). That is, encountering an inanimate object when an animate word is expected by the prosodic pattern, or vice versa, is expected to elicit N400, and the reanalysis of the sentence structure is expected to yield P600. Moreover, if the immediate effect of prosody is strong enough to neutralize the structural bias otherwise present in favor of embedded structure, there should not be N400-P600 effects in the comparison of congruent conditions (ES-EP vs. MS-MP) (e.g., Kjelgaard & Speer, 1999).

Figures 9 and 10 show waveforms at the disambiguating word, plotted at a selection of representative electrodes for native speakers and L2 learners, respectively.

Native Speakers. The visual inspection of native speakers' waveforms suggested that there was a N400-P600-like effect due to the structural effect, although it was somewhat later in time than is typical, in the time windows (500-900 ms and 1000-1400 ms); thus, ANOVA were performed for each of these time windows. A full report of all statistical analyses for these time windows is summarized in Appendices H (ANOVA) and I (*t*-tests).

In the time window of 500-900 ms, ANOVA results revealed that there was a main effect of anteriority, reflecting that the anterior region is more negative. There was also a significant interaction between structure and anteriority, reflecting that anterior negativity was only observed for main-clause-structure condition; there was also an interaction between structure and laterality, reflecting that the right hemisphere was considerably more negative in the case of main-clause structure conditions; and there was a marginal interaction between anteriority and laterality, reflecting that the right anterior region is more negative compared to other regions. A separate ANOVA for the midline revealed a significant main effect of structure, reflecting that the waveforms for main-clause structure yielded a negativity.

Paired *t*-tests within each region were conducted between the congruent conditions (ES-EP vs. MS-MP) to examine whether the effect of prosodic congruency was strong enough to neutralize the structural bias. The results in the lateral regions revealed that there was a marginal negativity in the right anterior region for the main-clause condition. In the midline, there was a significant negativity for main-clause structure in electrodes FZ and CZ; marginal negativity in FCZ and CPZ. This confirms that there was negativity in the midline to right anterior regions for the main-clause structure condition even when the prosody was congruent.

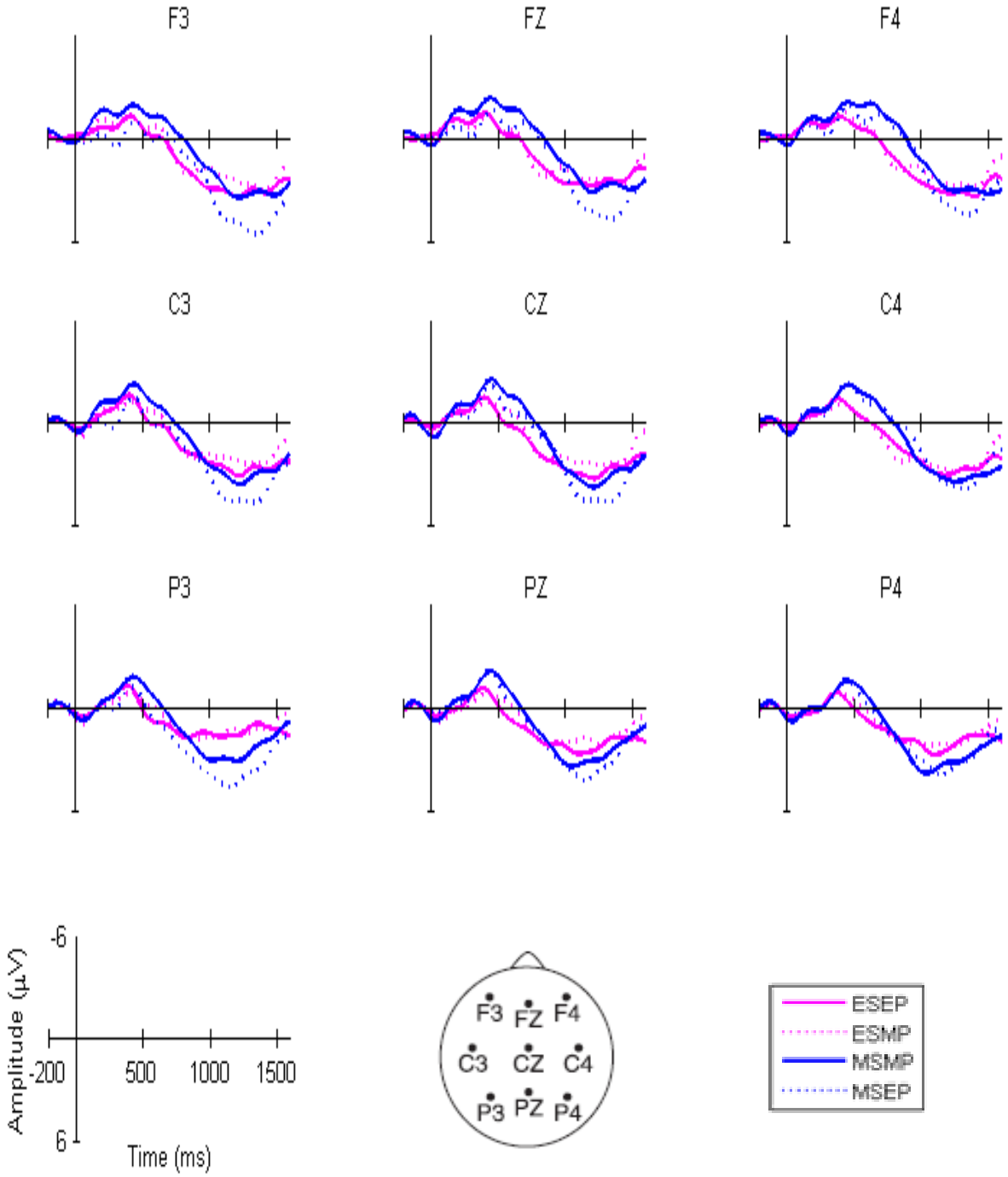


Figure 9. Native speakers' brain responses, time locked at the onset of the disambiguating fifth word. The data were filtered using a 5Hz low-pass-filter for plotting purposes only. Pink lines represent embedded structure, and blue lines represent main structure. Overall, main-clause-structure conditions are more negative compared to embedded-clause-structure conditions.

ANOVA in the time windows of 1000-1400 ms for L1 revealed that there was a significant main effect of structure, reflecting that the waveforms for main-clause structure were more positive; and there was a marginal main effect of anteriority, reflecting that anterior region was more positive. There was also a significant interaction between structure and anteriority, reflecting that the main-clause structure conditions yielded a positivity in both anterior and posterior regions while embedded-clause conditions did not yield a positivity in the posterior region. There was also an interaction between structure and laterality, reflecting that the left hemisphere was more positive only in the main-clause structure conditions. The interaction between anteriority and laterality was also marginally significant, reflecting that the anterior region of the left hemisphere was more positive, while the posterior region of the right hemisphere was more positive. A separate ANOVA for the midline revealed that there was a significant main effect of structure, reflecting that the waveforms for main-clause-structure conditions yielded more positivity compared to embedded-clause-structure conditions.

Paired *t*-tests within the same regions were conducted between the congruent conditions (ES-EP vs. MS-MP). The results revealed that there was a significant positivity for the main-clause-structure condition (MS-MP) observed in the left posterior region and right posterior region.

The ANOVA and *t*-test results for both time windows (500-900 ms and 1000-1400 ms) confirmed a delayed N400-P600-like effect for the main-clause structure. Thus, the prosody did not give a strong enough effect to override the structural bias.

As for the effect of prosody, does it have any effect on the processing of the sentences? In order to test whether the prosody plays a role in the building of the syntactic structure of each sentence type, congruent and incongruent conditions were compared within the same structure.

Therefore, *t*-tests within the same regions were conducted for each 200 ms time window from 200 ms after the onset of the disambiguating word. As for the 'easy' embedded-clause structure, none of the time windows yielded any significant difference. In the comparison of 'difficult' main-clause structure conditions, on the other hand, there was a significant difference in the time window of 1200-1400 ms. There was a significant positivity for the incongruent embedded-clause prosody in the left anterior region, and two anterior midline electrodes, FZ and FCZ. CZ also yielded a marginal significant difference. A full report of the analyses for L1 is summarized in Appendix J along with L2's results, which are discussed below.

In short, it was found that there was no immediate effect of prosody in the analysis of 'easy' embedded-clause structure; that is, even when the prosody is not congruent with the syntactic structure, this does not present detectable processing difficulty as long as the structure is an 'easy' embedded-clause structure. However, it *is* utilized in the analysis of a 'difficult' main-clause structure.

L2 Learners. Visual inspection of the L2 learners' data suggested that there were negativities between 600-900 ms and 1200-1600 ms; thus, ANOVA were conducted for these time windows. A full report of all statistical analyses for these time windows is summarized in Appendices K (ANOVA) and L (*t*-tests).

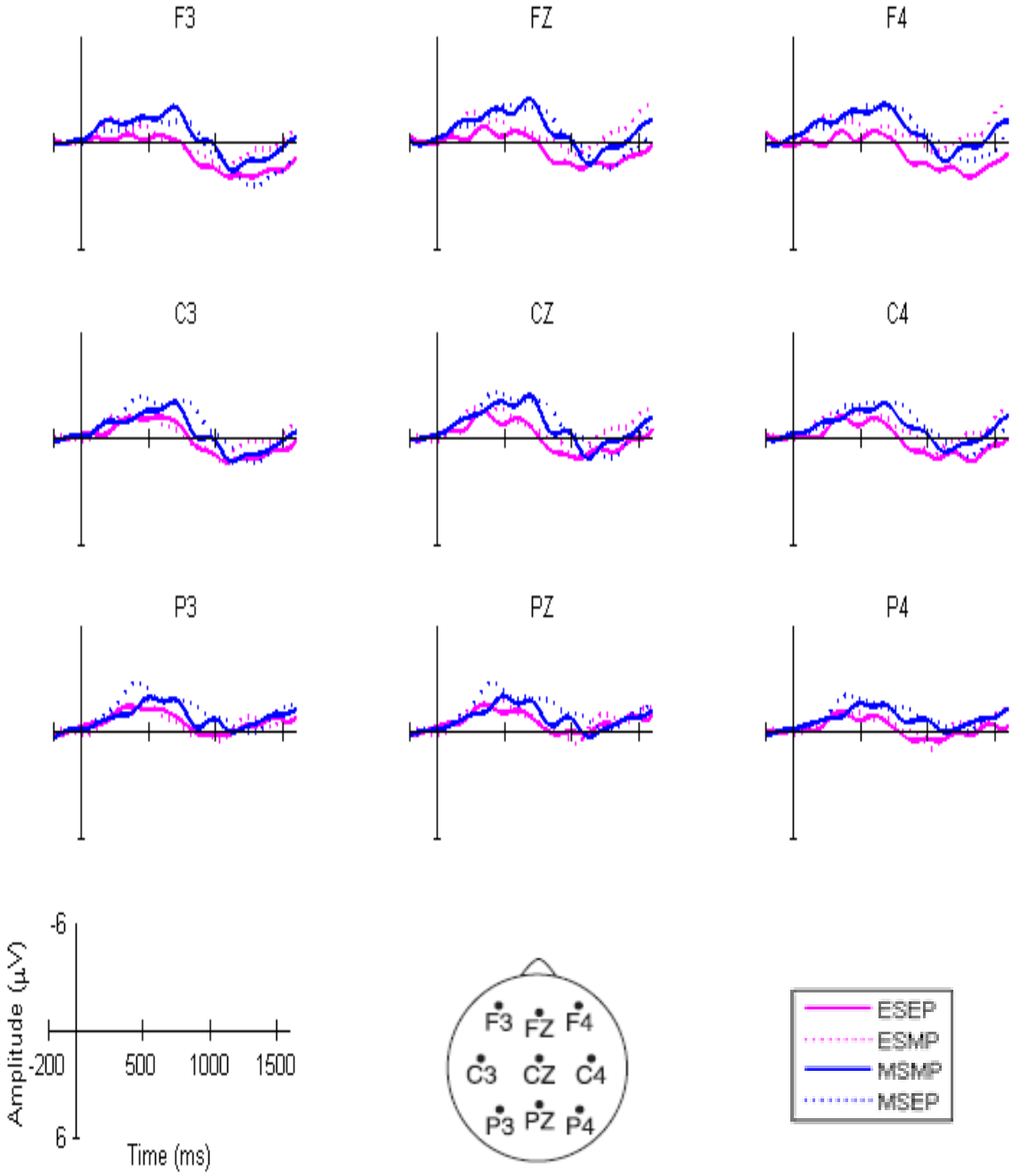


Figure 10. L2 learners' brain responses, time locked at the onset of the disambiguating fifth word. The data were filtered using a 5Hz low-pass-filter for plotting purposes only. Pink lines represent embedded structure, and blue lines represent main structure. Overall, main-clause-structure conditions are more negative compared to embedded-clause-structure conditions.

ANOVA in the time window of 600-900 ms in the lateral regions revealed that there was a significant main effect of structure, reflecting that the waveforms for main-clause structure were more negative; and that there was a marginal main effect of laterality, reflecting that the right hemisphere yielded more negativity. There was a marginal interaction between structure and anteriority, reflecting that, while the embedded-clause structure yielded more negativity in the posterior region, main-clause structure yielded more negativity in the anterior region. There was also a marginal interaction between prosodic congruency and laterality, reflecting that the negativity was greater for the right hemisphere for the incongruent conditions, as compared to congruent conditions. There was also a marginal interaction between anteriority and laterality, reflecting that that the left anterior region was specifically more positive compared to other regions.

A separate ANOVA for the midline electrodes revealed that there was a main effect of structure, reflecting that the waveforms for main-clause structure yielded a greater negativity; and that there was a marginally significant interaction between structure and anteriority, reflecting that the negativity in the anterior region was only evident for the main-clause structure.

Paired *t*-tests within the same regions were conducted between the congruent conditions (ES-EP vs. MS-MP) to examine whether the effect of prosodic congruency was not strong enough to neutralize the structural bias. The results revealed that there was a significant negativity for the main-clause-structure sentences in the left anterior region, right anterior region, and midline electrodes, FZ, FCZ and CZ as well as a marginal negativity in CPZ.

ANOVA in the time window of 1200-1600 ms for lateral regions revealed that there was a main effect of anteriority, reflecting that anterior regions were more positive. There is also an interaction between structure and prosodic congruency, reflecting that main-clause prosody is

consistently more negative regardless of the (in)congruency of prosody. There was also an interaction among structure, prosodic congruency and anteriority, reflecting that the anterior positivity was larger for the conditions with embedded-clause prosody. There was a marginal interaction between prosodic congruency and laterality, reflecting that the right hemisphere was more negative when prosody is incongruent with the structure. A marginal interaction between anteriority and laterality was present, reflecting that the left anterior region was more positive compared to other regions.

A separate ANOVA for the midline electrodes revealed no main effects, but an interaction between structure and prosodic congruency, reflecting that the main-clause prosody was always more negative regardless of the congruency of the prosody. There was also an interaction among structure, prosodic congruency and anteriority, reflecting that the anterior region was more positive when embedded-clause prosody was used.

Paired *t*-tests between congruent conditions (ES-EP vs. MS-MP) were conducted within the same regions to examine whether the effect of prosodic congruency was strong enough to neutralize the structural bias. The results revealed that there was a significant negativity in the left anterior region and right anterior region, and a marginal negativity in a midline electrode, FZ. L2 learners' results also revealed processing difficulty for main-clause structure, although their brain responses were not totally native-like. While native speakers yielded a delayed N400-P600 effect, L2 learners yielded N400-like effect that is sustained (i.e., sustained negativity) rather than leading to a P600.

The ANOVA results suggested some interactions with prosody. Thus, in order to look into the prosodic effect in detail, *t*-tests for 200 ms-long consecutive time windows 200 ms after the onset of the fifth word until 1600 ms were conducted within the same structure. The results

revealed significant differences for both structure types in the time window of 1200-1600 ms. A full report of all statistical analyses of prosodic congruency effects is summarized in Appendix J along with the L1 results. As for the embedded-clause structure, there were significant negativities for the incongruent main-clause prosody in the left anterior region, in the right anterior region, and two anterior midline electrodes, FZ and FCZ. CZ also yielded a marginally significant negativity. As for the main-clause structure, there was a significant positivity for the incongruent embedded-clause prosody in the left anterior region. The midline frontal electrode, FZ, also yielded a marginal positivity. Considering the opposite directions for two structures (i.e., negativity for incongruent prosody in the embedded-clause-structure conditions and positivity for incongruent prosody in the main-clause-structure conditions), it may be more natural to interpret these effects as negativity for main-clause prosody for both cases.

4.3. Discussion

The EEG results indicated that both L1 and L2 listeners of Japanese detect prosodic boundaries immediately, eliciting CPS. There were no qualitative differences between the two groups.

Furthermore, the effect of prosody was not strong enough to neutralize the structural bias for both L1 and L2. Their brain responses revealed interesting differences in terms of how they utilize prosody during sentence processing. Topographical differences are shown in Figure 11. L1 listeners showed a delayed N400-P600-like effect for the main-clause-structure sentences, suggesting that they were initially surprised by the inanimate word (N400), but the sentence structure was successfully revised (P600) regardless of the prosodic congruency. The judgment data were consistent with this early effect of structure, showing a strong preference toward embedded-clause structure.

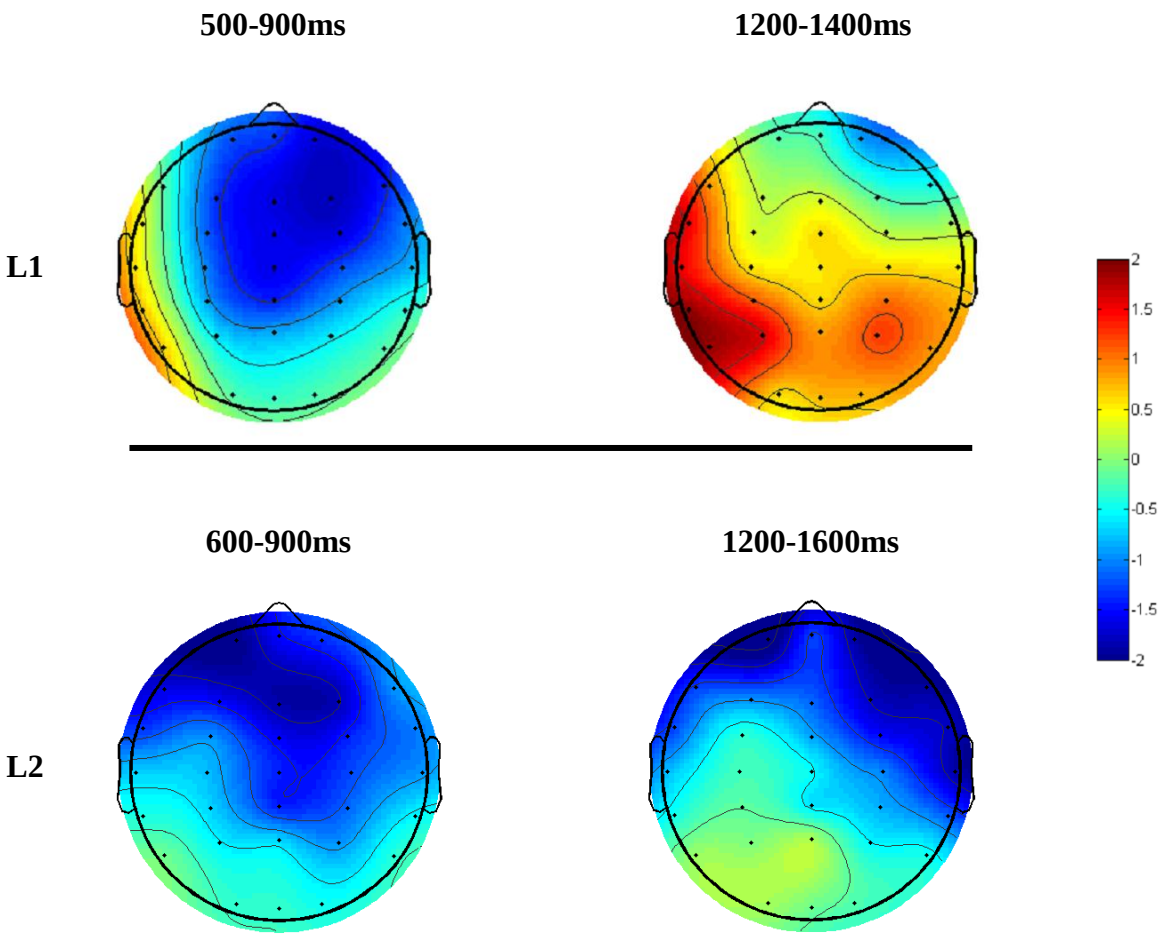


*Figure. 11.*Difference maps for Main-clause-structure congruent condition (MS-MP) minus the Embedded-clause-structure congruent condition (ES-EP) for L1 and L2 listeners. L1 shows a negativity followed by a positivity, whereas L2 shows a continued negativity.

L2 listeners showed a sustained negativity instead of N400-P600, which may indicate a surprise at the inanimate word, and that structure may not be successfully revised even when the prosody is congruent. In the case of L2 listeners, the analysis of main-clause sentences itself is challenging, which may prevent them from incorporating the prosodic information into the analysis of the sentence. This speculation is also supported by L2 learners' judgment results: they prefer embedded-clause structure, but there was no difference between main-clause-structure sentences with congruent and incongruent prosodies.

Nevertheless, prosody has an immediate effect to some extent, and the effects for L1 and L2 seemed quite different. The topographical differences are shown in Figure 12. It was observed that L1 listeners utilized prosodic information to analyze only 'difficult' main-clause-structure sentences, yielding positivity. The positivity for the incongruent condition of the main-clause structure may be interpreted as revision of the structure caused by the wrong prosody. However, a wrong prosody had no effect on the analysis of 'easy' embedded-clause-structure sentences. These results suggest that the immediate use of prosody is evident in native Japanese primarily when other aspects of processing, such as the assembly of structure, become more difficult. Nonetheless, the native speakers preferred the congruent prosody for both structures at the judgment point; thus, it is evident that prosody is ultimately utilized in sentence processing regardless the type of sentence structure.

L2 listeners, on the other hand, yielded an anterior negativity for the incongruent main-clause prosody in the analysis of embedded-clause-structure sentences, and an anterior positivity for the incongruent embedded-clause prosody in the analysis of main-clause-structure sentences.

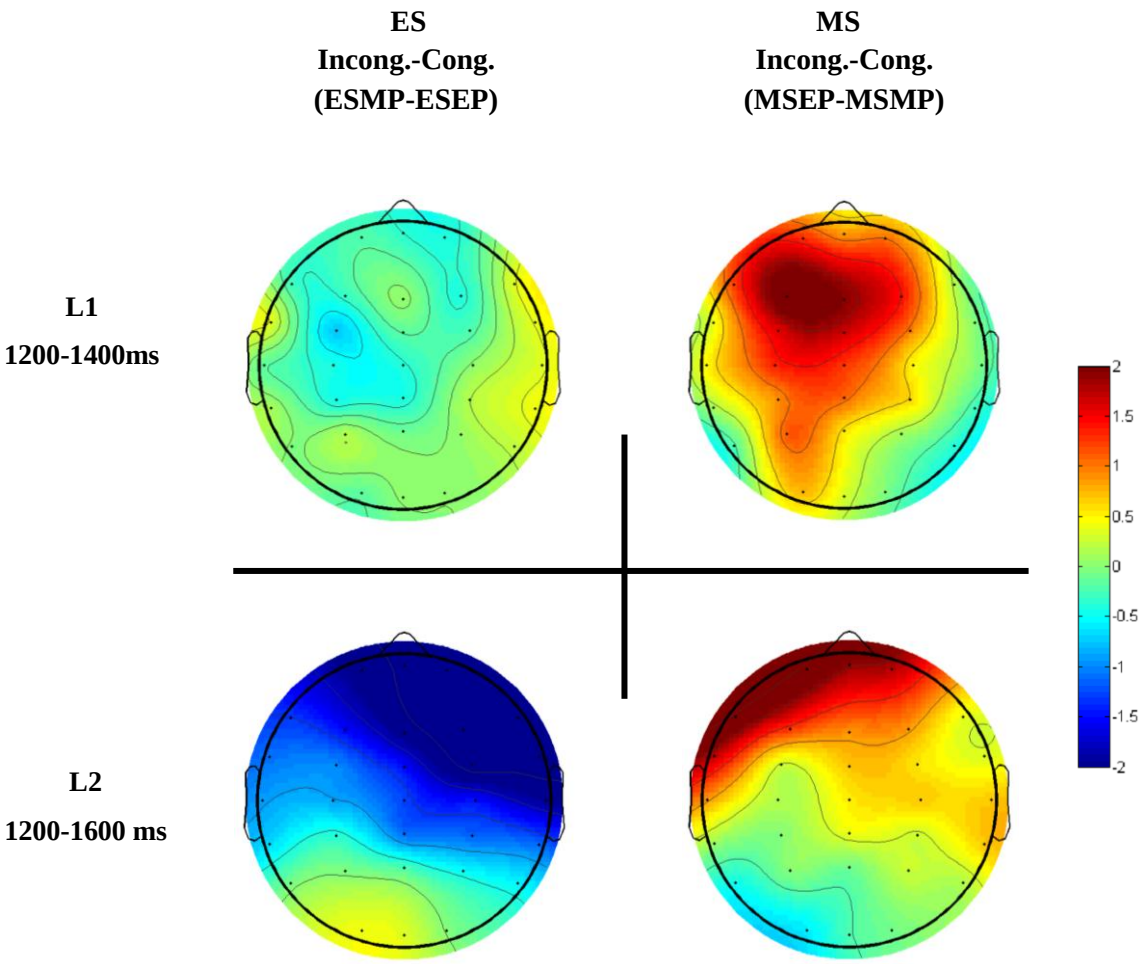


Figure 12. Difference maps for Incongruent minus Congruent conditions within the same structure for L1 and L2 listeners. L1 shows a positivity in the Main-clause Structure condition (MS) only. L2 shows a frontal negativity for the Embedded-clause Structure (ES), but a frontal positivity for the Main-clause Structure (MS).

These opposite directions of effects may be most naturally interpreted as negativity for main-clause prosody which is a congruent prosody for sentences that involve word-order scrambling (i.e., non-default word order). The L2 learners may have had problems with integrating the main-clause prosody, a congruent prosody for a non-default type of sentence structure.

In sum, the neurolinguistic approach revealed that while both native speakers and L2 learners of Japanese detected the prosodic boundaries in a qualitatively similar manner, L2 learners were not able to utilize the prosodic information in the same way as native speakers. Employing a neurolinguistic approach together with judgment data, what is native-like and non-native-like in processing as well as performance can be monitored precisely, which will contribute to more accurate teaching implications.

4.4. Summary

Neurolinguistic approaches such as the one presented in this chapter are well-suited to probing the nature of native speakers' and L2 learners' language processing. For, it is speculated that the process that leads to a certain performance may not be the same for native speakers and L2 learners. In this study, it was found that both L1 and L2 listeners immediately detected prosodic boundaries, though neither group showed evidence of immediately utilizing prosody to build the syntactic structure in all cases. Rather, evidence for the utilization of prosody by L1 listeners emerged when they had difficulty analyzing the sentence. L2 listeners, on the other hand, may not have been able to relate prosodic information with sentence structure, showing that they had a problem with analyzing non-default-type, main-clause structure regardless of the prosodic congruency, as well as with main-clause prosody, a congruent prosody for main-clause structure sentences. The neurolinguistic approach, together with the analysis of the participants'

performance in the sentence judgment task, indicated these different natures of Japanese language processing among L1 and L2 listeners.

Chapter 5

General Discussion and Pedagogical Implications

5.1. General Discussion

Previous literature on closure ambiguity in European languages indicated that prosody has an immediate and strong enough effect to neutralize structural bias, allowing the parser to avoid garden-path effects (e.g., Kjelgaard & Speer, 1999; Pauker et al., 2011; Steinhauer et al., 1999). In this dissertation, this line of research was extended to Japanese, a typologically different language which holds opening ambiguity (Hirose, 2003), as well as the auditory sentence processing of not only native speakers but also L2 learners. This study is, to my knowledge, the first study investigating the prosody-syntax interaction at the brain level in L2, and the first study investigating the role of prosody in parsing this type of structural ambiguity in either native speakers or L2 learners of Japanese. The results of this EEG study revealed a CPS effect during the processing of ambiguous sentences for Japanese speakers. Crucially, the current study also revealed that L2 learners can elicit qualitatively native-like CPS effects, which had not been previously established in the literature. Also, a strong effect of structural bias in parsing Japanese relative clauses was found, and prosody was indeed observed to play a role in parsing Japanese, though not a deterministic role. Moreover, the results revealed both similarities and remaining differences in the utilization of prosody among L1 and L2, which prompts further research and motivates a pedagogical effort to capitalize on what learners know and remedy the limitations revealed in the current study in L2 language processing.

Experiments 1A and 1B, timed acceptability judgment and comprehension studies on globally ambiguous sentences, revealed a structural bias among native speakers of Japanese which was not reported in previous studies conducted without time pressure (Eda et al., 2009; Misono et al., 1997). This structural effect, however, is predicted based on the parsing operations needed to build these structures in real time, and align well with similar structural biases revealed in European languages. The current study with time pressure revealed strong structural bias and a limited effect of semantic information, while previous studies without time pressure, failed to detect this effect and only revealed the effects of semantic information. Nevertheless, there was no substantial difference in prosodic effects: both studies suggested a certain degree of prosodic effect, though it was not deterministic.

Experiments 2A and 2B, timed acceptability judgment and comprehension studies on Japanese temporarily ambiguous sentences, revealed that main-clause-structure sentences which require both subject and object reanalysis and contain word-order scrambling are not as highly accepted by native speakers as embedded-clause-structure sentences which require only subject reanalysis and have a default word order. The main-clause-structure sentences were not as accurately interpreted as embedded-clause-structure sentences under time pressure, especially when the prosody was incongruent with the structure. As for the embedded-clause-structure sentences, the acceptability was lower for the incongruent prosody condition; however, the prosody did not affect the accuracy of the interpretation of embedded-clause-structure sentences, though the response time was longer for the incongruent prosody condition. These results suggest that prosody-structure congruency modulates the comprehension of auditory sentences, especially when the structure is not a default type. Unlike the case of closure ambiguity in European languages (e.g., Kjelgaard & Speer, 1999), the current study did not yield a

deterministic effect of prosody on judgments even under time pressure in Japanese. Nevertheless, the fact that prosody modulated the interpretation even though other information actually disambiguated the meaning before it concluded confirms that prosodic information affects the comprehension of Japanese sentences.

Experiment 3, a neurolinguistic study utilizing Electroencephalography (EEG), was conducted in order to test how prosody affects native speakers and L2 learners process Japanese auditory sentences. EEG is a brain-level measurement, which directly monitors brain activity moment by moment; thus, with EEG one can examine effects right at prosodic boundaries and the disambiguating word, not just at the participant's judgment of the sentence. In other words, the *detection* of prosodic boundaries and the *utilization* of prosody can be separately measured in the time course of processing.

The participants engaged in an acceptability judgment task on temporarily ambiguous sentences as their brain activation was monitored. The results revealed that, both native speakers and L2 learners detected prosodic boundary immediately, but it was not immediately utilized by the parser to build a syntactic structure. Rather, it was evident among native speakers that when there was a difficulty in analyzing sentences which yield a garden-path effect (i.e., main-clause structure), prosody was utilized to revise the syntactic structure. On the other hand, while L2 learners detected the prosodic boundary immediately just like native speakers, they did not seem to take advantage of it in structural analysis. L2 learners dispreferred main-clause-structure sentences like native speakers, but it was also observed that only L2 learners had difficulty utilizing main-clause prosody, a congruent prosody for main-clause structure, regardless of the sentence structure unlike native speakers.

In sum, a major contribution of the experiments in this dissertation is the finding that prosody plays a certain role in Japanese sentence processing. However, prosody does not have a strong enough effect to neutralize the syntactic structure in Japanese opening ambiguity among native speakers, as opposed to the reports that prosody used for closure ambiguity in European languages has a strong enough effect to cause or cancel the garden-path effect that the structural bias elicits (e.g., Kjelgaard & Speer, 1999; Steinhauer, 1999). Another major contribution is the discovery of L2 learners' immediate detection of prosodic boundary and their inability to effectively utilize prosody in structural analysis in Japanese. This has teaching implications for L2 Japanese teaching, which are summarized later in this chapter.

Nevertheless, since the current study is one of the first studies to investigate the processing of prosody in Japanese among L1 and L2, there is a need for more research. First, there is a need for investigation into what information from 'prosodic boundaries' the listeners (especially L2 listeners) detect. In the current study, there was a pause at every prosodic boundary, so it is not clear what aspects of the *prosodic boundary* the listeners detect. It has been reported among European languages that native speakers detect prosodic boundaries even without a pause (e.g., Steinhauer, et al., 1999). Thus, further research is needed to look into whether the boundary tone and/or final lengthening information of the prosodic boundary is sufficient for the detection of a prosodic boundary during Japanese language processing among L2 learners as well as native speakers.

Second, the effect of prosody on sentences that have less differences in difficulty levels needs to be investigated. The temporarily ambiguous sentences that were compared in the current study clearly have different levels of processing cost: embedded-clause-structure sentences require only subject reanalysis and have a default word-order, while main-clause-structure

sentences require subject and object reanalysis and have word-order scrambling. In other words, the reason prosody did not have a strong enough effect to neutralize sentence structure may be that main-clause-structure sentences were too difficult for the prosody to resolve the structure. It will be beneficial to examine the use of prosody in less difficult types of complex sentences of Japanese.

Third, the effects of other aspects of prosody need to be investigated. In the current study, 'prosodic boundary' information was focused on; however, other prosodic information, such as pitch accents, may have an effect on sentence processing as well (e.g., Bögels et al., 2011, Shibata & Hurtig, 2007). How these other aspects of prosody affect sentence interpretations during Japanese language processing should be investigated using precise methods like EEG in the future.

Fourth, it may be meaningful to test learners of different levels of proficiency, including low-level learners. The L2 listeners recruited in the current study were intermediate to advanced-level students, and even the intermediate students immediately detected prosody just like native speakers and could use the prosodic information at least in the analysis of the embedded-clause-structure sentences at the judgment point. However, it is still not clear whether or how much low-level L2 learners can detect or utilize the prosody. By testing different levels of L2 learners, it may be understood how they develop skills of using prosody in sentence processing.

These lines of study will provide a fuller understanding of the role of prosody in sentence processing among L1 and L2 learners, which will suggest effective pronunciation/prosody training in the future.

5.2. Pedagogical Implications

The current study revealed that L2 learners have a problem not only with 'difficult' main-clause-structure sentences, but also with utilizing the main-prosody. This may suggest the necessity of training students by showing them how to use prosodic boundaries as a guide with various non-default types of sentences which include scrambling. First of all, long complex sentences are challenging for L2 learners; however, the prosody and structure usually match. Thus, teaching complex sentences utilizing prosodic cues may help them process the auditory sentence more efficiently and effectively. Second, although some may argue that teaching flexible word-order may encourage the learner to overuse a non-default type of structure, one cannot argue the fact that scrambling does indeed naturally occur in Japanese speech. Thus, it may be helpful for the advanced-level learners to be exposed to various non-default types of sentences uttered with the congruent prosody of the sentence.

By exposing L2 learners to auditory sentences whose prosodic boundaries are carefully controlled, they may be trained to utilize prosody in auditory sentence processing. For example, Processing Instruction (VanPatten, 1996) may be a useful technique, although it was originally developed for grammar instruction. This technique puts importance on developing learners' processing of the input, making language *input* into learners' *intake*. In fact, Processing Instruction has been reported as successful not only in perception development but also in contributing to the production of language (VanPatten & Cadierno, 1993; VanPatten & Oikkenon, 1996; VanPatten & Sanz, 1995). Gonzalez-Bueno and Quintana-Lara (2011) implemented Processing Instruction in L2 pronunciation training, and found some improvement in production, although no improvement was found in perception. Hirano-Cook (2011) also employed Processing Instruction in L2 Japanese accent training along with production training,

and the L2 learners' perception improved significantly, as well as their production of some types of accentual patterns. Wang et al. (2003), though they did not specifically use Processing Instruction, also reported that Mandarin Chinese tone training focused solely on the perception of tones increased the L2 learners' successful production of tones. Processing Instruction has not been applied to prosody training, so this line of effective prosody perception training method should be implemented in the future. Acquiring native-like pronunciation and prosody is even more challenging for advanced-level learners than utilizing prosodic information in listening; thus, the relationship between perception and production in terms of pronunciation and prosody should further be explored to suggest an effective pronunciation/prosody training method.

5.3. Conclusion

Experiments utilizing precise measurements such as neurolinguistic methods shed light on the nature of language processing. This dissertation explored the nature of Japanese prosody processing in sentence comprehension among native speakers and L2 learners. The results revealed that prosody has a certain effect on sentence processing though it is not deterministic, and that L2 processing of prosody has both similarities and differences compared to that of native speakers. It needs to be investigated whether or not prosody perception training will improve the use of prosody in Japanese sentence comprehension among L2 learners in the future. Effective teaching methods may be developed based on those findings, and implemented to remedy the limitations of L2 language processing.

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Appendix A
ANOVA and *t*-tests on Acceptability Judgment Task Results for Globally Ambiguous Sentences

ANOVA for Acceptability Judgment Task Results for Three Semantic Conditions				
	Rating		Reaction Times	
	Effect by participants	Effect by items	Effect by participants	Effect by items
Semantic Bias (ES, MS and NS)	$F_1(2, 46) = 55.25$***	$F_2(2, 54) = 23.79$***	-	-
Prosody (EP and MP)	-	$F_2(1, 27) = 4.56$**	$F_1(1, 23) = 5.68$**	$F_2(1, 27) = 6.49$**
Semantic Bias x Prosody	$F_1(2, 46) = 18.45$***	$F_2(2, 54) = 9.72$***	-	-
t-tests for Acceptability Judgment Results				
	Rating		Reaction Times	
	Effect by participants	Effect by items	Effect by participants	Effect by items
a. Congruent Conditions				
ES-EP vs. MS-MP	$t_1(23) = 5.10$***	$t_2(27) = 3.80$***	-	-
ES-MP vs. MS-EP	$t_1(23) = 6.19$***	$t_2(27) = 7.65$***	-	-
b. Effect of Semantic Bias within the Same Prosody				
ES-EP vs. MS-EP	$t_1(23) = 10.18$***	$t_2(27) = 6.97$***	-	$t_2(27) = -1.87$*
ES-EP vs. NS-EP	$t_1(23) = 2.15$**	-	-	-
MS-MP vs. ES-MP	$t_1(23) = -3.12$**	$t_2(27) = -2.96$**	-	-
MS-MP vs. NS-MP	$t_1(23) = -3.12$**	$t_2(27) = -2.03$**	-	-
MS-EP vs. NS-EP	$t_1(23) = -7.65$***	$t_2(27) = -5.24$***	-	$t_2(27) = 1.99$*
ES-MP vs. NS-MP	-	-	-	-
c. Effect of Prosody within the Same Semantic Bias				
ES-EP vs. ES-MP	$t_1(23) = 2.05$**	-	-	$t_2(27) = -1.71$*
MS-MP vs. MS-EP	$t_1(23) = 4.89$***	$t_2(27) = 3.93$***	-	-
NS-EP vs. NS-MP	-	-	$t_1(23) = -3.41$**	$t_2(27) = -2.56$**

* $p < .1$; ** $p < .05$; *** $p < .001$

Appendix B
ANOVA and *t*-tests on Comprehension Task Results for Globally Ambiguous Sentences

ANOVA for Comprehension Task Results				
	Proportion of Main-Clause Interpretation		Reaction Times	
	Effect by participants	Effect by items	Effect by participants	Effect by items
Semantic Bias (ES, MS and NS)	$F_1(2, 46) = 24.75$***	$F_2(2, 54) = 25.63$***	$F_1(2, 46) = 4.08$**	$F_2(2, 54) = 5.15$**
Prosody (EP and MP)	$F_1(1, 23) = 85.24$***	$F_2(1, 27) = 227.07$***	$F_1(1, 23) = 10.02$**	$F_2(1, 27) = 12.91$***
Semantic Bias x Prosody	$F_1(2, 46) = 1.83$	$F_2(2, 54) = .81$	$F_1(2, 46) = 3.15$**	$F_2(2, 54) = 3.26$**
t-tests for Comprehension Task Results				
	Judgments		Reaction Times	
	Effect by participants	Effect by items	Effect by participants	Effect by items
a. Congruency (SB-based interpretation)				
ES-EP vs. MS-MP	$t_1(23) = 4.90$***	$t_2(27) = 6.21$***	$t_1(23) = -4.25$***	$t_2(27) = -3.45$**
ES-MP vs. MS-EP	$t_1(23) = 2.30$**	$t_2(27) = 2.53$**	-	-
b. Effect of Semantic Bias within the Same Prosody (Prosody-based Interpretation)				
ES-EP vs. MS-EP	$t_1(23) = 4.65$***	$t_2(27) = 7.89$***	$t_1(23) = -4.01$***	$t_2(27) = -5.86$***
ES-EP vs. NS-EP	$t_1(23) = -1.69$*	$t_2(27) = -1.69$*	-	-
MS-EP vs. NS-EP	$t_1(23) = -4.46$***	$t_2(27) = 6.60$***	$t_1(23) = 1.98$*	$t_2(27) = 2.82$**
MS-MP vs. ES-MP	$t_1(23) = 5.23$***	$t_2(27) = 3.87$***	-	-
MS-MP vs. NS-MP	$t_1(23) = 2.55$**	$t_2(27) = 3.39$**	-	-
ES-MP vs. NS-MP	$t_1(23) = -2.30$*	-	-	-
c. Effect of Prosody within the Same Semantic Bias (SB-based Interpretation)				
ES-EP vs. ES-MP	$t_1(23) = 8.60$***	$t_2(27) = 9.38$***	$t_1(23) = -5.80$***	$t_2(27) = -4.52$***
MS-MP vs. MS-EP	$t_1(23) = 5.57$***	$t_2(27) = 8.82$***	-	-
NS-EP vs. NS-MP	$t_1(23) = +/-7.97$***	$t_2(27) = +/-11.42$***	$t_1(23) = -/+1.94$*	$t_2(27) = -/+2.48$**

* $p < .1$; ** $p < .05$; *** $p < .001$

Appendix C
ANOVA and *t*-tests on Acceptability Judgment Task Results for Temporarily Ambiguous Sentences

ANOVA for Acceptability Judgment Task Results				
	Rating		Reaction Times	
	Effect by participants	Effect by items	Effect by participants	Effect by items
Structure	$F_1(1, 23) = 114.66$***	$F_1(1, 83) = 280.00$***	$F_1(1, 23) = 8.23$**	$F_1(1, 83) = 8.63$**
Prosodic Congruency	$F_1(1, 23) = 49.24$***	$F_1(1, 83) = 230.75$***	$F_1(1, 23) = 8.17$**	$F_1(1, 83) = 8.96$**
Structure x Prosodic Congruency	$F_1(1, 23) = 2.87$*	-	-	-
t-tests for Acceptability Judgment Results				
	Rating		Reaction Times	
	Effect by participants	Effect by items	Effect by participants	Effect by items
a. Effect of Structure within the Same Congruency				
ES-EP vs. MS-MP	$t_1(23) = 8.83$***	$t_1(83) = 12.48$***	$t_1(23) = -4.21$***	$t_1(83) = -3.15$**
ES-MP vs. MS-EP	$t_1(23) = 10.76$***	$t_1(83) = 16.14$***	-	-
b. Effect of Structure within the Same Prosody				
ES-EP vs. MS-EP	$t_1(23) = 16.00$***	$t_1(83) = 39.73$***	$t_1(23) = -3.26$**	$t_1(83) = -4.26$***
MS-MP vs. ES-MP	-	$t_1(83) = -2.63$*	-	-
c. Effect of Prosody within the Same Structure				
ES-EP vs. ES-MP	$t_1(23) = 6.10$***	$t_1(83) = 10.82$***	$t_1(23) = -3.74$***	$t_1(83) = -2.96$**
MS-MP vs. MS-EP	$t_1(23) = 6.92$***	$t_1(83) = 13.19$***	-	-

* $p < .1$; ** $p < .05$; *** $p < .001$

Appendix D
ANOVA and *t*-tests on Comprehension Task Results for Temporarily Ambiguous Sentences

ANOVA for Comprehension Task Results				
	Accuracy Rates		Reaction Times	
	Effect by participants	Effect by items	Effect by participants	Effect by items
Structure	$F_1(1, 23) = 164.69$***	$F_1(1, 83) = 220.20$***	$F_1(1, 23) = 113.24$***	$F_1(1, 83) = 303.47$***
Prosodic Congruency	$F_1(1, 23) = 60.71$***	$F_1(1, 83) = 51.27$***	$F_1(1, 23) = 36.05$**	$F_1(1, 83) = 70.00$***
Structure x Prosodic Congruency	$F_1(1, 23) = 38.26$***	$F_1(1, 83) = 33.02$***	-	-
t-tests for Comprehension Task Results				
	Accuracy Rates		Reaction Times	
	Effect by participants	Effect by items	Effect by participants	Effect by items
a. Effect of Structure within the Same Congruency				
ES-EP vs. MS-MP	$t_1(23) = 7.07$***	$t_1(83) = 7.39$***	$t_1(23) = -11.38$***	$t_1(83) = -11.87$***
ES-MP vs. MS-EP	$t_1(23) = 12.79$***	$t_1(83) = 13.24$***	$t_1(23) = -7.58$***	$t_1(83) = -12.31$***
b. Effect of Structure within the Same Prosody				
ES-EP vs. MS-EP	$t_1(23) = 10.08$***	$t_1(83) = 14.07$***	$t_1(23) = --11.48$***	$t_1(83) = -17.66$***
MS-MP vs. ES-MP	$t_1(23) = -4.78$***	$t_1(83) = -6.77$***	$t_1(23) = 5.09$***	$t_1(83) = 8.17$***
c. Effect of Prosody within the Same Structure				
ES-EP vs. ES-MP	-	-	$t_1(23) = -4.61$***	$t_1(83) = -6.74$***
MS-MP vs. MS-EP	$t_1(23) = 9.47$***	$t_1(83) = 7.08$***	$t_1(23) = -4.59$***	$t_1(83) = -4.45$***

* $p < .1$; ** $p < .05$; *** $p < .001$

Appendix E

ANOVA and *t*-tests on EEG Behavioral Results (Acceptability Judgment Task) for Temporarily Ambiguous Sentences

Three-way Mixed ANOVA for Behavioral Results				
	Accuracy Rates		Reaction Times	
	Effect by participants	Effect by items	Effect by participants	Effect by items
Group	-	-	$F_1(1, 34) = 52.38$***	$F_2(1, 166) = 1502.74$***
Structure	$F_1(1, 34) = 110.17$***	$F_2(1, 166) = 825.73$***	$F_1(1, 34) = 30.12$***	$F_2(1, 166) = 52.62$***
Prosodic Congruency	$F_1(1, 34) = 76.97$***	$F_2(1, 166) = 188.90$***	-	-
Group x Structure	$F_1(1, 34) = 50.93$***	$F_2(1, 166) = 374.81$***	$F_1(1, 34) = 3.88$*	$F_2(1, 166) = 8.83$**
Group x Prosodic Congruency	$F_1(1, 34) = 39.77$***	$F_2(1, 166) = 97.63$***	-	-
Structure x Prosodic Congruency	-	-	$F_1(1, 34) = 4.82$**	$F_2(1, 166) = 4.31$**
Group x Structure x Pro. Cong.	$F_1(1, 34) = 6.50$**	$F_2(1, 166) = 10.18$**	-	-
t-tests for the Behavioral Results				
	Accuracy Rates		Reaction Times	
	Effect by participants	Effect by items	Effect by participants	Effect by items
a. L1 Congruency				
ES-MP vs. ES-EP	$t_1(17) = -6.10$***	$t_2(83) = -10.78$***	$t_1(17) = 3.61$***	$t_2(83) = 2.91$**
MS-EP vs. MS-MP	$t_1(17) = -7.79$***	$t_2(83) = -11.13$***	-	-
b. L1 Effect of Structure				
MS-MP vs. ES-EP	$t_1(17) = -10.95$***	$t_2(83) = -17.07$***	$t_1(17) = 6.53$***	$t_2(83) = 8.93$***
MS-EP vs. ES-MP	$t_1(17) = -8.31$***	$t_2(83) = -28.21$***	$t_1(17) = 2.56$**	$t_2(83) = 3.75$***
c. L2 Congruency				
ES-MP vs. ES-EP	$t_1(17) = -2.58$**	$t_2(83) = -3.36$**	-	-
MS-EP vs. MS-MP	-	-	-	-
d. L2 Effect of Structure				
MS-MP vs. ES-EP	$t_1(17) = -3.44$**	$t_2(83) = -5.91$***	$t_1(17) = 2.14$**	$t_2(83) = 2.18$**
MS-EP vs. ES-MP	$t_1(17) = -3.14$**	$t_2(83) = -3.59$***	-	-

* $p < .1$; ** $p < .05$; *** $p < .001$

Appendix F
ANOVA for CPS Effect at the First Prosodic Boundary

	L1	L2
	Effect by participants	Effect by participants
Lateral Region		
Structure	-	-
Prosody	$F_1(1, 17) = 64.61$***	$F_1(1, 17) = 18.95$***
Anteriority	$F_1(1, 17) = 17.25$***	$F_1(1, 17) = 11.47$**
Laterality		
Prosody x Anteriority	$F_1(1, 17) = 14.46$***	$F_1(1, 17) = 6.83$**
Midline		
Structure	-	-
Prosody	$F_1(1, 17) = 34.49$***	$F_1(1, 17) = 9.17$**
Anteriority	$F_1(1.31, 22.32) = 138.52$***	$F_1(1.18, 20.08) = 138.52$***
Prosody x Anteriority	$F_1(1.65, 27.98) = 6.56$**	$F_1(1.62, 27.53) = 6.94$**

* $p < .1$; ** $p < .05$; *** $p < .001$

Appendix G
ANOVA for CPS Effect at the Second Prosodic Boundary

	L1	L2
	Effect by participants	Effect by participants
Lateral Region		
Structure	-	-
Prosody	$F_1(1, 17) = 22.23$***	$F_1(1, 17) = 49.81$***
Anteriority	$F_1(1, 17) = 19.23$***	-
Prosody x Anteriority	$F_1(1, 17) = 11.64$**	$F_1(1, 17) = 30.15$**
Midline		
Structure	-	-
Prosody	$F_1(1, 17) = 21.88$***	$F_1(1, 17) = 21.70$***
Anteriority	$F_1(1.43, 24.32) = 9.98$**	-
Prosody x Anteriority	$F_1(1.19, 20.29) = 10.97$**	$F_1(1.41, 24.02) = 31.43$***

* $p < .1$; ** $p < .05$; *** $p < .001$

Appendix H
ANOVA on EEG Amplitude at the Disambiguating Word for L1

ANOVA for the Effect at the Disambiguating Word for L1		
	500-900 ms	1000-1400 ms
	Effect by participants	Effect by participants
Lateral Region		
Structure	-	$F_1(1, 17) = 13.17$**
Prosodic Congruency	-	-
Anteriority	$F_1(1, 17) = 18.90$***	$F_1(1, 17) = 3.80$*
Laterality	-	-
Structure x Prosodic Congruency	-	-
Structure x Anteriority	$F_1(1, 17) = 6.84$**	$F_1(1, 17) = 8.33$**
Structure x Laterality	$F_1(1, 17) = 12.24$**	$F_1(1, 17) = 6.81$**
Prosodic Congruency x Laterality	-	-
Anteriority x Laterality	$F_1(1, 17) = 3.20$*	$F_1(1, 17) = 3.95$*
Midline		
Structure	$F_1(1, 17) = 5.79$**	$F_1(1, 17) = 9.64$**
Prosodic Congruency	-	-
Anteriority	-	-
Structure x Anteriority	-	-

* $p < .1$; ** $p < .05$; *** $p < .001$

Appendix I

t-tests for the Structural Effect on EEG Amplitude at the Disambiguating Word for L1

	500-900 ms	1000-1400 ms
	Effect by participants	Effect by participants
a. Effect of Structure: MS-MP vs. ES-EP		
Left Anterior	-	-
Right Anterior	$t_1(17) = -2.03$*	-
Left Posterior	-	$t_1(17) = 2.98$**
Right Posterior	-	$t_1(17) = 2.41$**
Midline: FZ	$t_1(17) = -2.29$**	-
Midline: FCZ	$t_1(17) = -2.05$*	-
Midline: CZ	$t_1(17) = -2.21$**	-
Midline: CPZ	$t_1(17) = -1.78$*	-
Midline: PZ	-	-

* $p < .1$; ** $p < .05$; *** $p < .001$

Appendix J

t-tests for the Congruency Effect on EEG Amplitude at the Disambiguating Word for L1 and L2

	L1 (1200-1400 ms)	L2 (1200-1600 ms)
	Effect by participants	Effect by participants
(i) Embedded-clause Structure (ES-MP vs. ES-EP)	-	
Left Anterior	-	$t_1(17) = -3.19$**
Right Anterior	-	$t_1(17) = -3.97$***
Left Posterior	-	-
Right Posterior	-	-
Midline: FZ	-	$t_1(17) = -2.87$**
Midline: FCZ	-	$t_1(17) = -2.46$**
Midline: CZ	-	$t_1(17) = -1.90$*
Midline: CPZ	-	-
Midline: PZ	-	-
(ii) Main-clause Structure (MS-EP vs. MS-MP)		
Left Anterior	-	$t_1(17) = 2.99$**
Right Anterior	-	-
Left Posterior	-	-
Right Posterior	-	-
Midline: FZ	$t_1(17) = 3.19$**	$t_1(17) = 1.78$*
Midline: FCZ	$t_1(17) = 2.64$**	-
Midline: CZ	$t_1(17) = 1.92$*	-
Midline: CPZ	-	-
Midline: PZ	-	-

* $p < .1$; ** $p < .05$; *** $p < .001$

Appendix K
ANOVA on EEG Amplitude at the Disambiguating Word for L2

ANOVA for the Effect at the Disambiguating Word for L2		
	600-900 ms	1200-1600 ms
	Effect by participants	Effect by participants
Lateral Region		
Structure	$F_1(1, 17) = 28.53$***	-
Prosodic Congruency	-	-
Anteriority	-	$F_1(1, 17) = 16.81$***
Laterality	$F_1(1, 17) = 3.14$*	-
Structure x Prosodic Congruency		$F_1(1, 17) = 16.41$***
Structure x Anteriority	$F_1(1, 17) = 4.09$*	-
Structure x Laterality	-	-
Prosodic Congruency x Laterality	$F_1(1, 17) = 3.79$*	$F_1(1, 17) = 3.28$*
Anteriority x Laterality	$F_1(1, 17) = 4.01$*	$F_1(1, 17) = 3.91$*
Structure x Prosodic Congruency x Anteriority	-	$F_1(1, 17) = 7.37$**
Midline		
Structure	$F_1(1, 17) = 17.37$***	-
Prosodic Congruency	-	-
Anteriority	-	-
Structure x Prosodic Congruency	-	$F_1(1, 17) = 4.70$**
Sentence Structure x Anteriority	$F_1(1.42, 24.10) = 3.17$*	$F_1(1.42, 24.10) = 3.17$*
Structure x Prosodic Congruency x Anteriority	-	$F_1(1.82, 30.97) = 6.69$**

* $p < .1$; ** $p < .05$; *** $p < .001$

Appendix L

t-tests for the Structural Effect on EEG Amplitude at the Disambiguating Word for L2

	600-900 ms	1200-1600 ms
	Effect by participants	Effect by participants
Effect of Structure: MS-MP vs. ES-EP		
Left Anterior	$t_1(17) = -2.52$**	$t_1(17) = -2.79$**
Right Anterior	$t_1(17) = -2.16$**	$t_1(17) = -3.11$**
Left Posterior	-	-
Right Posterior	-	-
Midline: FZ	$t_1(17) = -3.72$**	$t_1(17) = -1.89$*
Midline: FCZ	$t_1(17) = -2.80$**	-
Midline: CZ	$t_1(17) = -2.39$**	-
Midline: CPZ	$t_1(17) = -1.96$*	-
Midline: PZ	-	-

* $p < .1$; ** $p < .05$; *** $p < .001$

Appendix M
Globally Ambiguous Sentences

Neutral Sentences (NS)

1 千賀子はインタビューを受けながら泣いている母親に何気なく目配せした。
2 麻美はテレビを見つめながら着替えている兄にふと語りかけた。
3 佳恵はタクシーを呼びながら走っている弟に何気なく手を振った。
4 強は魚を煮ながら歌っているおばさんに大声で不平を言った。
5 和江はウクレレをひきながら踊っている祖母にふと見とれた。
6 仁は絵をかきながら笑っているおじさんに何気なく向き合った。
7 和夫は写真をとりながら歩いている息子に急いで駆け寄った。
8 朝雄はため息をつきながらさまよっている秘書に大声で不平を言った。
9 理沙子はため息をつきながら泳いでいる教師に大声で謝った。
10 喜久雄はくぎを打ちながらよろめいている上司に急いで呼びかけた。
11 敦は助けを呼びながら溺れている高校生に大声で怒鳴った。
12 秀子は音楽を流しながらわめいているおばあさんに大声で詰め寄った。
13 栄治は警察を呼びながら隠れている高校生に急いで向き合った。
14 創はスナックをつまみながらはしゃいでいるｳｪｲﾄﾚｽに何気なくキスした。
15 健太はテレビを見つめながら勉強している親友に急にしがみついた。
16 麻衣子は汚れを見つめながら掃除しているお父さんに急いで謝った。
17 真紀子はインタビューを受けながら運動している青年に急に向き合った。
18 正子は食べ物をつまみながら運転している若者に突然絡んだ。
19 美津子は水を流しながら洗濯している祖母にやさしく寄り添った。
20 奈々子は写真をとりながら散歩しているサラリーマンにやさしくつぶやいた。
21 百合子はサンプルをもらいながら買い物している若者にふと見とれた。
22 久は絵をかきながら電話している彼女にふとキスした。
23 久子はスナックをつまみながら翻訳しているお父さんに何気なく詰め寄った。
24 学は食べ物をつまみながらゲームしている彼女にやさしくつぶやいた。
25 恵子はﾀｸｼｰを呼びながらあくびしているおじいさんにやさしくつぶやいた。
26 祥子は広告を見つめながらお喋りしている従兄弟に何気なく絡んだ。
27 小百合は涙を流しながら握手しているスポーツ選手にやさしく語りかけた。
28 清は日光を浴びながら昼寝している彼女にふと見とれた。

Embedded-clause bias Sentences (ES)

29 佳恵は涙を流しながら泣いているｳｪｲﾄﾚｽにやさしく寄り添った。
30 千賀子は音楽を流しながら着替えている弟にふと不平を言った。
31 春樹は汗をかきながら走っている兄に突然衝突した。
32 仁はｽﾎﾟｯﾄﾗｲﾄを浴びながら歌っている上司に突然拍手した。
33 梅子はｽﾎﾟｯﾄﾗｲﾄを浴びながら踊っている息子に何気なく拍手した。
34 梅子はﾌﾟﾚｾﾞﾝﾄをもらいながら笑っている妹にやさしく語りかけた。
35 理沙子は杖をつきながら歩いているおじいさんに何気なく手を振った。
36 和夫はゴミをとりながらさまよっているおばさんに急いで謝った。
37 功は鼻をつまみながら泳いでいる妹に突然衝突した。
38 秀子は杖をつきながらよろめいているおじいさんにやさしく寄り添った。
39 喜久雄は悲鳴をあげながら溺れているおばさんに大声で呼びかけた。
40 敦は賞金をもらいながらわめいている秘書に急に飛びついた。
41 健太は水を流しながら隠れている生徒に急いで駆け寄った。
42 栄治はﾌﾟﾚｾﾞﾝﾄをもらいながらはしゃいでいるおばあさんにふと語りかけた。
43 創は英和辞典をひきながら勉強している高校生に急に飛びついた。
44 正子はゴミをとりながら掃除している母親にふと拍手した。
45 浩二は汗をかきながら運動しているスポーツ選手にふと拍手した。
46 喜美子はｻｲﾄﾞﾌﾞﾚｰｷをひきながら運転しているお母さんに急いで謝った。
47 百合子は汚れを見つめながら洗濯しているお母さんに突然衝突した。
48 美津子は日光を浴びながら散歩している祖父に急に飛びついた。
49 進は広告を見つめながら買い物している主婦に急いで駆け寄った。
50 さやかは奇声をあげながら電話しているお母さんにふと目配せした。
51 久は英和辞典をひきながら翻訳している留学生にやさしくキスした。
52 久子は奇声をあげながらゲームしているおじさんに突然怒鳴った。
53 小百合は授業を受けながらあくびしている生徒に急に詰め寄った。
54 恵子はシチューを煮ながらお喋りしている祖父に急いで駆け寄った。
55 祥子は賞金をもらいながら握手している親友にふとしがみついた。
56 進はいびきをかきながら昼寝している留学生に急にキスした。

Main-clause bias Sentences (MS)

57 亜由美は寝返りを打ちながら泣いている弟に突然叫んだ。
58 春樹はシャワーを浴びながら着替えている母親に大声で呼びかけた。
59 麻美は魚を煮ながら走っている従兄弟に大声で怒鳴った。
60 亜由美はいびきをかきながら歌っている妹に突然寝言を言った。
61 強は睡眠をとりながら踊っている従兄弟に突然寝言を言った。
62 和江は助けを呼びながら笑っている息子に何気なくしがみついた。
63 薫は天ぷらをあげながら歩いている青年に大声で怒鳴った　。
64 功はそばを打ちながらさまよっている生徒に急に絡んだ。
65 朝雄はもちをつきながら泳いでいるスポーツ選手にふと見とれた。
66 巌は授業を受けながらよろめいている教師に大声で叫んだ。
67 巌は野菜を煮ながら溺れているおじさんに急いで呼びかけた。
68 薫は睡眠をとりながらわめいている上司に急に寝言を言った。
69 郁代はウクレレをひきながら隠れている秘書に突然飛びついた。
70 郁代は警察を呼びながらはしゃいでいるお父さんに急に詰め寄った。
71 浩二はシャワーを浴びながら勉強している兄に大声で不平を言った。
72 梢はシチューを煮ながら掃除している青年に何気なく向き合った。
73 麻衣子はサンプルをもらいながら運動している若者に急いで目配せした。
74 真紀子は野菜を煮ながら運転している主婦に何気なく手を振った。
75 健吾はくぎを打ちながら洗濯している主婦に何気なく絡んだ。
76 喜美子はテストを受けながら散歩している留学生にやさしく手を振った。
77 奈々子は天ぷらをあげながら買い物しているｻﾗﾘｰﾏﾝにやさしくつぶやいた。
78 学は寝返りを打ちながら電話しているｻﾗﾘｰﾏﾝに突然寝言を言った。
79 梢はもちをつきながら翻訳している教師に急に叫んだ。
80 修はテストを受けながらゲームしている親友に急いで目配せした。
81 修は悲鳴をあげながらあくびしているおばあさんに急にしがみついた。
82 健吾はｻｲﾄﾞﾌﾞﾚｰｷをひきながらお喋りしているｳｪｲﾄﾚｽに大声で叫んだ。
83 清はそばを打ちながら握手している祖父に突然衝突した。
84 さやかは鼻をつまみながら昼寝している祖母にやさしく寄り添った。

Appendix N
Temporarily Ambiguous Sentences

Embedded-clause-structure Sentences

1 美智子はリボンを編んでいるかわいい人にすぐに言い寄った。
2 綾子はマフラーを編んでいる大きな人にそっと質問した。
3 和歌子は髪の毛を編んでいる華奢な人に不注意にも倒れ掛かった。
4 聡はお金を抱えている大きな男に恐る恐る質問した。
5 久美子は辞書を抱えている格好良い男に無言で微笑んだ。
6 智子はビールを抱えている渋い男にいきなり抱きついた。
7 さちこはポケットを縫っている華奢な少女に乱暴に文句を言った。
8 奈津子はイニシャルを縫っているかわいい少女に恐る恐る声をかけた。
9 悦子はぬいぐるみを縫っている素敵な少女に乱暴に殴りかかった。
10 千恵子はおかしを持っている小さい子どもに素早く近づいた。
11 佳代子はいちごを持っているかわいい子どもにおもむろに囁いた。
12 五郎は醤油を持っている華奢な子どもに静かに笑いかけた。
13 健二はスプーンを拭いている懐かしい女優にそっと言い寄った。
14 留美子はティーカップを拭いている有名な女優に不注意にも倒れ掛かった。
15 俊夫はナイフを拭いている美しい女優にいきなり抱きついた。
16 信夫はドラムを作っているきれいな学生に早速挨拶した。
17 雅夫はギターを作っている素敵な学生におもむろに会釈した。
18 信子は詩を作っている格好良い学生に恐る恐る話しかけた。
19 秀雄はボートを修理している大きな芸能人に恐る恐る歩み寄った。
20 定雄はライトを修理している有名な芸能人に早速挨拶した。
21 光男はピアノを修理している格好良い芸能人にゆっくり近づいた。
22 隆は手紙を読んでいる新しい先生にそっと会釈した。
23 寛子はメモを読んでいる懐かしい先生に無言で近寄った。
24 輝夫は論文を読んでいるきれいな先生にさり気なく会釈した。
25 彰人は橋を訪れているきれいな女性に早速ウインクした。
26 武は山小屋を訪れている美しい女性に恐る恐る囁いた。
27 勝也は別荘を訪れている懐かしい女性にいきなり抱きついた。
28 太郎は靴を磨いている新しい友達に無言で会釈した。
29 拓也は歯を磨いている格好良い友達にすぐに挨拶した。
30 まことはめがねを磨いている素敵な友達にゆっくり近づいた。
31 宏はレモンを切っている上品な兄嫁に静かに歩み寄った。

正志はココナッツを切っている小さい兄嫁に早速声をかけた。
満はメロンを切っているきれいな兄嫁に無言で接近した。
道夫は記事を編集している有名な記者に早速質問した。
紀夫はインタビューを編集している新しい記者にいきなり文句を言った。
雄二は新聞を編集している渋い記者に乱暴に殴りかかった。
由紀子は車を売っている格好良い店員にうっかり寄りかかった。
靖子はハンドバッグを売っているお洒落な店員におもむろに質問した。
朝子は傘を売っている新しい店員にさり気なく囁いた。
和子はお茶漬けを食べている渋い彼氏にいきなり抱きついた。
理恵子は味噌汁を食べている新しい彼氏にすぐに笑いかけた。
柚子はフォアグラを食べている上品な彼氏にそっと言い寄った。
貴子はジュースを飲んでいる懐かしい恩人にゆっくり歩み寄った。
咲子はウイスキーを飲んでいる上品な恩人に静かにウインクした。
桃子は薬を飲んでいるきれいな恩人にそっと声をかけた。
靖男は地図を開いている有名なモデルにおもむろに歩み寄った。
明は扇子を開いている懐かしいモデルにそっとお辞儀した。
耕太は手帳を開いているお洒落なモデルにすぐに言い寄った。
花子はかばんを直している格好良い同僚におもむろにお辞儀した。
辰夫は時計を直しているかわいい同僚に無言で微笑んだ。
翔太はトラックを直している大きな同僚にうっかり倒れ掛かった。
朋子は小麦粉をこねている小さいシェフに静かに囁いた。
直美はハンバーグをこねている美しいシェフにうっかり寄りかかった。
隆夫はパン生地をこねている華奢なシェフに乱暴に殴りかかった。
真美子はシールをにぎっているかわいい坊やに素早く接近した。
敏子は花びらをにぎっている小さい坊やに早速話しかけた。
香住はコインをにぎっている華奢な坊やにさり気なく声をかけた。
さとるは氷を割っている渋い俳優におもむろに文句を言った。
和也はくるみを割っている懐かしい俳優にうっかりぶつかった。
絹子は茶碗を割っている有名な俳優に素早く接近した。
不二男は小指を立てている美しい恋人にゆっくり話しかけた。
敦子は前髪を立てている渋い恋人にすぐに笑いかけた。
紀子は襟を立てている上品な恋人に素早く近寄った。
富雄は炭を焼いている上品な夫婦に不注意にも倒れ掛かった。
哲也はりんごを焼いている素敵な夫婦に乱暴に文句を言った。
七恵はマシュマロを焼いているかわいい夫婦にゆっくり近づいた。

67 愛子は万年筆を使っている上品な老人に静かに微笑んだ。
68 静子は虫眼鏡を使っている素敵な老人に無言でお辞儀した。
69 美代子は老眼鏡を使っている小さい老人に不注意にもぶつかった。
70 佳子は紅茶を選んでいる華奢な少年にうっかり寄りかかった。
71 郁子は指輪を選んでいる美しい少年にゆっくり近寄った。
72 昭夫は小石を選んでいる小さい少年に不注意にもぶつかった。
73 希は香水を見ているお洒落な男性に素早く近寄った。
74 翔はカメラを見ている渋い男性に不注意にも寄りかかった。
75 秀樹はコーヒーを見ている大きな男性にうっかりぶつかった。
76 守はスカーフをたたんでいるお洒落な女の子に素早くウインクした。
77 理香子はテーブルクロスをたたんでいる大きな女の子にさり気なく微笑んだ。
78 京子はハンカチをたたんでいるきれいな女の子にいきなり接近した。
79 幹夫はドレッシングを味見している素敵な友人にすぐに笑いかけた。
80 明日香はワインを味見しているお洒落な友人に静かに挨拶した。
81 珠子はつけものを味見している新しい友人にさり気なくお辞儀した。
82 隼人は洋服をデザインしている美しい外人に乱暴に殴りかかった。
83 共恵は家具をデザインしている有名な外人に恐る恐る話しかけた。
84 幸恵はｱｸｾｻﾘｰをデザインしているお洒落な外人にさり気なくウインクした。

Main-clause-structure Sentences

85 美智子はリボンを編んでいるかわいいかごにすぐに添えた。
86 綾子はマフラーを編んでいる大きなかごにそっと入れた。
87 和歌子は髪の毛を編んでいる華奢なかごに不注意にも引っ掛けた。
88 聡はお金を　抱えている大きな袋に恐る恐る移した。
89 久美子は辞書を抱えている格好良い袋に無言で押し込んだ。
90 智子はビールを抱えている渋い袋にいきなりこぼした。
91 さちこはポケットを縫っている華奢なバッグに乱暴につけた。
92 奈津子はイニシャルを縫っているかわいいバッグに恐る恐る加えた。
93 悦子はぬいぐるみを縫っている素敵なバッグに乱暴に押し込んだ。
94 千恵子はおかしを持っている小さいお皿に素早く並べた。
95 佳代子はいちごを持っているかわいいお皿におもむろに移した。
96 五郎は醤油を持っている華奢なお皿に静かに入れた。
97 健二はスプーンを拭いている懐かしい器にそっと添えた。
98 留美子はティーカップを拭いている有名な器に不注意にもぶつけた。

99 俊夫はナイフを拭いている美しい器にいきなり叩きつけた。
100 信夫はドラムを作っているきれいな旋律に早速加えた。
101 雅夫はギターを作っている素敵な旋律におもむろにかぶせた。
102 信子は詩を作っている格好良い旋律に恐る恐るつけた。
103 秀雄はボートを修理している大きな新幹線に恐る恐る運んだ。
104 定雄はライトを修理している有名な新幹線に早速つけた。
105 光男はピアノを修理している格好良い新幹線にゆっくり載せた。
106 隆は手紙を読んでいる新しい教科書にそっとはさんだ。
107 寛子はメモを読んでいる懐かしい教科書に無言で貼り付けた。
108 輝夫は論文を読んでいるきれいな教科書にさり気なく重ねた。
109 彰人は橋を訪れているきれいな田舎に早速かけた。
110 武は山小屋を訪れている美しい田舎に恐る恐る運んだ。
111 勝也は別荘を訪れている懐かしい田舎にいきなり移した。
112 太郎は靴を磨いている新しい自動車に無言で運んだ。
113 拓也は歯を磨いている格好良い自動車にすぐにぶつけた。
114 まことはめがねを磨いている素敵な自動車にゆっくり載せた。
115 宏はレモンを切っている上品なデザートに静かにかけた。
116 正志はココナッツを切っている小さいデザートに早速混ぜた。
117 満はメロンを切っているきれいなデザートに無言で並べた。
118 道夫は記事を編集している有名な本に早速貼り付けた。
119 紀夫はインタビューを編集している新しい本にいきなり載せた。
120 雄二は新聞を編集している渋い本に乱暴に叩きつけた。
121 由紀子は車を売っている格好良い自転車にうっかりぶつけた。
122 靖子はハンドバッグを売っているお洒落な自転車におもむろに運んだ。
123 朝子は傘を売っている新しい自転車にさり気なく引っ掛けた。
124 和子はお茶漬けを食べている渋い料理にいきなりかけた。
125 理恵子は味噌汁を食べている新しい料理にすぐに混ぜた。
126 柚子はフォアグラを食べている上品な料理にそっと加えた。
127 貴子はジュースを飲んでいる懐かしい水割りにゆっくり入れた。
128 咲子はウイスキーを飲んでいる上品な水割りに静かに足した。
129 桃子は薬を飲んでいるきれいな水割りにそっと混ぜた。
130 靖男は地図を開いている有名な雑誌におもむろにはさんだ。
131 明は扇子を開いている懐かしい雑誌にそっと重ねた。
132 耕太は手帳を開いているお洒落な雑誌にすぐに添えた。
133 花子はかばんを直している格好良い原付におもむろに載せた。

134 辰夫は時計を直しているかわいい原付に無言で叩きつけた。
135 翔太はトラックを直している大きな原付にうっかりぶつけた。
136 朋子は小麦粉をこねている小さいパイに静かに足した。
137 直美はハンバーグをこねている美しいパイにうっかり落とした。
138 隆夫はパン生地をこねている華奢なパイに乱暴にかぶせた。
139 真美子はシールをにぎっているかわいいノートに素早く貼り付けた。
140 敏子は花びらをにぎっている小さいノートに早速はさんだ。
141 香住はコインをにぎっている華奢なノートにさり気なく並べた。
142 さとるは氷を割っている渋い日本酒におもむろに足した。
143 和也はくるみを割っている懐かしい日本酒にうっかり落とした。
144 絹子は茶碗を割っている有名な日本酒に素早くかぶせた。
145 不二男は小指を立てている美しいお抹茶にゆっくり入れた。
146 敦子は前髪を立てている渋いお抹茶にすぐにつけた。
147 紀子は襟を立てている上品なお抹茶に素早くかぶせた。
148 富雄は炭を焼いている上品なケーキに不注意にも落とした。
149 哲也はりんごを焼いている素敵なケーキに乱暴に加えた。
150 七恵はマシュマロを焼いているかわいいケーキにゆっくり　はさんだ。
151 愛子は万年筆を使っている上品な筆箱に静かに移した。
152 静子は虫眼鏡を使っている素敵な風呂敷に無言で押し込んだ。
153 美代子は老眼鏡を使っている小さい風呂敷に不注意にも引っ掛けた。
154 佳子は紅茶を選んでいる華奢な宝石にうっかりこぼした。
155 郁子は指輪を選んでいる美しい宝石にゆっくり重ねた。
156 昭夫は小石を選んでいる小さい宝石に不注意にも混ぜた。
157 希は香水を見ているお洒落な長靴に素早くかけた。
158 翔はカメラを見ている渋い長靴に不注意にも落とした。
159 秀樹はコーヒーを見ている大きな長靴にうっかりこぼした。
160 守はスカーフをたたんでいるお洒落なワンピースに素早く　引っ掛けた。
161 理香子はﾃｰﾌﾞﾙｸﾛｽをたたんでいる大きなワンピースにさり気なく重ねた。
162 京子はハンカチをたたんでいるきれいなワンピースにいきなり押し込んだ。
163 幹夫はドレッシングを味見している素敵な定食にすぐにこぼした。
164 明日香はワインを味見しているお洒落な定食に静かに添えた。
165 珠子はつけものを味見している新しい定食にさり気なく足した。
166 隼人は洋服をデザインしている美しい人形に乱暴に叩きつけた。
167 共恵は家具をデザインしている有名な人形に恐る恐る並べた。
168 幸恵はｱｸｾｻﾘｰをデザインしているお洒落な人形にさり気なく貼り付けた。

Appendix O
Survey for Native Speakers of Japanese

アンケート調査

回答の秘密は厳守され、外部に漏れることは一切ありません。
空欄に書ききれない場合は、用紙の裏面を利用していただいても結構です。

受験者番号.:.....

年齢: .....　　性別: □ 男　□ 女　　出生国及び都道府県名: .....

学生ですか?　□ はい　□ いいえ

「はい」と答えた場合、現在の所属を教えてください。(例: 高校一年生、大学三年生、大学院一年生): .....

日本語は母国語ですか?　□ はい　□ いいえ

お母さんは何語を話しますか？ .....　お父さんは?.....

外国語を話せますか。話せる場合は、何語ですか。 .....　何歳の時にその言葉を学び始めましたか。.....

その外国語のレベルを教えてください。
□ 流暢に話せます。　□ まあ上手に話せます。　□ 勉強したけれど、あまり上手に話せません。　□ 少ししか話せません。　□ 外国語は話せません。

その他の外国語の読み書きができますか。それは何語ですか。 .....

その外国語のレベルを教えてください。
□ とても上手に読み書きができます。　□ まあ上手に読み書きができます。　□ 勉強したけれど、あまり上手に読み書きができません。　□ 少ししか読み書きができません。　□ その他の外国語の読み書きはできません。

外国に住んだことがありますか。□ いいえ　□ はい
「はい」と答えた場合、いつ、どこに、どのくらい居たか教えてください。

.....

日本語がほとんど話されない環境下に、２ヶ月以上いたことがありますか?　□ いいえ　□ はい
「はい」と答えた場合、いつ、どこに、どのくらい居たか教えてください。

.....

教育環境(当てはまるもの全てにチェックをつけてください。「外国語環境」の場合は、空欄に何語かを書いて下さい。)

小学校	□ 日本語環境	□ 外国語環境.....
中学校	□ 日本語環境	□ 外国語環境.....
高校	□ 日本語環境	□ 外国語環境.....
大学	□ 日本語環境	□ 外国語環境.....
大学院	□ 日本語環境	□ 外国語環境.....

Appendix P
Survey for L2 Learners of Japanese

BACKGROUND INFORMATION

All personal information you will provide is confidential. Feel free to use the back of the sheet if you need more room.

Participant No.: .....

Age: ..... Sex: □ male □ female City/Country of birth: ....

Are you a student? □ yes □ no

If yes, please indicate your current level of education: ....
(For example: high school- first year; college-third year; graduate school-first year)

Is English your native language? □ yes □ no

What language(s) does your mother speak? ..... your father?.....

How old were you when you started to learn Japanese?.....

How many years have you studied Japanese? .....

Please rate your proficiency in Japanese:
□ I speak it fluently □ I speak it somewhat well □ I have studied it, but I don't speak it well □ I speak it a little

Do you study Japanese in your free time (not for school purposes)? □ yes □ no

If yes, how many hours per week do you practice Japanese? .....

What do you do to study Japanese?
□ read books
□ watch movies or television
□ listen to music
□ other .....

Do you speak Japanese outside of your language class? □ yes □ no

If yes, how many hours per week do you speak Japanese? .....

Who do you speak Japanese with?
□ significant other who is native speakers of Japanese
□ friends who are native speakers of Japanese
□ friends who are not native speakers of Japanese
□ boss or other people at work
□ other .....

Do you have a job that requires you to use Japanese on a daily basis? □ yes □ no

If yes, what job do you have? .....

Do you know any additional language? □ yes □ no

If yes, what language is it? .....

Please rate your proficiency in that language:
□ I speak it fluently □ I speak it somewhat well □ I have studied it, but I don't speak it well □ I speak it a little

Have you ever lived outside of the United States?
□ No
□ Yes. Describe briefly where, when, and for how long: .....

Have you spent any time longer than two months living in an environment where English is not the majority language?

- ☐ No.
- ☐ Yes. Describe briefly where, when, and for how long: .....
  .....

Education background (check all that apply, and please list the language, if applicable, on the right):

elementary school	☐ in English	☐ in another language.....
junior high school	☐ in English	☐ in another language.....
high-school	☐ in English	☐ in another language.....
college	☐ in English	☐ in another language.....
graduate school	☐ in English	☐ in another language.....

Location (check all that apply, and please list the place, if applicable, on the right):

Where did you attend elementary school?	☐ in the U.S.	☐ elsewhere .....
Where did you attend junior high school?	☐ in the U.S.	☐ elsewhere .....
Where did you attend high-school?	☐ in the U.S.	☐ elsewhere .....
Where did/do you go to college?	☐ in the U.S.	☐ elsewhere .....
Where did/do you go to graduate school?	☐ in the U.S.	☐ elsewhere .....

Thanks for your cooperation!

Please take a moment now to make sure that you have filled in all the blanks.