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Sentence Processing and Prosody:
A comparison between hearing-loss and hearing readers

by

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "Sentence Processing and Prosody: A comparison between hearing-loss and hearing readers" submitted by Seiko Sagae in partial fulfillment of the requirements for the degree of Master of Arts.

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ABSTRACT

When we read the written form of a language, we evidently need to convert from the written form to the phonological form (phonological coding). Fodor (1998, 2002) claimed that the prosody of inner speech (implicit prosody) which is the product of phonological coding is an important factor in the resolution of syntactically ambiguous sentences in silent reading. Bader (1998) also claimed that prosody influences the levels of difficulty readers have in sentence processing. This thesis investigates the role of prosody in silent reading conducting a questionnaire and an eye-tracking study by comparing hearing-loss and hearing readers. The studies show that while the behavior of hearing-loss subjects was similar to that of hearing subjects when the sentence processing did not involve certain prosodic factors, it was different when the sentence processing involved prosodic analysis. The results indicate that the hearing-loss subjects were less sensitive to the prosodic structure of the sentences.

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CHAPTER 1: INTRODUCTION

This thesis examines the relationship between prosody and sentence processing in silent reading. Many studies of sentence processing in silent reading involve syntactically ambiguous sentences and study how readers process the sentences to interpret them correctly. Although silent reading does not involve the articulation of sounds, studies have shown that there is some phonological processing involved. That is, when we read written sentences silently, we supply phonological information including prosody[1] to interpret the sentence. My interest is how we use phonological information during silent reading. If the interpretation of written languages requires phonological information, do people who cannot hear or cannot speak interpret the written language differently? In order to investigate the use of prosody during silent reading, I compared English sentence processing in silent reading by deaf and hard of hearing[2] people with hearing people.

Before discussing the relationship between sentence processing in silent reading and prosody, I will introduce the reading model of Rayner and Pollatsek (1989). Although there are many reading models (Goodman 1970, Gough 1972, Rumelhart 1977, Just and Carpenter 1980), it is not my goal to model the reading process, thus I have chosen this model to introduce two components which I am interested in (syntactic processing and phonological processing).

1.1 The Reading Process

The reading model of Rayner and Pollatsek (1989) begins with word recognition and lexical access in long term memory. For example in sentence (1), a reader starts looking at the letter

[1] Prosody: rhythm and intonation in speech

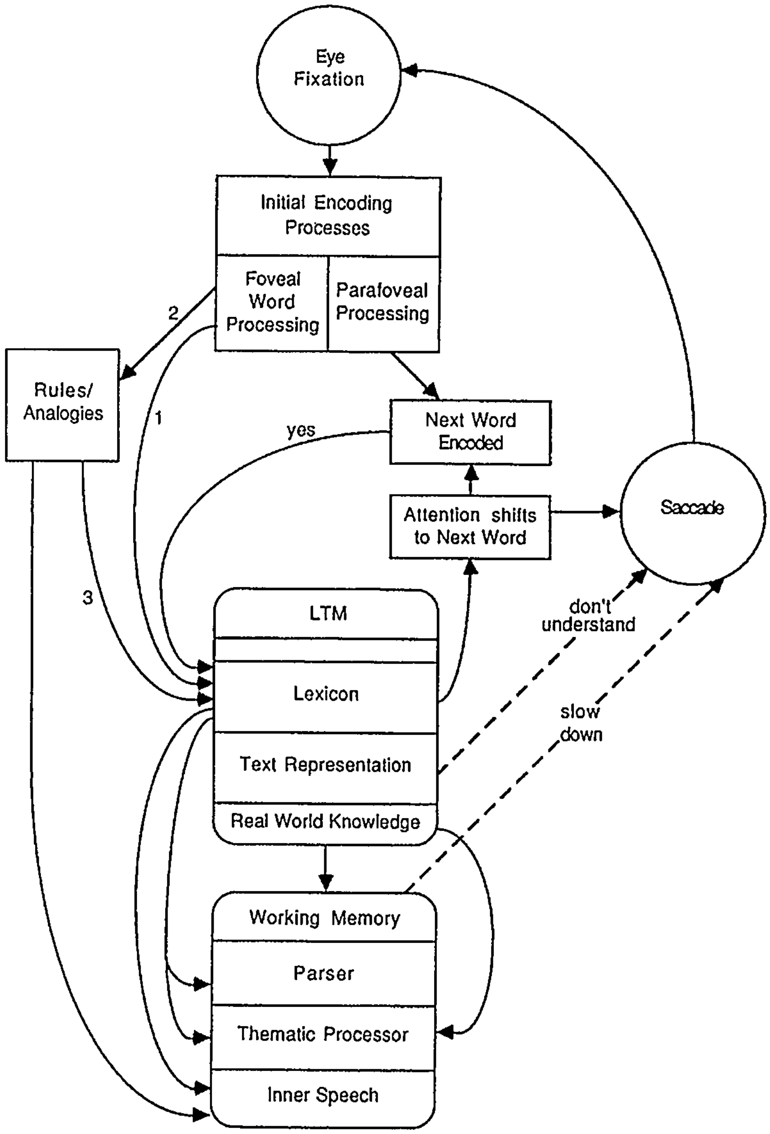
[2] Hard of hearing: Partially deaf (Colman 2006)

'S'… 'u' … 'p'… 'Superman', then finds out what 'Superman' is from the lexicon.

(1) Superman is Clark Kent.

Long-term memory has three components: (a) the lexicon; (b) real-world knowledge; (c) text representation (which is a product of what has been read). After lexical access has taken place, the reader's attention moves to the next word. At the same time as lexical access, however, other processes in working memory and long term memory also work together. Working memory involves three modules: (a) a module that holds inner speech; (b) a syntactic parser; and (c) a thematic processing module (Rayner and Pollatsek 1989).

Figure 1.1 A model of sentence reading[3] (Rayner and Pollatsek 1989)



The function of inner speech is holding (saving) phonologically coded information which is converted from written information (what has been read) in the working memory. If readers

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[3] Fovea: about 2 degrees of visual angle around eye fixation point

Parafovea: about 10 degrees of visual angle around eye fixation point (4 degrees to the left and to the right beyond the foveal region)

Saccade: eye movement

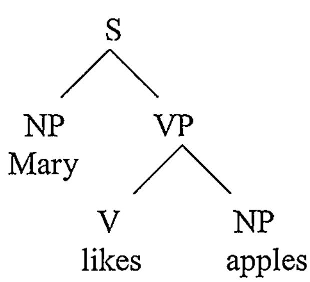
experience comprehension difficulty, they consult the inner speech representation or look back in the text. For example, sentence (2) can make the reader wonder "Tom … chases mice?". Then the inner speech representation of *Tom* in the working memory looks in the lexicon again to extract a more proper *Tom* which is the name of a cat.

(2) Tom likes chasing mice.

The function of the parser is to determine the syntactic structure of a sentence. The parser receives input from the lexicon about the syntactic information (such as syntactic class) of each word as it is read and constructs a syntactic representation. For example, the parser assigns the word *Mary* in sentence (3) to a subject of the sentence, *likes* to a head of a verb phrase and *apples* to a complement of a verb phrase and combines them to the syntactic structure in Figure 1.2.

(3) Mary likes apples.

Figure 1.2 A syntactic structure of sentence (3)



The function of the thematic processor is to monitor the semantic content of the text and choose the semantically and pragmatically most plausible one from a range of possible thematic interpretations. The thematic processor has available to it real-world pragmatic information which is in long-term memory. For example, the thematic processor judges *Tom* in sentence (2) is not a person from the context (what Tom likes chasing are mice) and real-world information (cats likes chasing mice) in long term memory. The details of inner speech and the parser will be discussed in Chapter 2.

1.2 Organization of this thesis

In Chapter 2, I will discuss aspects of two components in working memory: the parser and inner speech. In Chapter 3, I will discuss two theories of sentence processing (parsing) which involve implicit prosody. In Chapter 4, I will discuss the relationship between reading and hearing loss focusing on phonological coding. In Chapter 5, I will discuss the purpose of this thesis, assumptions and a hypothesis in my research, and general discussion about my research. Chapter 6 and 7 are reports of two studies, questionnaire and eye-tracking experiments. In Chapter 8, I will summarize the findings from two experiments and discuss future directions.

CHAPTER 2: PARSING AND PHONOLOGICAL CODING

In Chapter 1, I introduced the two components (parser and inner speech) of a reading model. In this chapter, I will discuss the details of these two components. In the first section, the parsing system and parsing strategies are discussed. In the next section, the evidence for phonological coding (which is the basis of inner speech) is discussed.

2.1 Parsing

The parser in working memory examines the string of words of an input sentence and assigns that string a well-formed syntactic structure, given a particular grammar. This process is called parsing. For example, sentence (4) is grammatical, sentence (5) is grammatical (even though pragmatically odd), but sentence (6) is not grammatical. The parser consults with a grammar and decides this sentence is not acceptable because the definite article *the* does not come after a noun in a grammar of English.

(4) The cat chases the mouse.

(5) The mouse chases the cat.

(6) *[4]The cat chases mouse the.

Sentence processing is highly incremental (i.e., proceeds on a word-by-word basis) (Bever 1970, Tyler and Marslen-Wilson 1977), in both spoken and written language. Language is processed on-line, as it is heard or read. For example, an English written sentence is processed from left to right. Because of the on-line nature of processing, the parser is sometimes required to analyze the sentence again when it is syntactically ambiguous. For example, sentence (7) is

[4] * indicates ungrammatical.

syntactically ambiguous and it causes the parser reanalyze the sentence.

(7) The horse raced past the barn fell. (Bever 1970)

This syntactic ambiguity is due to the word *raced*. The syntactic classification of the word *raced* is either a past tense verb or a past participle. First, the parser assumes the word *raced* is a past-tense verb, and it assumes that "*The horse raced past the barn*" is a complete sentence. When the parser reaches another verb *fell*, it realizes the analysis is not right, and then backtracks to the part which needs to be reanalyzed, in this case the word *raced*, and reanalyzes the word *raced* as a past participle.

Figure 2.1 Parsing process of sentence (7)

(7) The horse *raced* past the barn…*fell* ?

☹

backtrack

The horse *raced* past the barn *fell*.

☺

This type of sentence which requires backtracking to analyze the sentence again is called a 'garden-path' sentence. The reason why sentence (7) causes a garden-path effect is because the initial analysis of the parser is wrong. For example, sentence (8) does not require backtracking, because word *taken* is parsed as a past participle easily.

(8) The horse taken past the barn fell.

The example of the garden path sentence indicates that the parser does not wait until the syntactically ambiguous part becomes unambiguous before processing. In the case of sentence (7), if the parser did not assign the word *raced* as a past tense verb until the parser reaches the word *fell*, the parser would not need to backtrack and reanalyze the sentence. Does the parser always process this way or does it sometimes wait for a while to process? In the following sections, I will introduce some parsing strategies.

2.1.1 Late Closure

One of the parsing strategies Frazier (1978) proposed is 'Late Closure' which states that "every item which can (according to the rules of the language) be analyzed as part of the clause currently being parsed is analyzed as part of that clause."

(9) Hans claimed he went to London last week. (Frazier 1978)

For example, the phrase *last week* in sentence (9) can be attached to either the higher verb phrase (VP) *claimed* meaning *Hans claimed ... last week.* (Figure 2.2) or to the lower VP *went* meaning *Hans ... went to London last week.* (Figure 2.3).

Figure 2.2 High Attachment

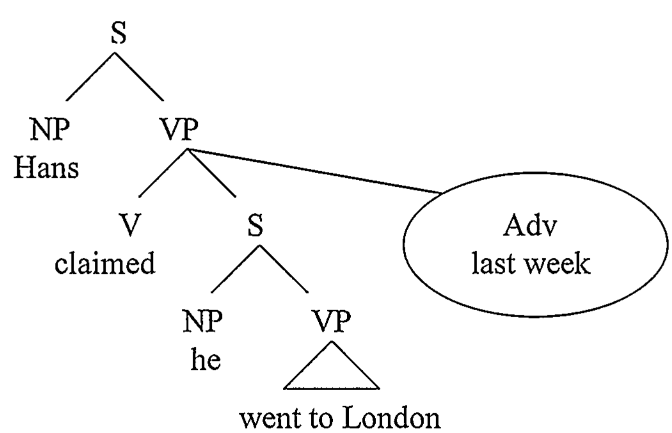
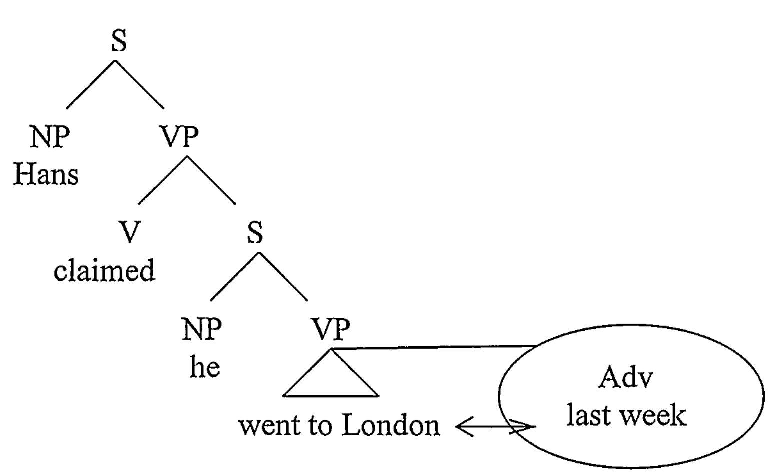


Figure 2.3 Low Attachment



According to LC, *last week* attaches into the clause currently being parsed (*he went to London*). Thus, Late Closure predicts that the preferred interpretation is the lower attachment *Hans … went to London last week*. Late Closure is a parsing strategy based on a locality preference for choosing as the attachment clause which is closer (a clause currently being parsed) to the incoming input (word).

2.1.2 Early Closure

The parsing strategy which readers close a syntactic phrase structure as soon as possible is called 'Closure'. This is defined as (10).

(10) Closure (Kimball 1973)

> A phrase is closed as soon as possible, i.e., unless the next node parsed is an immediate constituent of that phrase.

From now on, I will use the term 'Early Closure' for Kimball's 'Closure' in order to contrast with Frazier's (1978) principle of 'Late Closure'.

For example, sentence (11) is perceptually complex, because as soon as the parser reaches the word *the water*, which is the end of a potential sentence (S), the parser closed the processed sentence. After the sentence is closed, the parser finds another word *sank*. The parser's first analysis is wrong and it requires reanalysis of the sentence. This makes the interpretation of the sentence difficult.

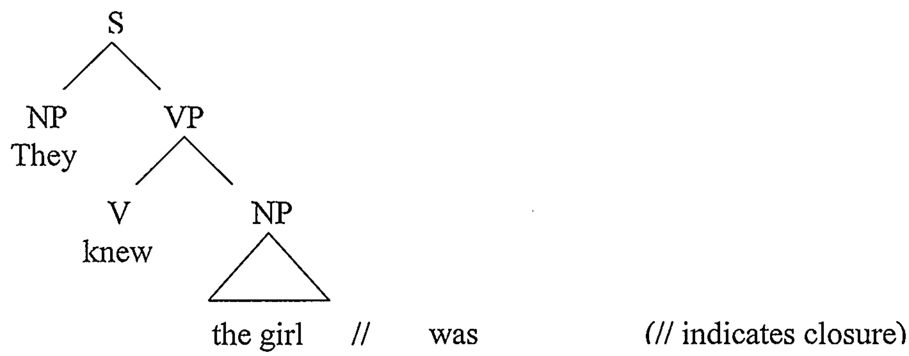
(11) The boat floated on the water sank.

The perceptual complexity of sentence (12b) over that of (12a) is also explained by Early Closure.

(12) a. They knew that the girl was in the closet.
b. They knew the girl was in the closet.

The complementizer *that* in (12a) signals that an embedded clause is coming. However the absence of the complementizer in (12b) makes the parser close the S when it processes “They knew the girl” (see Figure 2.4).

Figure 2.4 Early Closure



The parser notices this analysis is wrong when it reaches the next word *was* and requires reanalysis. Thus, sentence (12b) which requires reanalysis is perceptually more complex than sentence (12a) which does not require reanalysis.

2.1.3 The Dependency Locality Theory

The Dependency Locality Theory (Gibson 1998, 2000) states that the complexity of sentence interpretation is explained by the two components ‘integration’ and ‘storage’ in syntactic processing. Integration complexity depends on the distance between the head and dependent being integrated (i.e., locality). For example, the integration cost between the words α and β which is a new word is proportional to the number of discourse objects and events (nouns and verbs, roughly) which are processed after the word α.

For example, discourse objects in sentence (13) are *reporter* and *senator*, and a discourse event is *attacked.*

(13) The **reporter attacked** the **senator**.

1 1

The word *reporter* is the first discourse object. When the next discourse event *attacked* is parsed, it integrates to the *reporter* to make a syntactic phrase. This integration costs 1. Next, when the word *senator* is parsed, it integrates to the word *attacked*, integration cost 1 occurs. Thus, integration cost of this sentence is 2.

The evidence of the relationship between integration costs and the complexity of sentence interpretation is provided by a comparison between subject-extracted relative clause (RC) and object-extracted RC sentences. For example, sentence (14a) is a subject-extracted RC sentence. The subject of the RC corresponds to the relative pronoun. Sentence (14b) is an object-extracted RC sentence. The object of the RC corresponds to the relative pronoun.

(14) a. Subject-extracted RC: The reporter who ___ attacked the senator admitted the error.

b. Object-extracted RC: The reporter who the senator attacked ___ admitted the error.

The distance between the relative pronoun *who* and the position which it is extracted in the object-extracted RC is longer than that of the subject-extracted RC.

The integration costs of sentences (14a) and (14b) are shown in Figure 2.5 and 2.6.

Figure 2.5 Subject-extracted RC (boldface indicates discourse objects and events)

3

The **reporter** who **attacked** the **senator** **admitted** the **error**.

1 1 1 Total 6

In the subject-extracted RC sentence, the integration of a word *attacked* to *reporter* costs 1. The integration of a word *senator* to *attacked* costs 1. These integrations produce a noun phrase (NP) which is a part of the subject of the sentence. The word *admitted* needs to integrate to the NP.

Measurement of the integration costs of this NP and the verb *admitted* involves counting the number of discourse objects and events which are added since the head of the NP (*reporter*) was parsed. Since the word *reporter* was parsed, 1 discourse object (*senator*) and 2 discourse events (*attacked* and *admitted*) were added. Thus, integration costs are 3. Lastly, the discourse object *error* is integrated to *admitted* and it costs 1. The total integration costs are 6 in sentence (14a). The integration costs of sentence (14b) is measured the same way and calculated as 7.

Figure 2.6 Object-extracted RC (boldface indicates discourse objects and events)

1 3

The **reporter** who the **senator** **attacked** **admitted** the **error**.

2 1 Total 7

The integration costs of the object-extracted RC (= 7) are greater than those of the subject-extracted RC (= 6). Thus, the theory predicts that the object-extracted RC is more difficult to process than the subject-extracted RC.

Both integration costs and storage costs increase due to the distance between the head and dependent being integrated. I discussed only integration cost here. For the measurement and calculation of the storage costs, see Gibson (1998).

2.1.4 Relative Clause Attachment Ambiguity

A situation known as relative clause (RC) attachment ambiguity arises when the parser can chose either Late Closure or Early Closure for a given string. An RC is the clause that modifies a noun (or noun phrase). For example, in sentence (15), the RC *who is wearing a black hat* modifies the noun *man*.

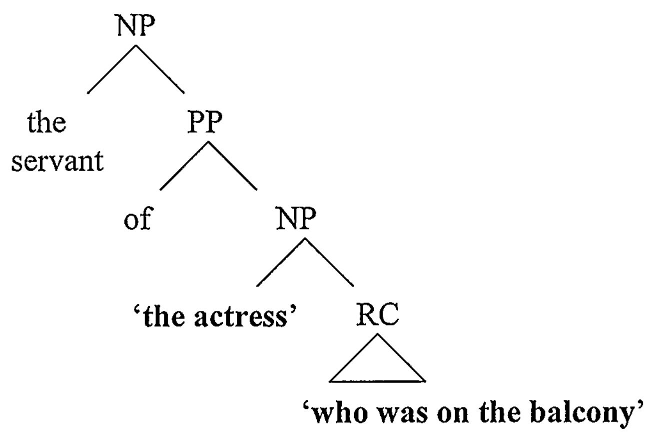
(15) I saw [the man [$_{RC}$ who is wearing a black hat]].

The possibility of ambiguity arises when there is more than one noun which the RC can modify, as shown in sentence (16). In this sentence, the RC *who was on the balcony* can modify either *servant* or *actress*.

(16) Someone shot the servant of the actress who was on the balcony.

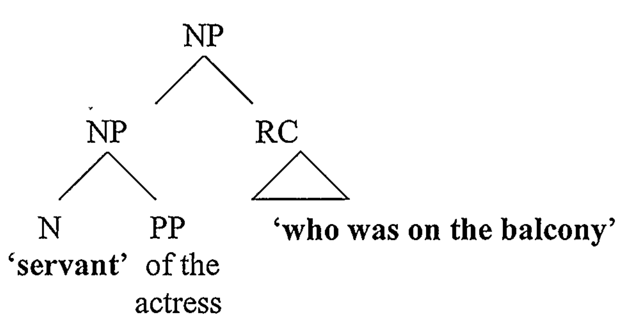
If the answer of the question "*who was on the balcony?*" for sentence (16) is *actress* (which is closer to the RC), it is called Low Attachment (LA). This interpretation is explained by Late Closure. The RC attaches to the phrase currently being parsed.

Figure 2.7 Low Attachment



However, if the answer of the question "*who was on the balcony?*" for sentence (16) is *servant* (which is far from the RC), it is called High Attachment (HA). This interpretation is explained by Early Closure. The NP "the servant of the actress" is closed before parsing the RC.

Figure 2.8 High Attachment



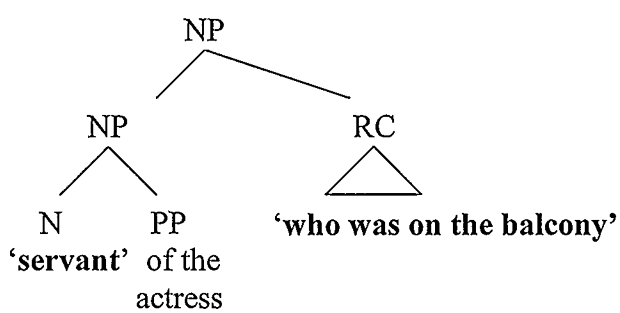
These RC-attachment preferences are non-universal phenomena. For example, English speakers prefer LA (Cuetos and Mitchell, 1988), while Spanish speakers prefer HA (Fernández, 1998), and Japanese speakers prefer HA (Kamide and Mitchell, 1997). The parsing strategy of a language is not based on the syntactic structure of that language (or word order of that language). For example, the Spanish RC constructions are syntactically identical to the English ones (see (17)).

(17) Spanish

Alguien disparó al sirviente de la actriz que estuvo en el balcón.
someone shot the servant of the actress who was on the balcony
'Someone shot the servant of the actress who was on the balcony.'

However, Spanish speakers prefer to interpret the RC as modifying the noun far from it, in this case *servant.*

Figure 2.9 Syntactic structure of RC of sentence (17)



HA preference

Who was on the balcony?... servant (Spanish)

The preference is also not consistent within a particular language. For example, French speakers strongly prefer HA when the relative clause is long, such as "*who cried all through the night*" but there is no preference for either HA or LA when the RC is short, such as "*who cried*". (Pynte & Colonna 2000). The issue of what influences the parser to choose HA or LA will be discussed in Chapter 3.1.

2.2 Phonological Coding

As I introduced in Chapter 1, one of the components of working memory in Rayner and Pollatsek's (1989) reading model is inner speech. This inner speech representation is the result of the phonological coding[5] of printed words. Rayner and Pollatsek defined phonological coding as "Mental representations of speech that can give rise to the experience of hearing sounds." They pointed out the experience of hearing the voice of the writer when you read a letter silently. In order to investigate this phonological coding during silent reading, a variety of studies were conducted. I will discuss those studies in chronological order.

2.2.1 Proof reading study

In order to investigate inner speech, Corcoran (1966, 1967) conducted two experiments. His evidence showed that the acoustic image of a word was processed as well as the visual stimulus during the silent reading. In his first experiment (Corcoran 1966), he asked subjects to cross out all the letters '*e*' from a text. Subjects were told to cross out '*e*' as quickly as possible, rather than slow down and try for perfect accuracy. The results, shown in Table 2.1, are categorized into three types. One is *e* in the word *the* (/ə/), one is *e* in words which pronounced the *e* (e.g., /ɛ/ as in *set*, /i/ as in *seat*), and the third is *e* in the word which is not pronounced (i.e., a silent *e* as in *liked*.).

Table 2.1 Probabilities of missing an e *in words: 'the', when pronounced, and when silent*

'the'	pronounced	silent
0.32	0.04	0.15

(Corcoran 1966)

Subjects missed crossing 15% of *e* in silent *e* words, while they missed crossing only 4% of *e* in

[5] It is also called *speech recording, phonetic recoding, phonemic recoding,* and *deep phonemic recoding.*

words with a pronounced *e*. Subjects were significantly more accurate crossing *e* which is pronounced than *e* which is silent. Corcoran explained that the significant missing of *e* in "the" could be due to the terminal position of *e* in the word and that the word "the" is highly redundant.

In his second experiment (Corcoran 1967) he asked subjects to identify instances where '*e*'s had been omitted from a text. The results are shown in Table 2.2.

Table 2.2 Probabilities of failing to detect missing letters

<table>
<tr><th></th><th>Pronounced "e"</th><th>Silent "e"</th><th>"the"</th></tr>
<tr><td>Early</td><td>0.17</td><td>0.66</td><td rowspan="3">0.27</td></tr>
<tr><td>Penultimate</td><td>0.13</td><td>0.35</td></tr>
<tr><td>Terminal</td><td>0.06</td><td>0.15</td></tr>
</table>

(Corcoran 1967 modified)

The probability of failing to notice the omission of a silent *e* is significantly greater than that for missing a pronounced *e*.

The results of both the detection of an existing *e* and the absence of an *e* tasks showed that readers activate an acoustic image of a word during silent reading. If these had been only visual tasks and not tasks involving phonology, then there should not have been difference.

2.2.2 Syllable-length effect

Klapp (1971) proposed that comprehension involves inner speech[6]. If comprehension in silent reading involves inner speech, the response latency (response time for the question after the subjects are given stimuli) should depend on the number of syllables. He asked subjects to look at and read silently two two-digit numbers which have the same numbers of syllables and asked them to answer as quickly as possible whether the two numbers are the same or different. For

[6] Klapp calls it implicit speech.

example, when reading two two-digit numbers which each have two syllables (14-20) which are different numbers, the subjects should respond aloud 'different'. When reading two numbers with 3 syllables (28-28) which the numbers are same, they should respond 'same'. The results are shown in Table 2.3.

Table 2.3 Response latencies for two two-digit numbers (msec.)

Response	Syllables to pronounce			
	2	3	4	average
Same	600	648	663	637
Different	699	675	717	697
Average	650	663	690	

(Klapp 1971)

The average of response time for 2 syllables number pairs were 650 msec. The numbers of syllables increased to 3 and 4, the average of response time increased 663 and 690 msec. respectively. This means the greater numbers of syllables leads to greater delay in the onset of vocalization.

The next experiment asked subjects to look at and read silently two words which have the same numbers of syllables and asked them to answer as quickly as possible whether the two words are the same or different. For example, subjects read two words with one syllable and they are the same words (*paint-paint*) and should respond 'same'. When reading two words of two syllables and they are different words (*color-cover*) they should respond 'different'. The results are shown in Table 2.4.

Table 2.4 Response latencies for two words (msec.)

Response	Syllables to pronounce		
	1	2	average
Same	662	662	662
Different	705	751	728
Average	684	707	

(Klapp 1971)

The results of both experiments showed that when the number of syllables increased the response latency increased in the comprehension of both printed numbers and words. These results support the argument that inner speech is involved in silent reading.

2.2.3 Tongue-twister effects

Based on the assumption "If there is no articulatory component in silent reading, then any differences in oral reading speed between tongue twisters and their controls should disappear during silent reading" (Haber and Haber 1982). The experiment of Haber and Haber measured reading speed of tongue-twister sentences in reading aloud and silent reading conditions. Subjects were asked to read each sentence five times as quickly as possible. Their reading aloud was recorded, and, for the silent reading, subjects were asked to tap a microphone when they finished each repetition. The paired sentences (tongue-twister sentences and control sentences) had the same syntactic structure, number of syllables, and number of stresses. The results are shown in Table 2.5.

Table 2.5 Mean duration of reading times (sec.), averaged over the five repetitions as a function of sentence form (tongue-twisted or control) and mode of reading (silent or aloud)

	Tongue-twister form	Silent	Aloud	Control form	Silent	Aloud
1	Barbara burned the brown bread badly.	1.8	2.7	Samuel caught the high ball neatly.	1.6	2.3
2	The wild wind whipped White from the wharf.	2.0	2.8	The good boy took meat from the store.	1.8	2.2
3	Nine nimble noblemen nibbled nuts.	1.8	2.4	The handsome fishermen baited hooks.	1.8	2.2
4	She sells seashells by the seashore.	1.7	2.5	He finds string beans by the small barn.	1.8	2.4
5	Francis Forbe's father fries five flounders.	2.1	3.0	Mary Wright's uncle cooks red lobsters.	1.8	2.6
6	Which witches wished wicked wishes?	2.2	2.9	Which pilot flew heavy bombers?	1.6	2.1
7	The bootblack brought the black book back.	2.6	2.4	The salesman brought the new car in.	1.8	1.6
8	Five French friars fanned the fainting flea.	2.2	2.8	Two old ladies saw the running man.	1.8	1.7
9	The Swiss wristwatch strap shop shuts soon.	2.6	4.1	The brown bearskin rug man left town.	2.0	2.5
10	Naughty Nan's knitting knotted nighties.	2.0	2.3	Little Tom's reading sexy novels.	1.8	1.8
	Mean	2.12	2.80	Mean	1.79	2.14

(Haber and Haber 1982)

These results showed that out-loud reading times of tongue twisters were longer than their control version. Mean times for individual subjects were analyzed in three-way analysis of variance form, mode, and repetition. All three effects were significant. Tongue twisters were read more slowly than their control version was read. Out-loud reading was slower than silent reading. Reading time speeded up with repetition. Although out-loud reading took longer than silent reading, the same effects occurred in silent reading. Thus, Haber and Haber concluded that silent reading involved a processing of an articulation.

2.2.4 Visual tongue-twister effects

McCutchen and Perfetti (1982) investigated whether phonological activation took place in silent reading. Subjects were asked to read tongue-twister sentences and non-tongue-twister sentences silently and aloud, and judge whether the sentence was semantically acceptable or not. They were asked to press the appropriate button as soon as a decision had been made. The response time was recorded. The tongue-twister sentences consisted of several words starting with bilabial consonants (/b/ or /p/), or alveolar consonants (/d/ or /t/), or velar consonants (/g/ or /k/). Examples in the experiments are shown in Table 2.6.

Table 2.6 Examples of materials

"yes"	Bilabial:	The bronze bars were brought in bags to the bank.
	Alveolar:	His tall tales were taken as truth by the twins.
	Velar:	The gas cans were claimed as the cause of the crash.
	Neutral:	His exaggerated stories were believed by his sons.
"no" [7]	Velar:	The ground clothes were concentrated as the cart of the code.

("yes": semantically acceptable, "no": semantically unacceptable)

(McCutchen and Perfetti 1982)

They found that the response time for tongue-twister sentences both in silent reading and reading aloud required more time than neutral sentences.

2.2.5 Electromyography Evidence

McGuian and Dollins (1989) recorded electromyography during silent reading to investigate whether phonetic coding is generated and transmitted through neuromuscular circuits. Electromyography (EMG) is the recording of the electrical activity of muscle tissue by means of electrodes. This is another way to see if articulatory activity is generated by silent reading, in

[7] Examples of semantically unacceptable sentences which include words starting with bilabial, alveolar, and neutral were not provided in McCutchen and Perfetti (1982).

other words, if covert speech occurs during silent reading.

The subjects were shown slides of the letters "P" (bilabial sound), "T" (coronal sound with tongue movement), plus a control letter "C" (coronal sound without tongue movement), and asked to read silently. When reading the letter "P", lip muscles were active (though not necessarily visibly moving). When reading the letter "T", the tongue muscles were active. Thus, if the muscles are active during silent reading, it demonstrates the existence of covert speech. The results are shown in Table 2.7.

Table 2.7 Mean increases over baseline for comparisons between stimulus conditions as a Function of speech muscle location (N=11)

Response	Stimulus Comparison	Difference	*t*
Lips	P vs. T	6.03	1.95*
	P vs. Control	8.2	2.77*
	T vs. Control	2.17	1.31
Tongue	T vs. P	13.8	1.83*
	T vs. Control	17.66	2.41*
	P vs. Control	3.86	1.05

*$P<0.05$, $df=10$

(McGuian and Dollins 1989)

The results showed that lip muscular activity increased when subjects processed "P" significantly more than when processing "T" and tongue muscular activity increased significantly more while processing "T" than it did while processing "P". On the other hand, since neither "T" nor "C" uses the lips, and neither "P" nor "C" uses the tongue, the contrasts between them were not significant. The results showed that phonological coding was generated and transmitted through neuromuscular circuits. This demonstrates that inner speech was invoked during silent reading.

In this chapter, I discussed parsing and phonological coding which is the basis of inner speech. I introduced parsing strategies: Late Closure (Locality Preference), Early Closure. RC-attachment preference is explained by Late Closure and Early Closure. In the next chapter, I will discuss two theories of parsing which involve prosody in inner speech.

CHAPTER 3: SENTENCE PROCESSING AND PROSODY

In Chapter 2, two components of sentence processing, — parsing and phonological coding (inner speech) — were discussed. In this chapter I will discuss two theories of sentence processing: the Implicit Prosody Hypothesis and the Prosodic Constraint on Reanalysis. These two theories have common idea that parsing is influenced by prosody in inner speech (implicit prosody).

3.1 The Implicit Prosody Hypothesis

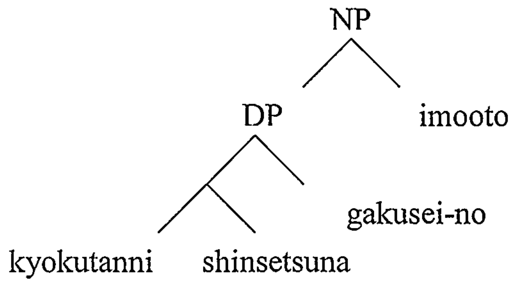
3.1.1 Prosodic Phrasing and Syntactic Structure

As we saw in Chapter 2.1, Low Attachment (LA) in Relative Clause (RC) attachment is the result of a Late Closure parsing strategy. However, remember that this LA preference is not universal because sometimes the parsing strategy of Early Closure results in a High Attachment (HA) preference. These contradictory parsing strategies can be found in the same language, thus they are not language-specific parsing strategies. For example, the Japanese sentence given in (18) can be interpreted in two ways as shown in Figure 3.1 and Figure 3.2.

(18) kyokutanni shinsetsuna gakusei-no imooto
extremely kind student-GEN sister (GEN: genitive case)
"extremely kind student's sister" [AMBIGUOUS]
(Fodor 1998 modified)

Figure 3.1 Interpretation #1 of sentence (18)

[[extremely kind student]'s [sister]] "sister of an extremely kind student"



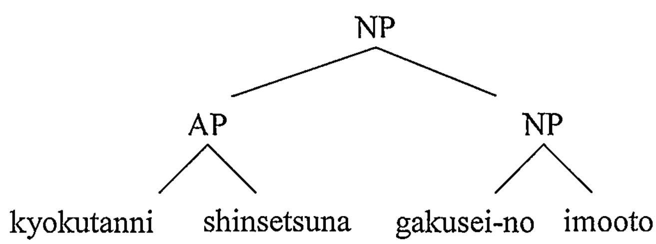
(Fodor 1998 modified)

Figure 3.1 shows that incoming words attached into the currently processed phrase (DP) as many as possible. This is the product of the Late Closure parsing strategy.

On the other hand, the syntactic phrase in Figure 3.2 closed as soon as possible. This is the product of the Early Closure parsing strategy.

Figure 3.2 Interpretation #2 of sentence (18)

[[extremely kind] [student's sister]] "extremely kind sister of a student"



(Fodor 1998 modified)

However, the preferred interpretation is Figure 3.2 which is the product of Early Closure. According to Fodor (1998), the sentence is syntactically balanced (the two branches of the syntactic tree are balanced[8]). In contrast, when the modifier is simple (*shinsetsuna* 'kind') instead of the complex modifier (*kyokutanni shinsetsuna* 'extremely kind'), the reading shown in (19b) is preferred.

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[8] The numbers of nodes in the left branch are the same or close to the number of nodes in the right branch.

(19) a. shinsetsuna gakusei-no imooto
kind student-GEN sister
"kind student's sister" [AMBIGUOUS]

b. [[kind student]'s [sister]]
"sister of a kind student" [PREFEERED]

c. [[kind] [student's sister]]
"kind sister of a student" (Fodor 1998)

Fodor (2002) claims that these modifier length effects are explained in terms of the syntax-phonology interface. Her explanation is based on the optimal length of a prosodic phrase (a major phrase in Selkirk (2000)). The optimal length of a prosodic phrase (a major phonological phrase[9]) consists of two minor (accentual) phrases, not one or three (Selkirk 2000).

(20) a. [[extremely kind student]'s / [sister]] [3 minor phrases / 1 minor phrase]
b. [[extremely kind] / [student's sister]] [2 minor phrases / 2 minor phrases]
c. [[kind student]'s / [sister]] [2 minor phrases / 1 minor phrase]
d. [[kind] / [student's sister]] [1 minor phrase / 2 minor phrases]
(/: prosodic phrase boundary)

This optimal length explains the different preferences of parsing strategies between Early Closure and Late Closure. The parsing strategy Late Closure produced the syntactic structures (20a) and (20c). The parsing strategy Early Closure produced the syntactic structures (20b) and (20d). In terms of the optimal length, which is 2, (20b) (= Early Closure) and (20c) (= Late Closure) are preferable.

The prosodic structure is generally preferred to be congruent with a syntactic structure. Thus, the preferred prosodic phrasing is balanced and this preference of the balanced prosodic structure influences the preference of the balanced syntactic structure.

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[9] The major phonological phrase is also known as intermediate phrase which is located between intonational phrase and prosodic word in a prosodic hierarchy. This major phonological phrase in Selkirk (2000) corresponds to the phonological phrase in Nespor and Vogel (1986).

3.1.2 The Implicit Prosody Hypothesis

Based on the relationship between prosodic phrasing and syntactic structure which was explained in the previous section, Fodor (1998, 2002) proposed the Implicit Prosody Hypothesis (IPH).

The Implicit Prosody Hypothesis (Fodor 2002)

> In silent reading, a default prosodic contour is projected onto the stimulus, and it may influence syntactic ambiguity resolution. Other things being equal, the parser favors the syntactic analysis associated with the most natural (default) prosodic contour for the construction.

She suggested that syntactic processing occurs in parallel with prosodic processing. If the resolution of syntactic ambiguity during the first pass (the first parse before backtracking and reanalysis would have happened) occurs, and other things are equal (alternative choice(s) are equally possible, for example RC-attachment ambiguity), the parser's decision is influenced by the prosodic processing.

She explains the difference in RC-attachment preferences found in long RCs in different languages via the IPH. RC-attachment ambiguity occurs when there is more than one noun (or NP) which the RC can modify. For short RCs, studies have found a strong LA preference in French (Pynte and Colonna 2000), and Croatian (Lovrić et al. 2000). In contrast, for long RCs, the preference is HA. This HA preference in French and Croatian is explained in terms of prosodic phrasing. Let us suppose that N1 (first noun) and N2 (second noun) are one minor (accentual) phrase, and that the short RC is one and the long RC is two minor phrases. For example, sentence (21a) contains a short RC while (21b) contains a long RC. A minor phrase is an accentual phrase and the accented words in the phrases are shown with boldface.

(21) a. Someone shot [$_{N1}$ the **servant**] [$_{N2}$ of the **actress**] [$_{SHORT\ RC}$ who was on the **balcony**].
b. Someone shot [$_{N1}$ the **servant**] [$_{N2}$ of the **actress**] [$_{LONG\ RC}$ who was on the **balcony** with her **husband**].

(boldface: accented word)

The total number of minor phrases of N1 plus N2 is 2. If the RC is short, the total number of minor phrase of N1, N2 and a RC is 3.

Figure 3.3 Minor phrases in short RC

$$\text{Someone shot } \underbrace{\underbrace{[_{N1}\text{ the }\textbf{servant}][_{N2}\text{ of the }\textbf{actress}]}_{2}[_{RC}\text{ who was on the }\textbf{balcony}]}_{3}.$$

(boldface: accented word)

If the RC is long, the total number of minor phrases in two noun phrases and a RC is 4.

Figure 3.4 Minor phrases in long RC

$$\text{Someone shot } \underbrace{\underbrace{[_{N1}\text{ the }\textbf{servant}][_{N2}\text{ of the }\textbf{actress}]}_{2}[_{RC}\text{ who was on the }\textbf{balcony}\text{ with her }\textbf{husband}]}_{4}.$$

(boldface: accented word)

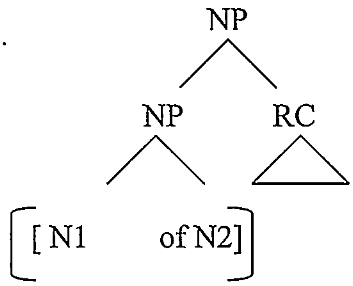
According to Selkirk (2000), the optimal length of a prosodic phrase consists of two minor phrases. Thus, if the RC is long, four minor phrases are divided into two two-minor phrases as in (22a). If the RC is short which consists of one minor phrase, the optimal length predicts that the RC cannot stands alone as a prosodic phrase. Thus, it is grouped into the previous phrase. This structure is shown in (22b). The possibility of (22c) occurs when N1 is grouped with the preceding minor phrase (e.g., the verb) and so becomes the optimal length of a prosodic phrase.

(22) Prosodic phrasing and RC-length

a. [N1 of N2] [RC] especially if RC is long
b. [N1 of N2 RC] if RC is short (one minor phrase)
c. …N1] [of N2 RC] (Fodor 2002)

The prosodic structure is generally preferred to be congruent with syntactic structure. Thus, if the prosodic structure is (22a), the syntactic structure is balanced and the RC-attachment is HA as in Figure 3.5.

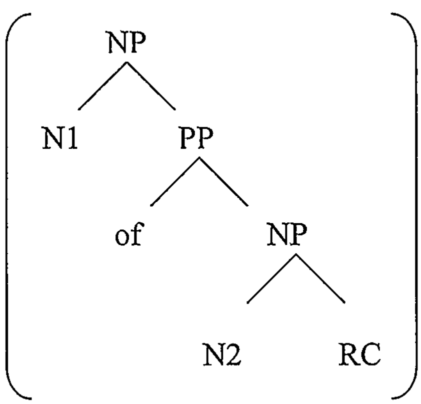
Figure 3.5 High Attachment (22a)



(bracket: prosodic phrase)

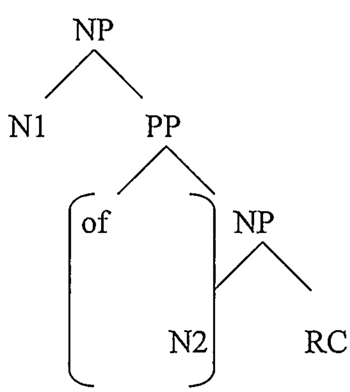
If the prosodic structure is either (22b) or (22c), then the RC will attach to the closest noun N2, and the RC-attachment is LA as shown in Figure 3.6 and 3.7 respectively.

Figure 3.6 Low Attachment (22b)



(bracket: prosodic phrase)

Figure 3.7 Low Attachment (22c)



(bracket: prosodic phrase)

The RC-length affects prosodic phrasing, and prosodic phrasing affects the RC-attachment preference. This is what the IPH states "the parser favors the syntactic analysis associated with the most natural (default) prosodic contour for the construction."

3.1.3 RC-attachment preference in English and French

Previous studies have shown that while English speakers prefer LA (Maynell 1999), French speakers strongly prefer HA when the RC is long (more than one prosodic word[10]), such as is shown in (23b), but show no preference when the RC is short (one prosodic word), such as shown in (23a). (Pynte & Colonna 2000).

(23) a. Someone shot the servant of the actress [$_{\text{SHORT RC}}$ who was on the **balcony**].
b. Someone shot the servant of the actress [$_{\text{LONG RC}}$ who was on the **balcony** with her **husband**].

(boldface: accented word)

These preferences of English speakers and French speakers are summarized in Table 3.1.

Table 3.1 RC-attachment preference of English and French speakers

	English[11]	French[12]
Long RC	Mild LA	Strong HA
Short RC	More LA	no attachment bias

(Fodor 2002)

Quinn et al. (2000) investigated the relationship between prosody and RC-attachment preference and conducted reading aloud experiments. The IPH is concerned with details of sentence processing in silent reading. However, we must remember that implicit prosody cannot be measured directly. In the IPH, Fodor (1998, 2000) assumed that implicit prosody (the default prosodic pattern) is projected onto a sentence during silent reading, and thus would be identical

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[10] One prosodic word in Fodor (1998, 2002) is equivalent to one minor (accentual) phrase of Selkirk (2000).

[11] Maynell 1999 (Cited in Fodor 2002)

[12] Offline study (questionnaire) (Pynte & Colonna 2000)

to the overt prosody for that sentence. In order to investigate implicit prosody, Quinn et al. investigated overt prosody of the relevant sentences. The sentences used in the experiments were either pragmatically biased to HA or LA. For example, in sentence (24a) it is pragmatically easy to attach *the dog* to the RC *who has not been fed since last week.* On the other hand, in sentence (24b) it is pragmatically easy to attach *the singer* to the RC *who won the music award.*

(24) a. A veterinarian gave a shot to the beloved dog of a singer who has not been fed since last week.

(Forced high: pragmatically biased to HA)

b. A veterinarian gave a shot to the beloved dog of a singer who won the music award.

(Forced low: pragmatically biased to LA)

English speakers and French speakers were given these unambiguous sentences (either pragmatically forced high or low) in English and French respectively to read and understand them first. This means that the subjects knew which noun the RC of the sentence attached to. After subjects clearly understood that the sentence was forced either high (e.g., (24a)) or low (e.g., (24b)), they were asked to read those sentences out loud and their readings were recorded. In order to identify a 'prosodic break', the fundamental frequency (F0) at the mid-point of the vowel in the stressed syllable of (1) the first noun, (2) the second noun, and (3) the RC verb was measured, and then the pauses and/or pre-pausal lengthening at the end of the first noun and the second noun were measured. If the prosodic break occurs before RCs with both forced high and low sentences, the reader strongly prefers to have a break before the RCs. In other words the default prosodic contour of the reader is to have a break before RCs.

The results of breaks before RC are shown in the Table 3.2.

Table 3.2 Distribution of pre-RC overt prosodic breaks in unambiguous sentences

	English	French
Long RC	forced high: **break**	forced high: **break**
	forced low: no break	forced low: **break**
Short RC	forced high: no break	forced high: no break
	forced low: no break	forced low: no break

Fodor (2002)

French speakers exhibited a strong preference to have a break before a long RC regardless of the attachment intended. On the other hand, English speakers exhibited a preference to have a break only before a long RC with a forced high interpretation. These results indicated that the default prosody with a long RC in French is a break before the long RC. As for short RCs which consist of one prosodic word, the results showed that neither English nor French subjects inserted a break before the RCs. Thus, the default prosody in short RC is no break before the short RC in both English and French. This is summarized in Table 3.3.

Table 3.3 Default prosody [English vs. French]

	English	French
Long RC	flexible	**break**
Short RC	no break	no break

With a long RC sentence in French, the sentence is divided into two prosodic phrases by inserting a break before the RC. There is a general preference for prosody to be congruent with syntax[13]. Thus, in order to be congruent with syntax, the structure becomes the structure in Figures 3.8. and 3.9.

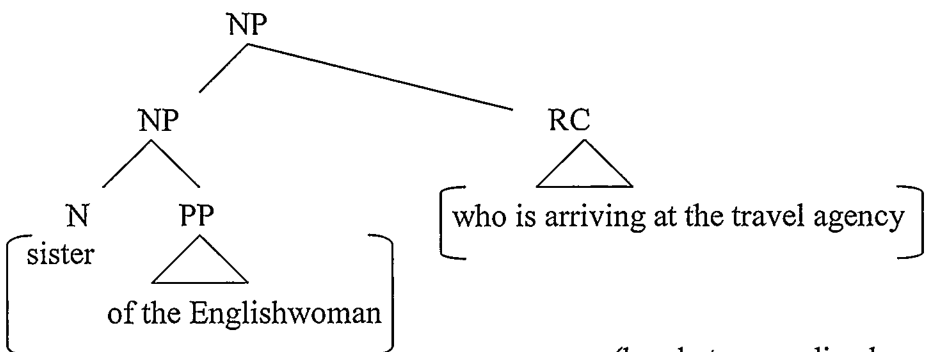
[13] For example, For example, Align_R XP constraint in English in an Optimality Theory framework proposed by Selkirk (2000) permits a boundary after a complement within a verb phrase, as in the example (She loaned her rollerblades) (to Robin.).

(25) Long RC = HA

Il aime [$_{\text{PROSODICP}}$ la sœur de l'Anglaise] // [qui arrive à l'agence de voyages].
He loves the sister of the Englishwoman who is arriving at the travel agency
(PROSODICP: prosodic phrase, //: prosodic break)

Qui arrive? la sœur
Who is arriving? the sister (sentences are from Fernández et al. 2003)

Figure 3.8 Syntactic structure of (25)



(bracket: prosodic phrase)

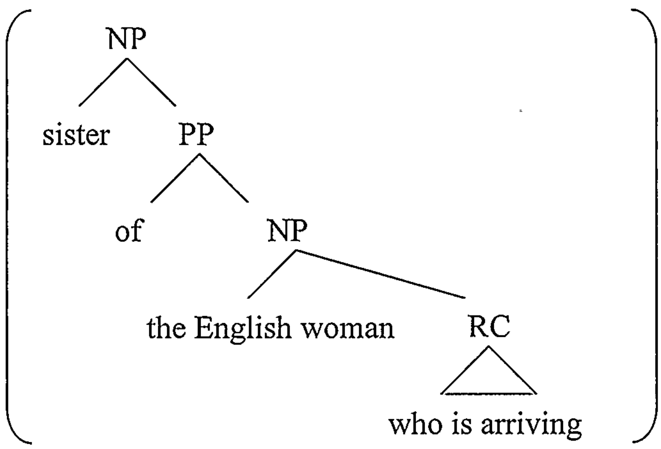
In a short RC sentence, however, the RC is included in the previous prosodic phrase because it is short and the Late Closure (locality preference) is applied. Therefore the RC attaches to the closest NP.

(26) Short RC = LA

Il aime [$_{\text{PROSODICP}}$ la sœur de l'Anglaise qui arrive].
He loves the sister of the Englishwoman who is arriving.
(PROSODICP: prosodic phrase)

Qui arrive? l'Anglaise
Who is arriving? the Englishwoman (sentences are from Fernández et al. 2003)

Figure 3.9 Syntactic structure of (26)



(bracket: prosodic phrase)

From these results, we can assume that if the default prosodic contour for the construction is to have a break before the RC (as in French), the language will prefer HA. If there is no prosodic break before the RC (as in English), the language will prefer LA. Once again, we see that RC-length affects prosodic phrasing and prosodic phrasing affects RC-attachment. These results are based on read-aloud experiments. This demonstrates the relationship between the parser and overt prosody, that is to say 'parsing is influenced by prosody'. Based on the assumption that implicit prosody is equivalent to the overt prosody, these results support Fodor's IPH.

3.1.4 RC-attachment preference in Croatian

Lovrić (2003) examined the prosodic phrasing and RC-attachment properties of two types of RC constructions in Croatian and argued that the IPH explains the Croatian RC-attachment preference. There are two RC constructions in Croatian as shown in (27) and (28).

(27) Croatian RC

Vidjeli smo prijatelje (od) arhitekata što plaču.
Saw are friends (of) architects that cry
"We saw the friends of the architects that are crying." (Lovrić 2003)

(28) Croatian RC constructions

a. N1-N2$_{[\text{GEN}]}$-RC
b. N1-*od* N2$_{[\text{GEN}]}$-RC (GEN: genitive case)

These two constructions do not affect the meaning of the sentence, and are in free variation. However, the constructions do affect prosodic phrasing.

The eight types of sentences used in this experiment are shown in Table 3.4.

Table 3.4 Default prosody [Croatian]

	Long RC	Short RC
RC with *od*	Forced high	Forced high
	Forced low	Forced low
RC without *od*	Forced high	Forced high
	Forced low	Forced low

(forced high: pragmatically biased to HA, forced low: pragmatically biased to LA)

Participants were given RC sentences to read and understand them first, and then their readings were recorded. The lengthening (duration) of the words were measured, for example, the lengthening of N1 (and a following pause) which indicates a prosodic break immediately after N1.

The construction of *od* favors a prosodic break at the left edge of the Prepositional Phrase (PP) (Godjevac 2000). The expected prosodic phrasing in terms of optimal length of prosodic phrase is shown in (29).

(29) a. [N1 N2] [RC] (especially if RC is long) favors N1-attachment
b. ...N1] [*od* N2 RC] (especially if RC is short) favors N2-attachment
(Fodor 2002)

With an RC with no preposition *od*, the two minor phrases (N1 and N2) becomes one prosodic phrase as shown in (29a). However, for a RC with the preposition *od*, because *od* favors a prosodic break at the left edge of the PP, the insertion of the break before the RC makes [*od* N2] one minor phrase which violates the constraint an optimal length of a prosodic phrase. Thus, *od* and N2 are grouped with the following RC as shown in (29b).

The results of prosodic breaks from the experiment are shown in Table 3.4. The total numbers of utterances in this analysis were 296, 148 RC with *od* and 148 RC without *od*. The scores encode either a clear presence (+break) or absence (-break) of a prosodic break immediately after N1.

Table 3.5 Prosodic break immediately after N1

	+*od*	-*od*
+break	84 (56%)	12 (8.1%)
-break	64 (43.2%)	136 (91.9%)

(Lovrić 2003)

The results demonstrate that *od* favors a prosodic break at the left edge of the PP (after N1/before *od*-N2) and the absence of *od* made the N2 group into the previous prosodic phrase (combined with N1 and N2) as shown in (29a). The results showed that the existence of *od* affected the prosodic phrasing. And Lovrić assumes it is the phonological characteristics of *od* which lead to these results.

The patterns of RC-attachment preference when the prosodic break is after N2 (before the RC) are shown in Tables 3.6 and 3.7. The scores encode either a clear presence (+break) or absence (-break) of a prosodic break immediately after N2.

Table 3.6 Prosodic break after N2 and RC-attachment preference in RC without od

	Long RC	Short RC
High attachment	100%	50%
Low attachment	100%	12.5%

(Lovrić 2003)

The results show fewer prosodic breaks before an RC when the RC is short. This means that if an RC consists of one minor phrase it tends to be grouped into the previous prosodic phrase. As for a long RC, the results (Table 3.6) show that the default prosodic contour for the RC construction without *od* is a break before the RC.

Table 3.7 Prosodic break after N2 and RC-attachment preference in RC with od

	Long RC	Short RC
High attachment	71.4%	55.6%
Low attachment	16.7%	11.1%

(Lovrić 2003)

In contrast, Table 3.7 shows that the existence of *od* suppresses the prosodic break before the RC because of the preference for the break before *od* along with the effects of the optimal length on the prosodic phrase. When the RC-attachment is pragmatically forced high, there is a break before the RC. In contrast, there are fewer prosodic breaks before the RC when the RC-attachment is pragmatically forced low. Once again, these results demonstrate the congruency between prosodic structure and syntactic structure.

These Croatian data show the insertion of *od* affects the prosodic pattern of the sentence. The default prosodic pattern of Croatian is to have a break before RC in long RC and Croatian speakers preferred HA. This supports the IPH which states that the parser favors the syntactic analysis associated with the default prosodic contour for the construction.

Evidence from both English and French presented in the previous section and from Croatian in this section support the claim that the default prosody of the language influences the syntactic processing of long RCs, which is what the IPH predicts about RC-attachment preference. The default prosody of English is flexible when it comes to having a break before a long RC, thus English speakers have a mild LA preference in long RCs. French and Croatian default prosody is to have a break before long RCs and as a result, they prefer HA in long RCs. None of these languages has a break before short RCs. This is also explained by the IPH because the RC is short and it is combined into the previous phrase and therefore the Late Closure (locality preference) causes a LA preference.

3.2 Prosodic Constraint on Reanalysis

3.2.1 Syntactic reanalysis and prosodic reanalysis

As we saw in Chapter 2, there are degrees of difficulty of garden-path sentences. Even if the sentences require the same level of syntactic reanalysis, some sentences can be more difficult to process than others. For example, both (30b) and (31b) required the same syntactic reanalysis. The NPs *the little boy* in (30b) and *the answer* in (31b) are easily misanalyzed as the object of the verb immediately before the NP, and need to be reanalyzed as the subject NP of the next verb.

(30) a. In order to help the little boy Jill put down the package she was carrying.
b. In order to help the little boy put down the package he was carrying.

(31) a. Peter knew the answer immediately.
b. Peter knew the answer would be false.

Thus, (30b) is more difficult than (30a) (Frazier & Rayner, 1982: Ferreira & Henderson, 1991). However, although (31b) needs the same type of syntactic reanalysis as (30b) needs, (31b) does not cause any difficulty (Gibson, 1991; Gorrell, 1995). The question is what causes this difference in difficulty (or degree of difficulties) of garden-path sentences?

In order to explain these difficulty differences found in Garden-path sentences which require the same type of syntactic reanalysis, Bader (1998) proposed the Prosodic Constraint on Reanalysis (PCR). He argued that prosody influences syntactic processing during silent reading, and that the degrees of difficulty of the garden-path sentences can be explained in terms of not only syntactic reanalysis, but also prosodic reanalysis.

Prosodic Constraint on Reanalysis (Bader 1998)

> Revising a syntactic structure is difficult if it necessitates a concomitant reanalysis of the associated prosodic structure.

In other words, revising a syntactic structure is more difficult if it also requires a prosodic structure reanalysis.

The PCR can explain the different difficulty of sentences (30) and (31).

(30) a. In order to help the little boy Jill put down the package she was carrying.
b. In order to help the little boy put down the package he was carrying.

According to the PCR, sentence (30a) is easy because neither syntactic nor prosodic reanalysis is required. The first intonational phrase ends with the end of the NP '*the little boy*' which is the same as the end of the syntactic phrase '*In order to help the little boy*'. The next syntactic and intonational phrases start from the word '*Jill*'.

(30 a) No reanalysis is required: easy

($_I$ In order to help *the little boy*) ($_I$ Jill put down the package she was carrying).
($_I$: intonational phrase)

In contrast, (30b) is difficult because the parser needs not only syntactic reanalysis but also prosodic reanalysis.

(30 b) Both syntactic and prosodic reanalysis are required: difficult

($_I$ [$_{CP}$ In order to help *the little boy*]) put down the package he was carrying.

($_I$ [$_{CP}$ In order to help]) ($_I$ *the little boy* put down the package he was carrying.)
($_I$: intonational phrase, $_{CP}$: complement phrase)

The NP '*the little boy*' is processed as an object of the verb '*help*' first, and then when the parser reaches the next verb '*put*' which is the verb of the main clause, the parser needs to reanalyze the NP '*the little boy*' as a subject of the main clause. This reanalysis makes the interpretation shown in (30b) difficult. In addition, because of the initial assignment of the prosodic (intonational) boundary which was congruent with the syntactic phrase boundary, this syntactic phrasing change requires a prosodic reanalysis. Thus, sentence (30b) requires both syntactic and prosodic reanalyses. The lack of difficulty in sentences such as (31) can also be explained by PCR.

(31) a. Peter knew the answer immediately.
  b. Peter knew the answer would be false.

The example in (31a) is easy, because neither syntactic nor prosodic reanalysis is required. The sentence is a simple sentence, subject + verb + object + adverb, and there is no requirement for syntactic reanalysis. The intonational phrase ends in the end of the sentence.

(31 a) No reanalysis is required: easy

  ($_I$ [$_{CP}$ Peter knew the answer immediately.]) ($_I$: intonational phrase, $_{CP}$: complement phrase)

On the other hand, (31b) requires syntactic reanalysis.

(31 b) Only syntactic reanalysis is required: not difficult

  ($_I$ [$_{CP}$ Peter knew the answer] would be false.)

  ($_I$ [$_{CP}$ Peter knew] the answer would be false.)

($_I$: intonational phrase, $_{CP}$: complement phrase)

The NP '*the answer*' is processed as an object of the verb '*knew*' first and when the parser reaches the next verb '*would be*', it requires the reanalysis of the NP '*the answer*' as a subject of the following embedded clause. Sentence (31b), however, does not require an intonational phrase reanalysis, because the intonational phrase of both sentences (31a) and (31b) ends at the end of the whole sentence. In sentence (31b), only syntactic reanalysis is required, not prosodic reanalysis. This lack of prosodic reanalysis explains the difference in difficulty between (30b) and (31b).

To sum up the above analyses, (30a) requires neither syntactic nor prosodic reanalysis and it is easy to interpret. (30b) requires both syntactic and prosodic reanalyses and it is difficult to interpret. (31a) requires neither syntactic nor prosodic reanalysis and it is easy to interpret. (31b) requires only syntactic reanalysis is required and it is easy to interpret. From these data, the difficulty of (30b) is the result of both syntactic and prosodic reanalysis.

Table 3.8 Difficulty difference and syntactic and prosodic reanalysis

Sentence	Syntactic reanalysis	Prosodic reanalysis	Prediction
(30a)			Easy
(30b)	√	√	Difficult
(31a)			Easy
(31b)	√		Easy

It supports the Prosodic Constraint on Reanalysis.

3.2.2 Ihr-Ambiguity

In order to demonstrate the Prosodic Constraint on Reanalysis, Bader conducted experiments using German *ihr*-ambiguity sentences. Sentences (32) provide examples of *ihr*-ambiguity sentences. *ihr* ('her') is lexically ambiguous as either an indirect object in (32a) or as a possessive pronoun in (32b). In order to distinguish the structures of (32a) and (32b), the structure of (32a) will be called the dative structure and (32b) will be called the possessive structure.

***ihr*-ambiguity**[14]

(32) a. Zu mir hat Maria gesagt, daβ man **ihr** Geld anvertraut hat.
to me has Maria said that one her money entrusted has
'Maria said to me that someone entrusted money **to her**.'

b. Zu mir hat Maria gesagt, daβ man **ihr** Geld beschlagnahmt hat.
to me has Maria said that one her money confiscated has
'Maria said to me that someone confiscated **her** money.' (Bader 1998)

[14] The English counterpart of *ihr*-ambiguity is the ambiguity of double-object verb '*give*'. For example, '*her*' is lexically ambiguous between a dative pronoun in a dative structure (i) and a possessive pronoun in a possessive structure (ii).

(i) Mary said that someone gave her money on her birthday.
(ii) Mary said that someone gave her money to Peter.

The *ihr*-ambiguity sentence is disambiguated by the verb of the clause. The verb in the embedded clause *anvertrauen* ('entrusted') in (32a) and *beschlagnahmen* ('confiscate') in (32b). The verb *anvertrauen* requires a dative object and the verb *beschlagnahmen* cannot be used with a dative object[15]. The prosodic pattern (sentence stress) of *ihr*-ambiguity sentences are shown in (33). A boldface word is stressed. The phrasal stress in a dative sentence is identical with the stress of a possessive sentence.

(33) a. … daβ man ihr **GELD** anvertraut hat. Dative
b. … daβ man ihr **GELD** beschlagnahmt hat. Possessive (Bader 1998)

In order to investigate the Prosodic Constraint on Reanalysis, Bader manipulated the prosody by inserting a focus particle into the *ihr*-ambiguity sentences.

(34) a. … daβ man **sogar** ihr Geld anvertraut hat. Dative
that one **even** her money entrusted has
'… that someone entrusted money **even** to her.'

b. … daβ man **sogar** ihr Geld beschlagnahmt hat. Possessive
that one **even** her money confiscated has
'… that someone confiscated **even** her money.' (Bader 1998)

The insertion of focus particles changes the sentences prosodically. For example, the insertion of a focus particle *sogar* in the dative structure makes *ihr* be stressed as in (35a), but not *Geld* (35b).

(35) a. … daβ man sogar {$_{F}$ **IHR**} Geld anvertraut hat. Dative
b. *… daβ man sogar ihr {$_{F}$ **GELD**} anvertraut hat. (Bader 1998)

On the other hand, the insertion of a focus particle *sogar* in the possessive structure allows either *ihr* or *Geld* to be stressed (36).

(36) a. …. daβ man sogar [$_{NP}$ {$_{F}$ **IHR**} Geld] beschlagnahmt hat. Possessive
b. …. daβ man sogar [$_{NP}$ ihr {$_{F}$ **GELD**}] beschlagnahmt hat. (Bader 1998)

---

[15] The word order in German embedded clause in these examples is Subject, Object, and Verb.

The summary of stress positions is shown in (37).

(37) a. … daβ man ihr **GELD** anvertraut hat. Dative
b. … daβ man sogar **IHR** Geld anvertraut hat. Dative + focus
c. … daβ man ihr **GELD** beschlagnahmt hat. Possessive
d. … daβ man sogar **IHR** Geld beschlagnahmt hat. Possessive + focus
e. … daβ man sogar ihr **GELD** beschlagnahmt hat. Possessive + focus

Based on the prosodic and syntactic change resulting from the insertion of a focus particle in *ihr*-ambiguity sentences in German, Bader conducted three experiments to test the PCR. All participants of the three experiments are native German speakers.

The first experiment is to find out whether the prosodic reanalysis required because of the focus particles causes a garden-path effect in the *ihr*-ambiguity sentences. These stimuli include the following four types of sentences.

(38) a. … daβ man [ihr $_{DAT}$] [Geld] anvertraut hat. Dative
b. … daβ man [ihr $_{POSS}$ Geld] beschlagnahmt hat. Possessive
c. … daβ man sogar [ihr $_{DAT}$] [Geld] anvertraut hat. Dative + Focus
d. … daβ man sogar [ihr $_{POSS}$ Geld] beschlagnahmt hat. Possessive + Focus

(Bader 1998)

The procedure is a self-paced reading task[16]. The syntactic assumption of this experiment is that *ihr* is analyzed as a possessive pronoun as a default.

The intonation of sentences with and without focus particle is shown in (39). Although the possessive structure with the focus particle can have two possible intonations as shown in (36), Bader assumed the intonation would be (36b) *ihr* ***GELD***, not (36a) ***IHR*** *Geld* based on a well-known fact that function words are prosodically less prominent than content words (Selkirk 1984, 1994).

[16] Self-paced reading: the reader presses the button to read the next word, and the word that was just read disappears and the new word appears.

(39) a. … daβ man [ihr $_{DAT}$] [**GELD**] anvertraut hat. Dative
b. … daβ man [ihr $_{POSS}$ **GELD**] beschlagnahmt hat. Possessive
c. … daβ man sogar [**IHR** $_{DAT}$] [Geld] anvertraut hat. Dative + focus
d. … daβ man sogar [ihr $_{POSS}$ **GELD**] beschlagnahmt hat. Possessive + focus

(Bader 1998)

If the possessive structure is the default structure, a dative structure without focus particle such as (39a) requires only syntactic reanalysis, but not prosodic reanalysis. A possessive structure without a focus particle such as (39b) requires neither syntactic nor prosodic reanalysis. A dative structure with a focus particle such as (39c) requires both syntactic and prosodic reanalyses. A possessive structure with a focus particle such as (39d) requires neither syntactic nor prosodic reanalysis. Thus, the PCR predicts that dative structures with focus particles which require both syntactic and prosodic reanalyses will be difficult. The predictions of four types of sentences are shown in Table 3.9.

Table 3.9 Prediction of Difficulty difference 1

	Syntactic reanalysis	Prosodic reanalysis	Prediction
Dative	√ (POSS → DAT)		Easy
Possessive			Easy
Dative + Focus	√ (POSS → DAT)	√ (**GELD → IHR**)	Difficult
Possessive + Focus			Easy

The results found that the reading times up until the disambiguating word (verb) of all four types of sentences are statistically similar while the reading times on the disambiguating word in the dative structure with focus particle is longer than that of the other three types of sentences. Reading times at that position on the other 3 types of sentence are statistically similar. Longer reading time indicates greater difficulty in processing. Thus, these results demonstrate that dative structures with a focus particle (which require both syntactic and prosodic reanalyses) are more difficult than sentences which require either syntactic reanalysis alone, or neither syntactic nor prosodic reanalysis. In addition, the similar results of dative sentences without a focus particle (which require syntactic reanalysis) and possessive sentences without a focus particle (which do not require syntactic reanalysis) shows that this syntactic reanalysis from possessive structure to dative structure is not difficult.

Bader's second experiment was designed to investigate whether prosodic reanalysis alone can cause a garden-path effect. From the previous experiment we know that, syntactic reanalysis from possessive structure to dative structure did not make the sentence difficult. Thus, the prediction Table 3.9 is changed as Table 3.10.

Table 3.10 Prediction of Difficulty difference 2

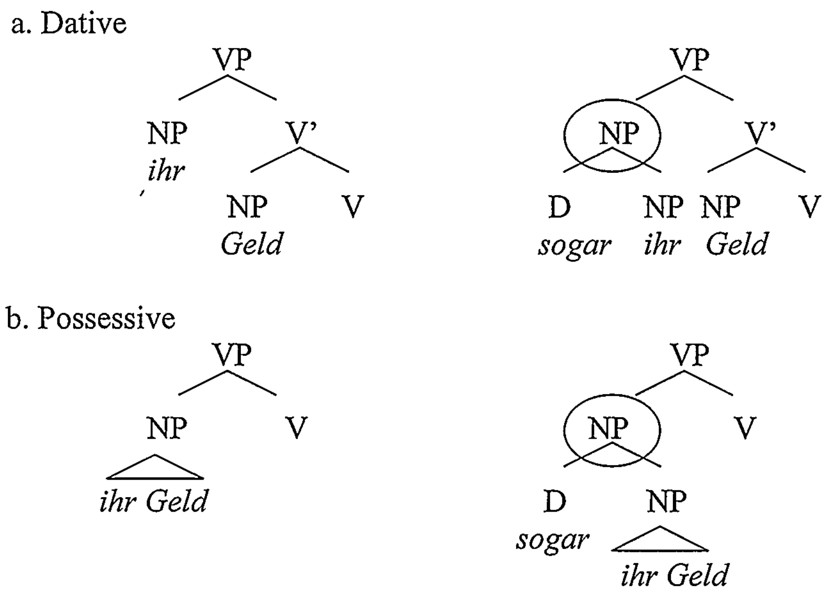
	Syntactic reanalysis	Prosodic reanalysis	Prediction
Dative			Easy
Possessive			Easy
Dative + Focus		√ **(GELD → IHR)**	Difficult
Possessive + Focus			Easy

However, the insertion of a focus particle changed the syntactic phrasal structures of ambiguous regions. The constituency test in (40) shows that the insertion of the focus particle creates a new node (NP) with focus particle *sogar* and *ihr* in the dative structure (Figure 3.10a), focus particle *sogar* and *ihr Geld* in the possessive structure (Figure 3.10b).

(40) a. [Sogar ihr] hatte man Geld anvertraut. Dative
even her had one money entrusted
'Someone entrusted money even to her.'

b. [Sogar ihr Geld] hatte man Geld beschlagnahmt. Possessive
even her money had one confiscated
'Someone confiscated even her money.' (Bader 1998)

Figure 3.10 Phrase structure with focus particle[17]



(Bader 1998)

The prediction of difficulty difference which includes this syntactic change is shown in Table 3.11.

Table 3.11 Prediction of Difficulty difference with syntactic change by focus particle

	Syntactic reanalysis	Prosodic reanalysis	Prediction
Dative			Easy
Possessive			Easy
Dative + Focus	√ (new NP)	√ **(GELD → IHR)**	Difficult
Possessive + Focus	√ (new NP)		Easy

In order to isolate the prosodic influence on sentence processing, it is necessary to exclude this syntactic influence. The insertion of sentence adverbials into *ihr*-ambiguity sentences behaves prosodically identical to the sentences with focus particles.

[17] Bader (1998) placed the focus particle under the determiner node.

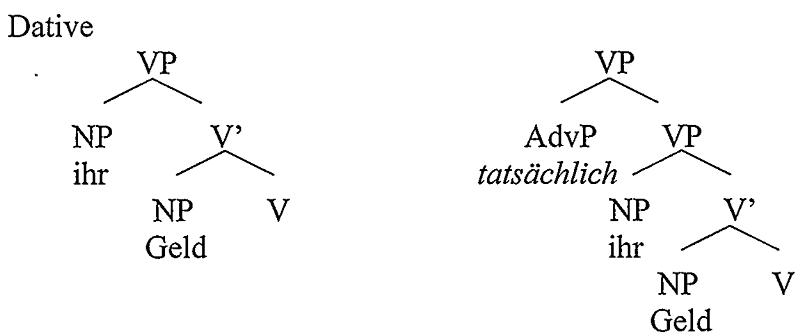
(41) a. .... daβ man **tatsächlich** ihr Geld anvertraut hatte. Dative
that one **indeed** her money entrusted had
'... that someone **indeed** entrusted money to her.'

b. ... daβ man **tatsächlich** ihr Geld beschlagnahmt hatte. Possessive
that one **indeed** her money confiscated had
'... that someone **indeed** confiscated her money.' (Bader 1998)

Although the insertion of focus particles changes the syntactic phrasal structures of the ambiguous regions, sentence adverbial insertion does not change the syntactic phrasal structures. The constituency tests of the sentences with sentence adverbials are shown in (42) and the syntactic structures are shown in Figures 3.11 and 3.12.

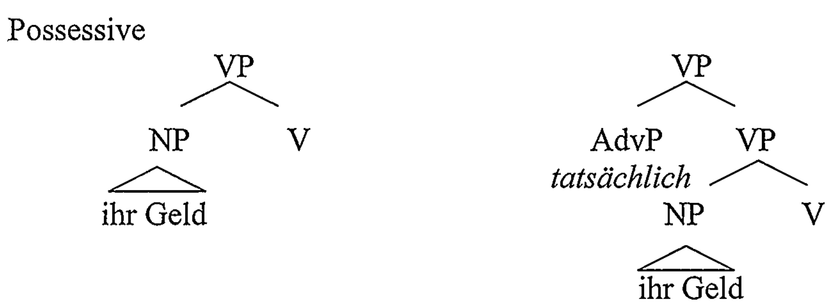
(42) a. *[Tatsächlich ihr] hatte man Geld anvertraut. Dative
b. *[Tatsächlich ihr Geld] hatte man Geld beschlagnahmt. Possessive (Bader 1998)

Figure 3.11 Phrasal structure of sentence with adverbial (Dative)



(Bader 1998)

Figure 3.12 Phrasal structure of sentence with adverbial (Possessive)



(Bader 1998)

The stimuli include the following four types of sentences.

(43) a. … daβ man tatsächlich [ihm $_{DAT}$] [Geld] anvertraut hatte. (unambiguous)
b. … daβ man tatsächlich [sein $_{POSS}$ Geld] beschlagnahmt hatte. (unambiguous)
c. … daβ man tatsächlich [ihr $_{DAT}$] [Geld] anvertraut hatte. (ambiguous)
d. … daβ man tatsächlich [ihr $_{POSS}$ Geld] beschlagnahmt hatte. (ambiguous)
(Bader 1998)

In order to make the sentences unambiguous, the dative form and the possessive form of masculine third person pronouns *ihm* ('him') *sein* ('his') are used. The procedure is the same self-paced reading task as in the first experiment.

The predictions of four types of sentences are shown in Table 3.12.

Table 3.12 Prediction of Difficulty difference 3

	Syntactic reanalysis	Prosodic reanalysis	Prediction
Unambiguous Dative			Easy
Unambiguous Possessive			Easy
Ambiguous Dative		√ **(GELD → IHR)**	Difficult
Ambiguous Possessive			Easy

The results found that: (i) the reading times for unambiguous dative and possessive sentences do not significantly differ; (ii) the reading times of ambiguous sentences are longer than those of unambiguous sentences; (iii) and reading times of ambiguous dative sentences are much longer than those of ambiguous possessive sentences. These results are consistent with the first experiment. Thus, syntactic reanalysis of additional new nodes caused by the insertion of a focus particle can be excluded. The difficulty of this dative ambiguous structure is due to the prosodic reanalysis alone. These results showed that prosodic reanalysis influences the difficulty of sentence processing.

The last experiment manipulates prosody using long focus particles in order to find out whether the garden-path effect is the result of the reanalysis of the initial prosodic analysis. In other words, if the initial prosodic analysis is correctly processed (if it does not need to be reanalyzed) the processing of the sentence should not be difficult. In order to manipulate the prosody of *ihr*-ambiguity sentences, long focus particles (*ausschließlich* and *ausgerechenet* which consist of a first stressed syllable followed by two or three unstressed syllables respectively) are used. The idea of using a long focus particle is based on rhythmic alternation 'lapse'. The phenomenon of lapse occurs in the long strings of unstressed syllables. Function words are unstressed by default. When many function words make long unstressed syllables in a sentence like (44), some of the function words will be stressed as shown in (45).

(44) He [must have been in] bed.

(45) a. He **MUST** have **BEEN** in bed.
b. He **MUST** have been in bed. (bold face: stress)

(Bader 1998)

When a long focus particle which has a stress on the first syllable is inserted into an *ihr*-ambiguity sentence, the rest of the two syllables of the long focus particle and *ihr* make a long string of unstressed syllables, underlined syllables in (46).

(46) ... daβ man au<u>sschließlich ihr</u> **GELD** anvertraut hatte. (bold face: stress)

Because of the phenomenon of lapse in this sentence, *ihr* will receive a stress instead of *Geld* even if it is a function word which is normally unstressed.

(47) ... daβ man ausschließlich **IHR** Geld anvertraut hatte.
that one exclusively her money entrusted had
'... that someone exclusively entrusted money to her.' (Bader 1998)

The stimuli include the following four types of dative sentences: two long focus particles, *ausschließlich* ("exclusively") and *ausgerechenet* ("of all people/things") and two short focus particles *nur* ("only")) and *sogar* ("even"). The procedure is the same self-paced reading task as in the first two experiments.

(48)

a. … daβ man ihm Geld anvertraut hatte. (unambiguous, no particle)
b. … daβ man ihr Geld anvertraut hatte. (ambiguous, no particle)
c. … daβ man sogar ihr Geld anvertraut hatte. (ambiguous, short particle)
d. … daβ man ausschlieβlich ihr Geld anvertraut hatte. (ambiguous, long particle)
(Bader 1998)

The predictions for the four types of sentences are shown in Table 3.13.

Table 3.13 Prediction of Difficulty difference 4

	Initial stress	Correct stress	Reanalysis	Prediction
Unambiguous	**GELD**	**GELD**	—	Easy
Ambiguous	**GELD**	**GELD**	—	Easy
Ambiguous + Short Focus	**GELD**	**IHR**	**GELD → IHR**	Difficult
Ambiguous + Long Focus	**IHR**	**IHR**	—	Easy

The stress in a dative sentence and a possessive sentence is identical (at the word *Geld*) as shown in (33). Thus, even tough the sentence is ambiguous, the initial stress is on the word *Geld*. The insertion of a short focus particle causes prosodic change (from the stress on *Geld* to *ihr*), but if the focus particle is long, the initial stress is on the word *ihr* as explained. Thus, an ambiguous dative sentence with a short focus particle which requires prosodic reanalysis will be difficult.

The results found that there was no significant difference between the reading times of sentences without focus particles and sentences with long focus particles, but there was a significant difference between (a) those sentences without focus particles and with long focus particles and (b) sentences with short focus particles. These results showed that if the initial prosodic analysis is wrong, and therefore requires reanalysis, sentence processing will be difficult.

Both the Implicit Prosody Hypothesis (Fodor 1998, 2002) and the Prosodic Constraint on Reanalysis (Bader 1998) claim that sentence processing in silent reading is influenced by prosody which readers assign to the written form of a language. The Implicit Prosody Hypothesis explains that first pass parsing is influenced by the default prosodic contour of the language. This default prosody can resolve syntactic ambiguity. The Prosodic Constraint on Reanalysis (Bader 1998) explains the degrees of sentence processing difficulty in terms of prosodic reanalysis. If readers assign wrong prosodic analysis initially, it makes the sentence difficult.

In this chapter, I discussed the importance of implicit prosody in silent reading. According to Fodor, implicit prosody (the default prosodic pattern) is projected onto a sentence during silent reading, and thus would be identical to the overt prosody for that sentence[18]. If implicit prosody is identical to the overt prosody, then this raises the question: Do deaf and hard of hearing people also use implicit prosody during silent reading? If deaf and hard of hearing people do not have inner speech, they also do not have implicit prosody. Thus, I will discuss phonological coding by deaf and hard of hearing readers in the next chapter.

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[18] This does not mean that implicit speech is identical to the overt speech.

CHAPTER 4: PHONOLOGICAL CODING AND HEARING LOSS

In this chapter, I will review the reading ability and the phonological coding ability of deaf and hard of hearing readers. Signed languages are languages which are used by many deaf and hard of hearing people. For example, the most common signed language in North America is American Sign Language (ASL) and in Japan it is Japanese Sign Language (JSL). The deaf and hard of hearing people in England use British Sign Language (BSL). Many sign languages users can read the written language most common in their environment to a certain extent. This means that ASL or BSL users who cannot speak English can still read English, and JSL users who cannot speak Japanese can still read Japanese.

4.1 Reading and Hearing Loss

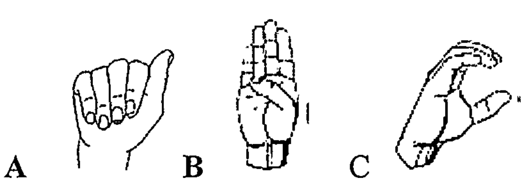
There are two options for deaf and hard of hearing children when they learn their first language: sign language or the spoken language. Because there is no written form for sign language, deaf and hard of hearing children have to learn the written form of spoken language just as hearing children do. However, children with hearing-loss have great difficulty acquiring reading and writing. Their reading levels are significantly lower than those of normal hearing readers. The reading levels of deaf students at the end of their primary school (mean age 13 years) have reading levels similar to or lower than the reading levels of hearing students whose mean age is 7 years (Monreal and Hernández 2005). The average reading level of 18- to 19-year-old deaf and hard of hearing students is the average reading level of 8- to 9- year-old hearing students (Traxler 2000). Other studies have found similar results. The average reading level of 14- to 16-year-old deaf and hard of hearing children is the reading level of 7- year-old hearing children (Pinter and

Patterson 1917). Only 8% of students with hearing-loss between the age of 10.5 and 16.5 years read above the fourth-grade level. (Furth 1966). The average reading level of age 20 years and older was equivalent to the reading level of grade 4.5 (Trybus and Karchmer 1977).

Hearing-loss children start learning written language, as hearing children do, when they start going to school. As the two factors of sentence processing which I am focusing on in this thesis are parsing and inner speech (phonological coding), the question here is whether deaf and hard of hearing readers use phonological coding from the written form of the language during silent reading in the way that hearing readers do. Could there be another type of coding taking place?

If inner speech is the result of phonological coding in the reading process, the question arises as to whether hearing-loss readers also have inner speech? If they cannot hear and cannot speak, do they have phonological representations; what kind of representation is equivalent to the phonological coding of hearing readers? Perhaps there is another type of representation, such as visual representation. ASL consists of signs and finger spelling. Finger spelling is a manual alphabet (the representation of the letters of a writing system). Some examples of finger spelling from ASL are shown in Figure 4.1.

Figure 4.1 Finger spelling A, B, C. in ASL



Just each sign language has different grammar and signs, finger spelling is also different in each sign language. For example, finger spelling for 'A' in BSL is different from that found in ASL. It is used in situations where there is no sign available in the language, e.g., people's names like

John or Mary. Thus, the possibilities for visual representation could be either signs or finger spellings.

4.2 Finger spelling coding

Locke and Locke (1971) conducted an experiment to investigate the coding difference between hearing and deaf readers. The deaf subjects were divided into two groups; (a) those with intelligible oral language and (b) those with unintelligible oral language. Thus, there were three subjects groups, hearing control (age 10-14[19] from public schools), deaf with intelligible oral language (age 14-20), and deaf with unintelligible oral language (age 14-19). Two types of paired consonant letters in the materials for the experiment are shown in Table 4.1.

Table 4.1 Three types of paired consonant letters

Stimuli	
Phonetically similar	Dactylically similar
B-V	B-Y
F-X	F-B
K-Y	K-P
P-T	P-K
R-Y	R-P
T-P	T-V
V-P	V-T
X-F	X-K
Y-R	Y-B

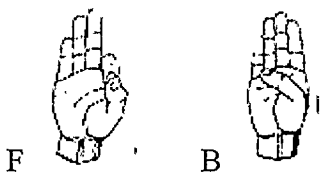
(Locke and Locke 1971 modified)

The phonetically similar pairs were the letters which the hearing subjects in the study of Conrad and Rush (1965) made the confusion errors frequently. The dactylo-kinesthetic similar pairs were similar as their hand shape of the finger spelling. These were from Locke (1970). For

[19] Locke and Locke did not mention the reason for the age difference between hearing and deaf subjects. I suspect that Locke and Locke chose hearing subjects whose reading levels were closer to the deaf subjects.

example, F-B pair is shown in Figure 4.2.

Figure 4.2 Finger spelling F and B



Subjects were shown three pairs of the same type of similarity pairs (5 SEC/pair with an interval 1.5 SEC) on the slide screen with a rehearsal time of 10 SEC and a response time of 10 SEC. During the response time, subjects were asked to write down what they had seen on the screen.

The results are shown in Table 4.2.

Table 4.2 The analysis of hearing control (HC), intelligible deaf (ID), and unintelligible deaf (UD) subjects' recall of phonetically similar and dactylically similar letter pairs and confusions of letters similar in phonetic or dactylic features.

Recall accuracy	Confusion errors
Phonetic similarity	
HC (.362) > UD (.353) > ID (.321)	HC (.568) > ID (.371) > UD (.193)
Dactylic similarity	
UD (.360) > ID (.349) > HC (.308)	UD (.452) > ID (.298) > HC (.199)

(Locke and Locke 1971 modified)

For the phonetically similarity pairs, the hearing control group made errors significantly more often than both deaf groups. This confirmed that hearing subjects used phonological coding. In the case of dactylic similarity pairs, both deaf groups made errors significantly more often than the hearing control group. The confusion of dactylic similarity pairs by deaf subjects indicates their use of finger spelling coding. In addition, observations during the experiment found that most of the deaf subjects were finger spelling during the rehearsal time.

4.3 Sign coding

Treiman and Hirsh-Pasek (1983) found that deaf subjects used sign coding instead of finger spelling coding. The difference from the study of Locke and Locke (1971) was that all deaf subjects (age 28-63) were second-generation deaf who learned ASL as a native language from their parents. The method used for the experiments was a sentence judgment task in which subjects were asked whether a sentence was correct or not semantically, pragmatically or grammatically. In order to investigate what kind of coding subjects used, three experiments were conducted: (a) homophone experiment, (b) similar finger spelling experiment, and (c) similar sign experiment.

The homophone experiment was a sentence judgment task in which subjects were asked whether a sentence including homophones was semantically, pragmatically or grammatically correct. Examples of the homophone sentences are shown in Table 4.3.

Table 4.3 Sample sentences for the homophone experiment

Correct sentences	Incorrect sentences
Apples grow on trees.	Homophone sentences
The dog barked loudly.	He doesn't like to eat meet.
She works in Philadelphia.	His favorite color is blew.
	Control sentences
	He doesn't like to eat melt.
	His favorite color is bled.

(Treiman and Hirsh-Pasek 1983)

Although "He doesn't like to eat meet." is incorrect, its phonological representation makes sense as "He doesn't like to eat ***meat***." If a subject uses phonological coding, judgment of this sentence is difficult. The results are shown in Table 4.4.

Table 4.4 The results of homophone experiment

Conditions	Time (sec)	Errors (%)	Sentences for which correct answer not known (%)
Deaf subjects			
Homophone sentences	2.61	16.3	0.5
Control sentences	2.63	15.7	3.0
Homophone-control	-0.02	0.6	-2.5
Hearing subjects			
Homophone sentences	3.39	30.3	6.9
Control sentences	3.16	18.2	1.4
Homophone-control	0.23	12.09*	5.53**

*$p < .005$, one tailed. **$p < .025$, one tailed. (Treiman and Hirsh-Pasek 1983)

The hearing subjects made more errors when judging homophone sentences than when judging control sentences (30.3% to 18.2%). However this is not the case for deaf subjects (16.3% to 15.7%). This indicates that hearing subjects use phonological coding but not deaf subjects.

The similar finger spelling experiment was a sentence judgment task in which subjects were asked whether a sentence including similar finger spellings was correct. The examples of the similar finger spelling sentences are shown in Table 4.5.

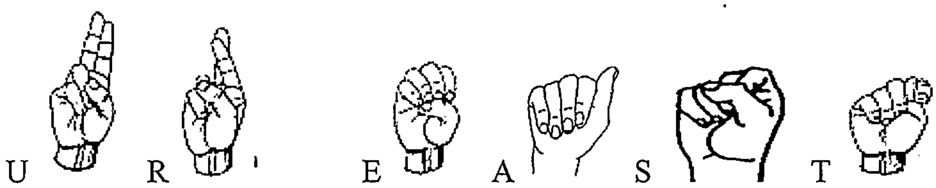
Table 4.5 Sample sentences for similar finger spelling experiment

Correct sentences	Incorrect sentences
Similar fingerspelling sentences	Similar fingerspelling sentences
Why don't you pour out our prune juice?	We ate steak easy hate.
That teacher hates easy tests.	Our ruler turned furious pour.
Control sentences	Control sentences
Why doesn't he throw away those peaches?	We had fish hard love.
The principal likes good children..	The president became angry fill.

(Treiman and Hirsh-Pasek 1983)

Finger spelling of “u” and “r” are similar, “e”, “a”, “s”, and “t” are similar, as shown in Figure 4.3.

Figure 4.3 Finger spelling U, R, E, A, S, T



Clearly the sentence “W*e ate stea*k *eas*y h*ate*.” is incorrect. In addition, this sentence includes many similar finger spellings as indicated with bold face in “W***e ate stea***k ***eas***y h***ate***.” Thus, if the subject uses finger spelling coding, this sentence would be difficult to judge as incorrect or not. The results are shown in Table 4.6.

Table 4.6 The results of similar finger spelling experiment

Conditions	Time (sec)	Errors (%)
Deaf subjects		
Similar fingerspelling sentences	3.21	9.15
Control sentences	2.93	8.98
Similar fingerspelling -control	.28**	0.17
Hearing subjects		
Similar fingerspelling sentences	3.8	9.88
Control sentences	3.57	11.69
Similar fingerspelling -control	.23*	-1.81

*$p < .005$, one tailed. **$p < .01$, one tailed. (Treiman and Hirsh-Pasek 1983)

The results show both deaf and hearing subjects took significantly longer on the similar finger spelling sentences than on the control sentences. No hearing subject is familiar with ASL. Thus, the longer time for judging may be due to factors other than finger spelling coding, such as repetition of the same letters.

The similar sign experiment was a sentence judgment task in which subjects were asked whether a sentence including similar signs was correct or not semantically, pragmatically or grammatically. The examples of the similar sign sentences are shown in Table 4.7.

Table 4.7 Sample sentences for similar sign experiment

Correct sentences	Incorrect sentences
Similar sign sentences	Similar sign sentences
I ate the apples at home yesterday.	The girl is jealous because is to sugar.
How exciting to be young and to enjoy happy vacations.	On a cold night, wear a milk cake.
Control sentences	Control sentences
I ate the bananas at work last week.	The boy is jealous because is to salt.
How wonderful to be young and to travel to the ocean.	On a warm day, put a soda cake.

Note. Words whose sign versions are similar are underlined. (Treiman and Hirsh-Pasek 1983)

The signs for "eat", "apple", "home", and "yesterday" are quite similar. If the subject uses sign coding for the sentence "I **ate** the **apples** at **home yesterday**." (bold face indicates the similar sign) it would be difficult to judge whether the sentence is correct or not because of the confusion of similar signs. In other words, this sentence is a sign-twister (or hand/finger-twister) sentence. The results are shown in Table 4.8.

Table 4.8 The results of similar sign experiment

Conditions	Time (sec)	Errors (%)
Deaf subjects		
Similar sign sentences	3.88	13.37
Control sentences	3.75	6.67
Similar sign -control	.13	6.70*
Hearing subjects		
Similar sign sentences	4.40	10.40
Control sentences	4.29	12.51
Similar sign -control	.10	-2.11

*$p < .005$, one tailed. (Treiman and Hirsh-Pasek 1983)

The deaf subjects made significantly more errors on the similar sign sentences than on the control sentences (13.37% to 6.67%). However this was not the case for hearing subjects (10.40% to 12.51%). This indicates that deaf subjects are using sign coding.

4.4 Phonological coding

The early studies of phonological coding in the deaf found that deaf readers also use phonological coding. However, these results were based on a certain group of deaf subjects. Their reading levels were very high which means their reading levels were much higher than the average reading levels of the entire deaf population. More recent studies focus on not only whether deaf readers use phonological coding, but also what the cause of the different results of phonological coding between deaf and hearing readers is. I will discuss three studies of phonological coding by deaf people in chronological order.

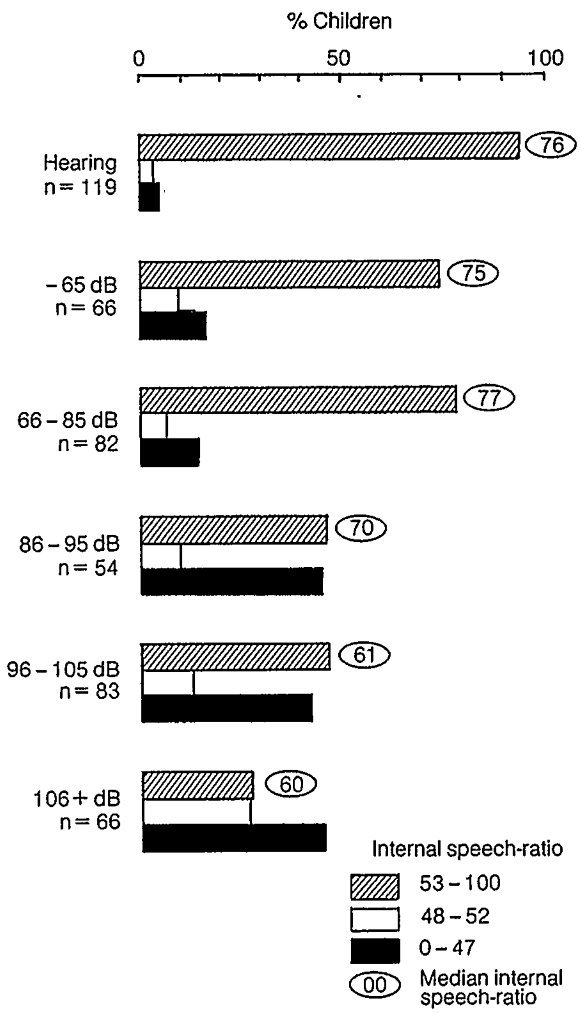
4.4.1 Internal Speech-Ratio

Conrad (1979) investigated whether deaf readers used phonological coding by conducting a word memorization experiment. The deaf subjects of this study were 15 to 16½ year olds from the schools for the Deaf and Partially Hearing in England and Wales. Their first language is English (spoken language). They were given two types of word list. One was a Homophone[20] set (rhyming words) (e.g., "do", "few", "who", "zoo"), and the other was a Nonhomophone set (e.g., "bare", "bean", "door", "furs"). The word list contained from two to five words and after the subjects were shown the words, they were asked to write down the words on the answer sheet. Conrad analyzed Internal Speech-Ratio (IS-Ratio) which was calculated to be the ratio of Homophone-word errors to all errors[21]. If all the errors of subject A were on the Homophone set, his score would be 100. On the other hand if all the errors of A were on the Nonhomophone set, his score would be 0. The results are shown in Figure 4.4.

[20] Conrad used the term 'homophone' for 'rhyme'.

[21] IS-Ration = Errors from Homophone set / All errors (Errors from Homophone set + Errors from Nonhomophone set)

Figure 4.4 Internal Speech - Ratio



(Conrad 1979)

The results found that the relationship between hearing loss and the use of internal speech that is the more hearing loss increases, the more internal speech decreases. The median of the IS-Ratio for the hearing subjects was 76, the median of IS-Ratio for the subjects whose hearing loss level[22] is 86-95dB was 70, and the median of IS-Ratio for the subjects whose hearing loss level is over 106dB was 60. Conrad concluded that hearing loss influenced their use of phonological coding and internal speech (inner speech).

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[22] Sound levels: 130 dB (loud enough to reach the pain threshold), 120 dB (a loud rock group), 100 dB (a person shouting at close range), 80 dB (a busy street), 70 dB (a loud conversation), 60 dB (a normal conversation), 50 dB (a soft whisper), (Colman 2006).

4.4.2 Phonological coding

Hanson, Goodell, and Perfetti (1991) investigated whether deaf readers used phonological coding during sentence comprehension by using tongue-twister sentences. In addition, they compared two conditions in terms of memory load from McCutchen, Bell, France, and Perfetti (1991). McCutchen et al. found that rehearsal of numbers starting with a fricative (in order to memorize them) influenced the response time for semantic acceptability judgment to the fricative sentences.

The deaf subjects were from Gallaudet University[23] and all had deaf parents and their first language is ASL. The hearing subjects were students from the University of Connecticut. In order to consider memory load influence, the subjects memorized five numbers on the screen before they saw tongue-twister sentences. The examples of numbers are shown in (49).

(49) Begin with the alveolar fricative /s/: 6, 7, 16, 17, 66, 63, 65, 68, 74, 79
Begin with the alveolar stop /t/ : 2, 12, 22, 23, 24, 25, 28, 29

The examples of sentences are shown in (50). Fricative sentences include the words which start with a fricative, and stop sentences include the words which start with a stop.

(50) Fricative: The <u>spacious</u> <u>zoo</u> <u>sits</u> beside a <u>sandy</u> <u>seashore</u>. (acceptable)
The <u>salty</u> <u>zone</u> <u>smashed</u> beside the <u>skillful</u> <u>station</u>. (unacceptable)

Stop : The <u>tiny</u> <u>toddler</u> <u>dreamed</u> of her <u>toy</u> <u>tiger</u>. (acceptable)
The <u>damaged</u> <u>detective</u> <u>dreamed</u> in the <u>tattered</u> <u>toddler</u>. (unacceptable)

Control : The amusement park was beside a rocky beach. (acceptable)
A black bush knew beside the walking stories. (unacceptable)

(Underline indicates the word which starts with a fricative or a stop.)

The subjects rehearsed the numbers, judged whether the sentence was semantically acceptable or

[23] The university is for education of the deaf and hard of hearing.

not, and then recalled the numbers and wrote down their answer on the answer sheet. Half of the material was a memory load condition. For example, reading fricative tongue-twister sentence after memorizing fricative numbers, or reading stop tongue-twister sentence after memorizing stop numbers. The other half was not a memory load condition. For example, reading fricative tongue-twister sentence after memorizing stop numbers, or reading control sentence after memorizing fricative numbers.

Phonological coding which is rehearsing numbers silently in order to memorize them and reading tongue-twister sentences influenced subjects' response times and judgments. The results are shown in Table 4.9.

Table 4.9 Mean correct response time (RTs) and percentage errors for acceptability judgments in the no memory load and memory load conditions on tongue-twister and control sentences

	No memory load			
	RTs		Errors	
	Hearing	Deaf	Hearing	Deaf
Acceptable sentences				
Tongue-twister	2897 (654)	2587 (547)	14.0 (11.3)	22.8 (9.9)
Control	2698 (505)	2454 (561)	5.1 (7.3)	16.5 (9.2)
Unacceptable sentences				
Tongue-twister	2899 (542)	2568 (549)	12.7 (13.5)	26.5 (16.7)
Control	2859 (661)	2543 (531)	9.3 (12.5)	28.0 (22.1)
	Memory load			
Acceptable sentences				
Tongue-twister	3158 (535)	2632 (619)	20.6 (13.5)	24.0 (6.0)
Control	2999 (410)	2471 (639)	15.2 (13.9)	14.6 (10.0)
Unacceptable sentences				
Tongue-twister	3169 (411)	2708 (547)	17.1 (12.6)	29.0 (17.0)
Control	3047 (611)	2656 (753)	14.8 (20.9)	29.6 (16.9)

Note. Standard deviations are shown in parenthesis. (Hanson, Goodell, and Perfetti 1991)

The response times to tongue-twister sentences were longer than the response times for control sentences by both deaf and hearing subjects. Both hearing and deaf subjects made more errors when judging tongue-twister sentences in memory load condition. For example, the hearing subjects made 12.7 errors in unacceptable tongue-twister sentence in no memory load condition and 17.1 errors in unacceptable tongue-twister sentence in memory load condition. The deaf subjects made 26.5 errors in unacceptable tongue-twister sentence in no memory load condition and 29.0 errors in unacceptable tongue-twister sentence in memory load condition. These results indicate that deaf subjects are also using phonological coding.

4.4.3 Different types of phonological awareness

Sterne and Goswami (2000) conducted three experiments of syllable awareness, rhyme awareness, and phoneme awareness. In these three experiments, pictures were used for the materials instead of printed words. Experimenters checked whether subjects knew the names (words) of the pictures before the experiments and when they did not know, the pictures were excluded from the experiments.

In the syllable awareness experiment, the deaf subjects were children whose mean age was 11 years old. Three groups of subjects participated in this study: deaf subjects, a chronological age-matched group, and a reading-level matched group[24]. Two pictures were shown on the computer screen and subjects were asked to judge whether two names (words) were the same number of syllables[25]. This experiment was designed to investigate whether the deaf subjects could judge syllable length without the influence of the word length, such as the longer word has more syllables than short word. Thus, there were two sets of word pairs used. One was a set of congruent word sets which consisted of word pairs that were orthographically

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[24] Deaf children and children of reading matched group are assessed reading levels with the Group Reading Test (NFER-Nelson, 1985). The mean age of reading matched group is 8.25.

[25] Experimenter instructed subjects about the concept of syllable before the experiment.

(the numbers of letters) and phonologically (the numbers of syllable) congruent. In other words, each word consisted of the same numbers of letters and the same numbers of syllables, for example, "hat-key". The other set was an incongruent word set which consisted of word pairs that were orthographically and phonologically incongruent. In other words, each word consisted of the same numbers of letters and the different numbers of syllables such as "church-finger", or the different numbers of letters and the same numbers of syllables such as "piano-elephant".

The mean number of correct judgments and the reaction times are shown in Table 4.10.

Table 4.10 Mean (SD) performance scores and reaction times for all groups for incongruent and congruent word pairs in syllable awareness experiment

	Performance (max. 18)		Reaction time (secs)	
	Incongruent	Congruent	Incongruent	Congruent
Deaf group	11.53 (4.58)	15.73 (2.55)	6.44 (2.21)	5.40 (2.06)
CA controls	13.77 (4.02)	16.92 (1.26)	5.66 (1.18)	5.01 (1.61)
RA controls	12.15 (3.31)	15.77 (1.48)	7.72 (2.16)	6.77 (1.84)

(CA: chronological age-matched, RA: reading-level matched) (Sterne and Goswami 2000)

The results showed that the three groups had similar patterns of performance. In the reaction time, all three groups took longer when judging the incongruent word set than when judging the congruent word set. These results suggest deaf subjects also have phonological representations of syllables.

In the rhyme awareness experiment, the deaf children whose mean age is 10 years old were used. For the control group, the reading-level matched group was used. Three pictures were shown on the computer screen. The target picture was presented above the two pictures (one was a rhyme of the target picture and the other was distracter). Subjects were asked to choose the rhyming one from two pictures. There were two rhyming word pair sets. One was an orthographically similar (O+) pair (e.g., "cl<u>ock</u>-s<u>ock</u>") which ended with the same letter(s). The other was nonorthographically similar (O-) pairs ("fly-eye") which did not end with the same letter(s). A distracter was phonologically similar to the target such as "owl" for "house-mouse", or orthographically similar to the target such as "witch" for "ball-wall".

The mean number of correct answer and the reaction times are shown in Table 4.11.

Table 4.11 Mean (SD) performance scores and reaction times for both groups on Rhyme awareness experiment

	Accuracy (max. 25)		Reaction times (sec)	
	O+	O-	O+	O-
Deaf group	20.71	18.36	6.36	7.48
	(3.69)	(4.62)	(1.69)	(2.61)
RA controls	23.81	23.50	4.69	4.75
	(2.43)	(2.10)	(1.52)	(1.57)

(RA: reading-level matched) (Sterne and Goswami 2000)

The deaf subjects performed better with O+ pairs (20.71 for accuracy and 6.36 for reaction time) than O- pairs (18.36 for accuracy and 7.48 for reaction time), while the hearing subjects performed equally well with both O+ (23.81 for accuracy and 4.69 for reaction time) pairs and O- pairs (23.50 for accuracy and 4.75 for reaction time). These results suggest deaf subjects were able to make rhyme judgment the same way as hearing subjects do. However, deaf subjects used orthographic similarity to support their judgment more than hearing subjects.

For the phoneme awareness experiment, the subjects were deaf children and a reading-level matched group from the syllable awareness experiment. Subjects were given a picture along with a written form of four made-up words and asked to choose one word from the four made-up words which sounds like the picture. For example, a picture of two boys and four made-up words "boiz", "roiz", "beiz", and "boin" were given, and the expected answer was "boiz". These four made-up words were orthographically similar (using the same letters from the expected answer). If deaf subjects choose the homophone on an orthographic basis, all made-up words have an equal chance to be chosen.

The mean numbers of correct answer are shown in Table 4.12.

Table 4.12 Mean number (SD) of correct choices for Phoneme awareness experiment

	Total (max = 20)		Total (max = 20)
Deaf group	12.59 (3.14)	RA controls	18.31 (2.10)

(RA: reading-level matched) (Sterne and Goswami 2000 modified)

Although the deaf subjects chose the correct answers at a level above chance[26], it is significantly worse than the performance of hearing group (12.59 to 18.31). These results suggest deaf children were able to make homophone judgment. However, their awareness level is lower than hearing subjects.

From these results, Sterne and Goswami concluded that although deaf subjects were able to use a phonological coding strategy, their scores on rhyme and phoneme awareness experiments were lower than hearing reading-level matched group whose ages were younger than the deaf subjects.

Although Locke and Locke (1971) and Treiman and Hirsh-Pasek (1983) found the evidence for finger spelling coding and sign coding respectively, the studies of Conrad (1971), Hanson, Goodell, and Perfetti (1991), and Sterne and Goswami (2000) found deaf subjects also used phonological coding. The common finding from the studies of Hanson et al. and Sterne and Goswami was that although deaf subjects used phonological coding, their scores in experiments were lower than hearing subjects' scores. The experimental materials caused phonological confusion based on actual speech. Besides raising the question of whether the products of phonological coding (inner speech) are exactly the same as actual speech or not, the results of the above studies indicate that deaf subjects' phonological coding is less close to actual speech than

[26] 63% accuracy

hearing subjects' phonological coding.

CHAPTER 5: RESEARCH GOAL AND METHODS

As discussed in Chapter 1, the reading process involves the interaction of many factors such as syntactic processing, semantic processing, phonological processing, and pragmatic processing. Studies of sentence processing in silent reading have found that prosody in inner speech (implicit prosody) is a factor during parsing (syntactic processing) as we saw in Chapter 3. The comparison between readers who use inner speech and those who do not would be an ideal way to investigate whether inner speech is necessary for parsing. However, because it is impossible to find subjects who do not use inner speech at all, we can investigate inner speech (phonological coding) only indirectly. Studies of deaf and hard of hearing readers have found that although they use phonological coding, their phonological coding is less close to the actual speech than hearing readers' phonological coding, or they might also use other types of coding, such as sign or finger spelling coding (see Chapter 4). Thus, the comparison between hearing-loss and hearing readers would show the influence of implicit prosody for parsing in silent reading.

5.1 Research goal

The goal of this thesis is to investigate whether prosody influences parsing in silent reading. It assumes that deaf and hard of hearing readers use phonological coding but their phonological coding is less close to the actual speech than hearing readers' phonological coding. Inner speech is a result of phonological coding. Thus, the use of implicit prosody in inner speech of deaf and hard of hearing readers could also be different from that of hearing readers. According to Fodor (1998, 2002) and Bader (1998), implicit prosody in inner speech is an important factor of the parsing process during silent reading. Thus, the parsing (which is influenced by implicit prosody) by deaf and hard of hearing readers could be different from hearing readers.

(51) Assumptions

- Hearing-loss readers also use phonological coding but their phonological coding is less close to the actual speech than hearing readers' phonological coding.
- Implicit prosody of hearing-loss readers is different from hearing readers' implicit prosody.
- Implicit prosody influences the parsing process in silent reading.

(52) Hypothesis

The parsing process (the use of parsing strategies and preferences of parsing strategies) during silent reading of hearing-loss readers is different from hearing readers.

5.2 Research method

5.2.1 Subjects

The study of Fernández (2003) found that the parsing strategies of a reader's first language (L1) influence their second language (L2) processing. Hearing levels could also influence their phonological coding skill (Chapter 4). In addition, one parsing strategy difference among languages is the preference of RC-attachment in ambiguous sentences (Chapter 2) which is syntactically complicated for deaf and hard of hearing readers whose average reading level is grade 3 to 4 (Chapter 4). Thus, this study provides a comparison of the parsing between hearing-loss and hearing readers, and also a comparison of the L1 influences to the parsing between their L1 is English and sign language. It would be ideal if all the hearing-loss subjects had the same hearing levels, the same language backgrounds, and the same reading levels. However, it is very difficult to find those ideal subjects for my study. The reasons are, (a) the deaf and hard of hearing population is small compared to the hearing population, (b) my study needs subjects who are able to read syntactically and prosodically complex and ambiguous sentences which require a higher than average reading level for deaf and hard of hearing people, and (c) the language background is influenced by their family members' language background. Thus, although I had hoped for subjects that fit a certain profile, I gathered data from as many subjects as possible. Hearing-loss subjects were recruited from Calgary and Edmonton in Canada. The criteria for the hearing-loss subjects are in (53). As a control group, hearing subjects whose L1 is English were recruited from the University of Calgary.

(53) The criteria for the hearing-loss subjects

- Subjects whose L1 is English or American Sign Language.
- Subjects who lost their hearing or started losing their hearing before they entered an elementary school.
- Subjects whose first written language is English.
- Subjects who know their hearing levels.

In order to compare two types of subjects groups, hearing-loss and hearing subjects, I am going to refer to the hearing-loss (deaf and hard of hearing) subjects as DH subjects.

5.2.2 Stimuli

First, in order to investigate whether there are parsing differences between DH readers and hearing readers, subject-extracted RC and object-extracted RC sentences pairs were chosen. If DH readers also prefer the locality parsing strategy, subject-extracted RC sentences would be easier to interpret than object-extracted RC sentences according to the Dependency Locality Theory (Gibson 1998, 2000).

(54) a. The **reporter** who **attacked** the senator admitted the error. ← easier

b. The **reporter** who the senator attacked **admitted** the error.

Next, in order to investigate whether DH readers and hearing readers also use implicit prosody during the parsing process, I tested them on sentences which required syntactic and prosodic reanalyses, and long RC and short RC sentences. According to the Prosodic Constraint on Reanalysis (Bader 1998), revising a syntactic structure is difficult if it also requires prosodic reanalysis. Thus, a sentence which requires both syntactic and prosodic reanalysis is more difficult to process, such as (18b) than a sentence which requires only syntactic reanalysis, such as (19b).

(18 b) Both syntactic and prosodic reanalysis are required: difficult

($_{I}$ [$_{CP}$ In order to help *the little boy*]) put down the package he was carrying.

($_{I}$ [$_{CP}$ In order to help]) ($_{I}$ *the little boy* put down the package he was carrying.)

(19 b) Only syntactic reanalysis is required: not difficult

($_{I}$ [$_{CP}$ Peter knew the answer] would be false.)

($_{I}$ [$_{CP}$ Peter knew] the answer would be false.)

Next, in order to investigate whether there are differences of RC-attachment preference between DH readers and hearing readers, and DH readers whose L1 is English and DH readers whose L1 is sign language, long RC and short RC sentences were used. RC-attachment preference is not a universal parsing strategy as I discussed in Chapter 2. The previous studies found English speakers prefer low attachment (LA). Thus, DH readers who are also English speakers should prefer LA and DH readers whose L1 is sign language could have a different preference.

(55) Someone shot the maid of the actress who was on the balcony.

Interpretation: The actress was on the balcony with her husband. (LA)

(56) Someone shot the maid of the actress who was on the balcony with her husband.

Interpretation: The maid was on the balcony with her husband. (HA)

The different preference of RC-attachment in ambiguous sentences is explained by the

Implicit Prosody Hypothesis (Fodor 1998, 2002) which states that the parser's resolution of syntactic ambiguity is influenced by prosodic processing. Fodor (1998, 2000) found that a default prosodic contour is characterized by no prosodic break before a short RC and by flexible break insertion before a long RC in English. The results of this prosodic phrasing in English, readers prefer LA for a short RC based on the locality preference (55) and flexible attachment preference in long RC which means the reader tends to prefer HA if they insert a prosodic break before a long RC (57) and LA if they do not insert a prosodic break before a long RC (55).

(57) Someone shot the maid of the actress // who was on the balcony with her husband.

Interpretation: The maid was on the balcony with her husband. (HA)

(//: prosodic break)

5.2.3 Procedure for DH subjects

Two experimental methods were chosen: offline and online experiments. Offline study elicits the data from subjects who are given time to think and judge as much as possible. On the other hand, online study is a real time experiment of a certain duration. A questionnaire was used for the offline study and an eye-tracking experiment was used for the online study. First, the subjects were asked to fill out a profile about their hearing and language background in order to find out whether they met the criteria (53). If the subject's L1 was not English or ASL even though his/her first written language was English, he/she was eliminated. One subject whose L1 was spoken German and first written language was English was eliminated. If the subject lost his/her hearing or started losing his/her hearing after he/she entered an elementary school, he/she would have been eliminated. No subject was eliminated because of this. If the subject's first written language was not English even though his/her L1 was English or ASL, he/she would have been eliminated. No subject was eliminated because of this. If the subject did not know his/her hearing level, he/she was eliminated. One subject claimed she would find out her hearing level later and participated in all studies, but she could not find out her hearing levels. Thus, after the experiments were done, her data was eliminated. Next, the subjects who met the criteria (53) were asked to participate in a questionnaire study. This questionnaire study was also used to assess their English reading levels. If the subjects skipped a lot of questions or if the answers to the questionnaire were extremely inconsistent, I assumed they did not understand the meaning of the question or sentence, and they would be eliminated. However, no subjects were eliminated after the participation of questionnaire study. Lastly, the subjects were asked to participate in an eye-tracking experiment. Many of the sentences in the materials were syntactically and prosodically ambiguous because there were no commas in the sentences. Once the subjects knew the pattern of syntactic structure of the materials, they would pay attention to the structure of the sentences. In order to avoid this familiarizing with the materials, participation of the eye-tracking study was at least a few days after participation in the questionnaire study[27].

5.2.4 Procedure for hearing subjects

The same experimental methods for DH subjects were used for hearing subjects. All subjects were students of the University of Calgary. Thus, their reading levels were high enough for my study. In order to avoid familiarizing the materials and not needing to assess their reading levels, subjects were asked to participate in an eye-tracking study first and questionnaire study second. They were also asked to fill out the profile about their language background before or after their participation in the studies.

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[27] Most of the hearing-loss subjects participated in an eye-tracking experiment more than two weeks after their participation of the questionnaire study.

CHAPTER 6: EXPERIMENT 1 – QUESTIONNAIRE

6.1 Subjects

A total of nine DH subjects from Edmonton and Calgary and six hearing subjects from Calgary participated in this study. DH subjects consisted of six deaf subjects and three hard of hearing subjects. Their hearing loss levels and language backgrounds are given in Table 6.1.

Table 6.1 DH group (DH1-6: deaf subjects, DH7-9: hard of hearing subjects)

Subject	Age	Gender	First hearing loss (age)	Hearing level[28]		L1
				Left ear (dB)	Right ear (dB)	
DH1	55	F	0	102	110-120	ASL
DH2	55	M	6	120	120	English
DH3	36	F	0	150	150	Eng-Sign[29]
DH4	39	M	1	over 100	over 100	English
DH5	40	F	0	over 180	95	ASL
DH6	25	F	4	80-85	75-80	English
DH7	34	F	0	90	95	English
DH8	43	M	3	30	40-50	English
DH9	18	M	0	80	75	Eng-Sign

(F: Female, M: Male)

Language backgrounds of the hearing subjects are given in Table 6.2.

[28] See footnote 22 (Chapter 4.4.1).

[29] English-based sign was developed by educators. It added grammatical features of English to ASL. For example, the sentence "I have three books." is signed in ASL as "I HAVE 3 BOOK", but it is signed "I HAVE 3 BOOK -S" in English-based sign.

Table 6.2 Hearing control group

Subject	Age	Gender	L1	L2
C1	18	F	English	French
C2	21	F	English	
C3	19	M	English	
C4	21	M	English	French
C5	20	M	English	Chinese
C6	22	F	English	French

(F: Female, M: Male, L1: first language, L2: second language[30])

6.2 Stimuli

The questionnaire consists of three parts (see Appendix C). Part 1 was designed to find the processing difficulty related to the locality preference, the syntactic reanalysis, and the prosodic reanalysis. Part 2 was designed to find out the preferred parsing strategy of RC-attachment in ambiguous sentences. Part 3 was designed to check whether readers consciously notice the prosodic boundary. Commas were omitted from all sentences and spaces between words were equal. Thus, some sentences were very ambiguous and the others were not.

Part 1 had 5 categories of sentence pair of difficulty judgment. The examples are shown in (58-62). Subjects were asked to choose which sentence was more difficult to comprehend. If they found the sentence equally comprehensible, they were asked to answer "same".

(58) Category I: Subject-extracted RC vs. Object-extracted RC (5 pairs[31])

a. The reporter who attacked the senator admitted the error.
b. The reporter who the senator attacked admitted the error. (difficult)

Category I: readers would find a subject-extracted RC to be easier than an object-extracted RC according to the Dependency Locality Theory (Gibson 1998, 2000). Thus, the expected answer would be (58b).

[30] Only subjects who can speak the second language fluently.

[31] 1 pair was misclassified to this category and it was omitted from the data analysis.

(59) Category II: Short RC vs. Long RC (5 pairs[32])

a. Julia saw the secretary of the lawyer that was on vacation. (Short RC)
b. Julia saw the secretary of the lawyer that was speaking on the phone all morning. (long RC)

Category II: although there is no theory that long RC is more difficult than shot RC or vice versa, I was curious to know whether DH readers would find a difference between long and short RCs.

(60) Category III: No reanalysis vs. Syntactic and Prosodic Reanalyses I (10 pairs)

a. In order to help the little boy Jill put down the package she was carrying.
b. In order to help the little boy put down the package he was carrying. (difficult)

Category III: the sentence requires both syntactic and prosodic reanalyses is predicted to be more difficult according to the Prosodic Constraint on Reanalysis (Bader 1998). Thus, the expected answer would be (60b).

(61) Category IV: No reanalysis vs. Syntactic and Prosodic Reanalyses II (long adverbial phrase vs. short adverbial phrase) (10 pairs)

a. John will explain to the kids that their grandfather died after they come home from school.
b. John will explain to the kids that their grandfather died tomorrow. (difficult)

Category IV: two sentences differ in the length of adverbial phrase (AdvP). The study of Frazier and Clifton (1996) found that a sentence including an embedded clause with a short AdvP was more difficult to process than one with a long AdvP. This can be explained with Prosodic Constraint on Reanalysis (Bader 1998). In sentence (61b), assuming readers tend to attach the adverb *tomorrow* to the previous phrase without a prosodic break before it based on early closure and making it require both syntactic and prosodic reanalyses. On the other hand, sentence (61a) would be easy to process because readers would tend to insert a prosodic break before the long

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[32] Long RC of one pair was forced to HA because of the plural (typing error) of the second noun. Thus, the pair was omitted from the data analysis.

AdvP in terms of syntactic and prosodic congruency. As a result of the prosodic break before the long AdvP, the prosodic break would match the syntactic boundary and prosodic boundary. Thus, the sentence does not require any reanalysis at all and it would be easy to process. Sentence (61b) would be predicted to be more difficult.

(62) Category V: No reanalysis vs. Syntactic Reanalysis (5 pairs)

a. Peter knew the answer immediately.
b. Peter knew the answer would be false.

Category V: although sentence (62b) requires syntactic reanalysis, the sentence is short and it would be within one prosodic phrase. Thus, the sentence does not require prosodic reanalysis, and the readers would not have difficulty processing this sentence. A total of 35 pairs from category I to V were randomly ordered in the questionnaire.

Part 2 was designed to investigate RC-attachment preference. The RC of the sentences can modify either the first noun (HA) or second noun (LA).

(63) Julia saw the secretary of the lawyer that was on vacation. (Short RC)

The RC sentence was followed by a question and two answers. The question of sentence (63) was "Who was on vacation?" and two answers were "the secretary" and "the lawyer". Subjects were asked to read and answer 10 short RC sentences and then 10 long RC sentences.

Part 3 was designed to investigate whether subjects have conscious knowledge of a prosodic phrase boundary. For example, "In order to help the little boy Jill put down the package she was carrying." The expected answer would be a break after the word *boy* as "In order to help the little boy / Jill put down the package she was carrying." 10 sentences (5 pairs) from category III, 10 sentences (5 pairs) from category IV, and 10 sentences (5 pairs) from category V were chosen from Part 1. In addition, a total of 30 RC sentences (Long RC 15 and Short RC 15) were used. Both short and long RCs were divided into three groups. (a) syntactically forced to HA (the number agreement makes HA): e.g., "Lisa couldn't find the ***refill*** for the pens that ***was*** on sale." (b) syntactically forced to LA (the number agreement makes LA): such as, "Lisa couldn't find the refill for the ***pens*** that ***were*** on sale." (c) ambiguous: "Lisa couldn't find the refill for the pen that was on sale." These RC sentences were extracted from Fernández (2003) and modified. In total 60 sentences were randomly ordered in Part 3.

6.3 Procedure

The questionnaire was distributed as a Microsoft Word document. Subjects were asked to check a box for the appropriate answer in Part 1 and Part 2. In Part 1, subjects were asked to choose which sentence was more difficult to comprehend. A check box was placed next to each sentences and there was also the option to check box "same". If the subjects found the sentences equally comprehensible, they were asked to check the box "same". In Part 2, subjects were asked which interpretation they prefer after reading ambiguous RC sentences. The question and two answers (interpretations) were provided under the RC sentence and a check box was placed next to the answers. In Part 3, subjects were asked to insert at most two[33] slashes ("/") in the sentences in order to read the sentence most naturally.

6.4 Results

6.4.1 Part 1: Difficulty Judgment

Locality Preference: Category I (Subject-extracted RC vs. Object-extracted RC)

The results of investigating the locality preference are shown in Table 6.3. The numbers are the

[33] In order to avoid subjects inserting slashes after many phrases.

numbers of the subjects who found that the sentence was difficult. The number on the left is the number of the subjects who found that the subject-extracted RC sentence was more difficult than the object-extracted RC sentence. The number on the right is the number of the subjects who found that the object-extracted RC sentence was more difficult than the subject-extracted RC sentence. Not all subjects found a clear difficulty difference between the two sentences, thus the total numbers of answers were less than the total numbers of subjects.

Table 6.3 Difficulty judgment for Locality Preference

	Subject-extracted RC	Object-extracted RC	DH subjects	Hearing subjects
(a)	The reporter who attacked the senator admitted the error.	The reporter who the senator attacked admitted the error.	1:5	0:3
(b)	I met the man who married my mother's friend.	I met the man who my mother's friend married to.	1:4	0:6
(c)	The black cat that chased the white cat was my pet.	The black cat that the white cat chased was my pet.	1:3	2:1
(d)	The man who went out with me last year was a poor actor.	The man who I went out with last year was a poor actor.	3:1	2:0
		Total	6:13	4:10

(Subject-extracted RC : Object-extracted RC)

The results from sentence pair (a) and (b) showed that the object-extracted RC was more difficult than the subject-extracted RC. These results are consistent with the results of the Dependency Locality Theory (Gibson 1998, 2000). The subjects had a locality preference. As in sentence pair (c), the answers of DH subjects showed locality preference, but two hearing subjects did not show a locality preference. The answers of sentence pair (d) did not reveal subjects' locality preference. From these results, DH subjects also had a locality preference similar to hearing subjects.

RC Length Effect: Category II (Long RC vs. Short RC)

The results for investigating any RC length effect are shown in Table 6.4. One pair was omitted from the data analysis because it was forced to HA due to a typing error. The number on the left is the number of the subjects who found that the short RC sentence was more difficult than the long RC sentence. The number on the right is the number of the subjects who found that the long RC sentence was more difficult than the short RC sentence.

Table 6.4 Difficulty judgment for RC Length Effect

	Short RC	Long RC	DH subjects	Hearing subjects
(a)	Julia saw the secretary of the lawyer that was on vacation.	Julia saw the secretary of the lawyer that was speaking on the phone all morning.	0:4	0:3
(b)	The plumber adjusted the pipe of the sink that was cracked.	The plumber adjusted the pipe of the sink that was installed before I moved in this apartment.	2:0	2:1
(c)	Patricia saw the teacher of the student that was in the zoo.	Patricia saw the teacher of the student that was in the library the other day.	4:1	2:2
(d)	Lisa couldn't find the refills for the pens that were on sale.	Lisa couldn't find the refills for the pens that were in the lower desk drawer.	2:2	3:3
		Total	8:7	7:9

(Short RC : Long RC)

The subjects did not show a clear difficulty with either short RC or long RC (the answers of both DH and hearing subjects were similar in pairs (a), (b), and (d)). From these results, it seems that the difficulty differences were not due to the length of RC. If there is a difficulty difference, it could be influenced by other factors.

Reanalysis 1: Category III (No Reanalysis vs. Syntactic and Prosodic Reanalysis I)

The results for Reanalysis 1 are shown in Table 6.5. One pair was omitted from the data analysis because one of the sentences had a typing mistake which caused an ungrammatical sentence.

This ungrammaticality could have influenced the judgment of the difficulty to interpret the sentence.

Table 6.5 Difficulty judgment for Reanalysis 1

	No reanalysis	syntactic and prosodic reanalysis	DH subjects	Hearing subjects
(a)	Without her contributions the funds would be inadequate.	Without her contributions would be inadequate.	1:5	0:6
(b)	Whenever the dog obeyed the little girl she showed her approval.	Whenever the dog obeyed the little girl showed her approval.	1:4	2:3
(c)	In order to help the little boy Jill put down the package she was carrying.	In order to help the little boy put down the package he was carrying.	1:7	1:5
(d)	Since Jay always walks a mile it seems like a short distance to him.	Since Jay always walks a mile seems like a short distance to him.	1:1	1:5
(e)	According to her studies the volcano would erupt in less than one year.	According to her studies predict the volcano would erupt in less than one year.	1:6	0:6
(f)	Because many students failed the exam it was made easier this year.	Because many students failed the exam was made easier this year.	2:3	0:5
(g)	Because of her contributions the funds would be adequate.	Because of her contributions would be adequate.	0:7	0:6
(h)	Every time Harry calls his mother she is out.	Every time Harry calls his mother is out.	2:3	1:3
(i)	Although I called John he didn't come to the party.	Although I called John didn't come to the party.	1:5	1:4
		Total	10:41	6:43

(No reanalysis : Syntactic and prosodic reanalyses)

The number on the left is the number of the subjects who found that the sentence which required no reanalysis was more difficult than the sentence which required both syntactic and prosodic reanayses. The number on the right is the number of the subjects who found that the sentence which required both syntactic and prosodic reanalyses was more difficult than the sentence which required no reanalysis.

Both DH and hearing subjects found sentences which required both syntactic and prosodic reanalyses to be more difficult than sentences which required no reanalysis. These results are consistent with the prediction by the Prosodic Constraint on Reanalysis (Bader 1998).

Reanalysis 2: Category IV (No Reanalysis vs. Syntactic and Prosodic Reanalysis II)

The results for Reanalysis 2 are shown in Table 6.6. The number on the left is the number of the subjects who found that the sentence which required no reanalysis was more difficult than the sentence which required both syntactic and prosodic reanalyses. The number on the right is the number of the subjects who found that the sentence which required both syntactic and prosodic reanayses was more difficult than the sentence which required no reanalysis.

Table 6.6 Difficulty judgment for Reanalysis 2

	No reanalysis	syntactic and prosodic reanalysis	DH subjects	Hearing subjects
(a)	Tom will give you the cat that my dog chased tomorrow.	Tom will give you the cat that my dog chased after he buys a cage for it.	5:3	3:3
(b)	You will hear from Lisa that Mike's wife fainted tomorrow.	You will hear from Lisa that Mike's wife fainted after Lisa comes back to town.	2:3	1:3
(c)	John will explain to the kids that their grandfather died tomorrow.	John will explain to the kids that their grandfather died after they come home from school.	1:2	0:4
(d)	Mary will tell you that Peter danced after tomorrow.	Mary will tell you that Peter danced after everyone comes to school.	0:4	0:3
(e)	Jack will tell you that you have failed tomorrow.	Jack will tell you that you have failed after he comes back to the office.	1:4	0:4
(f)	Mike will know that his mother was very sick tomorrow.	Mike will know that his mother was very sick after he sees her pictures.	3:3	0:4
(g)	We will see the movie that was famous in China tomorrow.	We will see the movie that was famous in China after our teacher gets the video.	3:3	2:2
(h)	You will believe that Jack told us the truth tomorrow.	You will believe that Jack told us the truth after you watch the news.	0:3	0:5
(i)	Harry will inform you that Tom failed the mission tomorrow.	Harry will inform you that Tom failed the mission after he returns next week.	1:3	0:4
(j)	He will hear from Mary that she broke her leg tomorrow.	He will hear from Mary that she broke her leg after he goes to a hospital.	0:5	0:5
		Total	16:33	6:37

(No reanalysis : Syntactic and prosodic reanalyses)

Both DH and hearing subjects found sentences which required both syntactic and prosodic reanalyses to be more difficult than sentences which required no reanalysis. These results are consistent with the prediction by the Prosodic Constraint on Reanalysis (Bader 1998).

Reanalysis 3: Category V (No Reanalysis vs. Syntactic Reanalysis)

The results for Reanalysis 3 are shown in Table 6.7. The number on the left is the number of the subjects who found that the sentence which required no reanalysis was more difficult than the sentence which required syntactic reanalysis. The number of right is the number of the subjects who found that the sentence which required syntactic reanalysis was more difficult than the sentence which required no reanalysis.

Table 6.7 Difficulty judgment for Reanalysis 3

	No reanalysis	syntactic reanalysis	DH subjects	Hearing subjects
(a)	Peter knew the answer immediately.	Peter knew the answer would be false.	1:1	0:0
(b)	I believe you with all my heart.	I believe you are innocent.	0:2	0:0
(c)	Mike heard the story yesterday.	Mike heard the story was boring.	1:0	1:0
(d)	Tom found the book yesterday.	Tom found the book was boring.	1:0	1:0
(e)	Mary will know his sister sooner or later.	Mary will know his sister is cute.	1:2	2:1
		Total	4:5	4:1

(No reanalysis : Syntactic reanalysis)

Both DH and hearing subjects did not find a difficulty difference between the two sentence types. Thus, these sentences which only required syntactic analysis did not give the difficulty to the readers. This is also predicted by the Prosodic Constraint on Reanalysis (Bader 1998).

The results for these difficulty judgments of the DH subjects were similar to those of the hearing subjects. This confirmed that the DH subjects also had a locality preference and found difficulty with the sentences which required syntactic and prosodic reanalyses.

6.4.2 Part 2: Relative Clause Attachment Preference

The results of question about RC-attachment preference are shown in Table 6.8.

Table 6.8 RC-Attachment Preference [DH vs. Hearing]

Short RC

	HA	LA		HA	LA
DH1	**9**	1	C1	0	**10**
DH2[34]	4	5	C2	4	6
DH3	**10**	0	C3	3	**7**
DH4	**10**	0	C4	0	**10**
DH5	5	5	C5	0	**10**
DH6	1	**9**	C6	2	**8**
DH7	4	6			
DH8	**10**	0			
DH9	**10**	0			

Long RC

	HA	LA		HA	LA
DH1	**9**	1	C1	1	**9**
DH2	**8**	1	C2	2	**8**
DH3	**10**	0	C3	4	6
DH4	**9**	1	C4	1	**9**
DH5	**7**	3	C5	0	**10**
DH6	4	6	C6	5	5
DH7	5	5			
DH8	0	**10**			
DH9	**10**	0			

(the numbers of sentences out of 10, boldface: over 2/3 of all sentences)

In order to analyze the data, if the subject chose HA on more than 1/3 of the total sentences of the same types of RC sentences, then this was scored as the subject preferring HA. If the subject chose LA on more than 1/3 of the total sentences of the same types of RC sentences, then this was scored as the subject preferring LA. Finally if the subject did not choose either HA or LA on more than 1/3 of the total sentences, the subject was scored as not having any preference.

Although five out of six hearing subjects preferred LA for short RC sentences, only one DH subject preferred LA in short RC sentences. Five DH subjects preferred HA in short RC sentences. The results for four DH subjects and one hearing subject did not indicate any preference in short RC sentences. Four out of six hearing subjects preferred LA for long RC sentences. Six DH subjects preferred HA and two DH subjects preferred LA. Most of the hearing subjects preferred LA in both short and long RC sentences. On the other hand, more than half of the DH subjects preferred HA for both short and long RC sentences. The results for the hearing subjects were consistent with the previous studies which found an LA preference by English speakers. From these results, it seems that DH subjects and hearing subjects had a different RC-

[34] H2 answered both HA and LA in one short RC and one long RC, thus total numbers of the answer is 9 in short RC and 9 in long RC.

attachment preference.

In order to investigate the influence of L1, DH subjects are divided into two groups: L1 English and L1 sign language. I am going to refer to the DH subjects whose L1 is English as DH (English) and the DH subjects whose L1 is sign language as DH (Sign). The results are shown in Table 6.9 and Table 6.10.

Table 6.9 RC-Attachment Preference for [DH (English) vs. Hearing]

Short RC						Long RC					
DH (English)	HA	LA	Hearing	HA	LA	DH (English)	HA	LA	Hearing	HA	LA
DH2	4	5	C1	0	**10**	DH2	**8**	1	C1	1	**9**
DH4	**10**	0	C2	4	6	DH4	**9**	1	C2	2	**8**
DH6	1	**9**	C3	3	**7**	DH6	4	6	C3	4	6
DH7	4	6	C4	0	**10**	DH7	5	5	C4	1	**9**
DH8	**10**	0	C5	0	**10**	DH8	0	**10**	C5	0	**10**
			C6	2	**8**				C6	5	5

(the numbers of sentences out of 10, boldface: over 2/3 of all sentences)

Of five DH (English) subjects, only one subject preferred LA, two subjects preferred HA in short RC, and two subjects did not indicate any preference in short RC sentences. For long RC sentences, one subject who preferred HA in short RC sentences changed to LA preference in long RC sentences, one subject who preferred LA in short RC sentences did not indicate a preference in long RC sentences, and one subject who did not indicate any preference in short RC sentences preferred HA in long RC sentences. Although these results do not indicate a clear preference of DH (English), they seemed to be different from hearing subjects who preferred LA. Thus, this could indicate that hearing loss influenced the DH (English) subjects' RC-attachment preference.

Table 6.10 RC-Attachment Preference for [DH (English) vs. DH (Sign)]

Short RC						Long RC					
DH (English)	HA	LA	DH (Sign)	HA	LA	DH (English)	HA	LA	DH (Sign)	HA	LA
DH2	4	5	DH1	**9**	1	DH2	**8**	1	DH1	**9**	1
DH4	**10**	0	DH3	**10**	0	DH4	**9**	1	DH3	**10**	0
DH6	1	**9**	DH5	5	5	DH6	4	6	DH5	**7**	3
DH7	4	6	DH9	**10**	0	DH7	5	5	DH9	**10**	0
DH8	**10**	0				DH8	0	**10**			

(number of sentences out of 10, boldface: over 2/3 of all sentences)

Three out of four DH (Sign) subjects preferred HA in short RC sentences and all of them preferred HA in long RC sentences. These results indicate that DH (Sign) subjects preferred HA. This could indicate their L1 influence DH (Sign) subjects' RC-attachment preference.

The results for the RC-attachment preference found that DH (English) did not prefer LA strongly as hearing subjects preferred and this could be due to the influence of their hearing loss. The DH (Sign) subjects prefer HA and this could be due to the influence of their L1 which is a sign language.

6.4.3 Part 3: Prosodic Boundary

Reanalysis 1: Category III (No Reanalysis vs. Syntactic and Prosodic Reanalysis I)

According to Bader (1998), sentence (64) requires both syntactic and prosodic reanalyses. To simplify the following discussion, I am going to refer to "incongruent position" (a double slashed position in (64a)) for the position of the syntactic phrase boundary which requires reanalysis in order to be congruent with the prosodic phrase boundary, and the position of the syntactic phrase boundary which does not require reanalysis is going to be referred to as an "congruent position" (a slashed position in (64b)).

(64) a. ($_I$ [$_{CP}$ In order to help the little boy]) // put down the package he was carrying.)

b. ($_I$ [$_{CP}$ In order to help]) / ($_I$ the little boy put down the package he was carrying.)

c. ($_I$ [$_{CP}$ In order to help the]) // little boy put down the package he was carrying.)

($_I$: intonational phrase = prosodic phrase, $_{CP}$: complement phrase = syntactic phrase)

However, there are other positions which can be congruent or incongruent positions. For example, a double slashed position in (64c) is an "incongruent position". In order to focus on the reanalysis of the noun phrase which is the subject of the main clause (*the little boy* in (64)), I refer to a "congruent position" as the position which is before the subject of the main clause and an "incongruent position" as the position which is after the subject of the main clause in sentences which require both syntactic and prosodic reanalyses.

Sentence (65) requires no reanalysis. In what follows, the position before the subject of the main clause in the sentence which requires no reanalysis, such as the position before *Jill* in sentence (65) (a slashed position) is going to be referred to as a "congruent position" and the other positions will be referred to as "incongruent positions".

(65) ($_I$ In order to help the little boy) / ($_I$ Jill put down the package she was carrying).

($_I$: intonational phrase = prosodic phrase)

Table 6.11 shows the percentages of insertion of a slashes in the congruent and incongruent positions by DH and hearing subjects. The denominator (total numbers of congruent or incongruent positions) was calculated from the number of sentences multiplied by the number of subjects. There were five sentences which require no reanalysis. There were nine DH subjects. Thus, the total number of congruent positions was 45 (5 x 9).

Table 6.11 A slash insertion for Reanalysis 1 [DH vs. Hearing]

	DH		Hearing	
	congruent	incongruent	congruent	incongruent
No reanalysis	77.8% (35/45)	4.4% (2/45)	96.7% (29/30)	0% (0/30)
Reanalyses	40% (18/45)	20% (9/45)	90% (27/30)	6.7% (2/30)

(Total numbers of answers / Total numbers of positions)

The results for sentences which required no reanalysis show that both DH and hearing subjects inserted a slash in congruent positions easily. On the other hand, the results for the sentences which required both syntactic and prosodic reanalyses suggest that DH subjects had difficulty finding congruent positions or they used less prosody during silent reading.

Table 6.12 shows the percentages of slashes inserted in congruent and incongruent positions by DH (English) and DH (Sign) subjects.

Table 6.12 A slash insertion for Reanalysis 1 [DH (English) vs. DH (Sign)]

	DH (English)		DH (Sign)	
	congruent	incongruent	congruent	incongruent
No reanalysis	76% (19/25)	8% (2/25)	80% (16/20)	0% (0/20)
Reanalyses	40% (10/25)	16% (4/25)	40% (8/20)	25% (5/20)

(Total numbers of answers / Total numbers of positions)

The comparison did not indicate a clear difference between the two subjects groups.

Reanalysis 2: Category IV (No Reanalysis vs. Syntactic and Prosodic Reanalysis II)

The sentences which require no reanalysis and the sentences which require both syntactic and prosodic reanalysis differ in the length of AdvP. The Prosodic Constraint on Reanalysis (Bader 1998) predicts the sentence with a short AdvP requires a prosodic reanalysis as is shown in (66) but not sentence with a long AdvP as is shown in (67), thus (66) is easier to comprehend than (67).

(66) a. ($_I$ John will explain to the kids) ($_I$ that their grandfather died tomorrow)

b. ($_I$ John will explain to the kids) ($_I$ that their grandfather died) ($_I$ tomorrow)

($_I$: intonational phrase = prosodic phrase) (Bader 1998 modified)

(67) ($_I$ John will explain to the kids) ($_I$ that their grandfather died) ($_I$ after they come home from school.)

($_I$: intonational phrase = prosodic phrase) (Bader 1998)

Table 6.13 shows the percentages of slashes inserted before AdvP by DH and hearing subjects.

Table 6.13 A slash insertion before AdvP for Reanalysis 2 [DH vs. Hearing]

	DH	Hearing
No reanalysis (long AdvP)	62.2% (28/45)	80% (24/30)
Reanalysis (short AdvP)	20% (9/45)	53.3% (16/30)

(Total numbers of answers / Total numbers of positions)

Although both DH and hearing subjects inserted a slash before long AdvP more often than before short AdvP, the percentages of DH subjects were lower than those of hearing subjects.

Table 6.14 shows the percentages of insertions of a slash before AdvP by DH (English) and hearing subjects.

Table 6.14 A slash insertion before AdvP for Reanalysis 2 [DH (English) vs. Hearing]

	DH (English)	Hearing
No reanalysis (long AdvP)	64% (16/25)	80% (24/30)
Reanalysis (short AdvP)	12% (3/25)	53.3% (16/30)

(Total numbers of answers / Total numbers of positions)

DH (English) subjects inserted a slash before both short and long AdvPs much less than hearing subjects. This indicates that the difference could be due to their hearing loss.

Table 6.15 shows the percentages of slash insertions before AdvP by DH (English) and DH (Sign) subjects.

Table 6.15 A slash insertion before AdvP for Reanalysis 2 [DH (English) vs. DH (Sign)]

	DH (English)	DH (Sign)
No reanalysis (long AdvP)	64% (16/25)	60% (12/20)
Reanalysis (short AdvP)	12% (3/25)	30% (6/20)

(Total numbers of answers / Total numbers of positions)

The percentage of slashes inserted before long AdvP were close between DH (English) and DH (Sign) subjects. However, DH (English) subjects inserted a slash before short AdvP less often than half of the percentages of DH (Sign) subjects (12% vs. 30%). This can suggest that DH (English) subjects had difficulty finding a syntactic phrase boundary or they used less prosody during the silent reading compared to DH (Sign) subjects.

Reanalysis 3: Category V (No Reanalysis vs. Syntactic Reanalysis)

No hearing subjects inserted a slash in both sentences which required no reanalysis and sentences which required syntactic reanalysis. On the other hand, one of DH (English) subjects inserted a slash after the subject of the embedded clause in two out of five sentences, such as, "Tom found the book / was boring." These results indicate that all subjects except for one DH (English) subject did not find difficulty with the sentences which required only syntactic reanalysis.

RC-Attachment Preference

Although five sentences in each type of RC were given to the subjects, one sentence in ambiguous short RC sentences became syntactically forced to HA because of the typing error. Thus, only four sentences in ambiguous short RCs were used for data analysis.

Table 6.16 shows the percentages of slash insertions before the RC by DH subjects and hearing subjects. Forced HA was syntactically forced to HA (the number agreement makes HA), such as "Lisa couldn't find the ***refill*** for the pens that ***was*** on sale." Forced LA was syntactically forced to LA, such as "Lisa couldn't find the refill for the ***pens*** that ***were*** on sale."

Table 6.16 A slash insertion before RC [DH vs. Hearing]

Short RC	DH	Hearing	Long RC	DH	Hearing
Forced HA	49% (22/45)	26.6% (8/30)	Forced HA	58% (26/45)	26% (8/30)
Forced LA	33% (15/45)	10% (3/30)	Forced LA	36% (16/45)	16% (5/30)
Ambiguous	47% (17/36)	8% (2/24)	Ambiguous	44% (20/45)	10% (3/30)

(Total numbers of answers / Total numbers of positions)

The percentage of slash insertions before syntactically forced HA RC sentences was higher than before syntactically forced LA RC sentences by both DH and hearing subjects. Hearing subjects inserted a slash before both short and long RCs with very low percentages. This indicates that their default prosodic break is not having a break before RCs. These results are consistent with the findings of Fodor (2002). DH subjects inserted a slash before RCs more than hearing subjects.

Table 6.17 shows the percentage inserted slashed before RC by DH (English) and hearing subjects.

Table 6.17 A slash insertion before RC [DH (English) vs. Hearing]

Short RC	DH (English)	Hearing	Long RC	DH (English)	Hearing
Forced HA	64% (16/25)	26.6% (8/30)	Forced HA	64% (16/25)	26% (8/30)
Forced LA	44% (11/25)	10% (3/30)	Forced LA	52% (13/25)	16% (5/30)
Ambiguous	50% (10/20)	8% (2/24)	Ambiguous	60% (15/25)	10% (3/30)

(Total numbers of answers / Total numbers of positions)

DH (English) subjects inserted a slash before both short and long RCs at a much higher rate than hearing subjects. Thus, this difference could be due to the hearing loss of DH (English) subjects.

Table 6.18 shows the percentages of slash insertions before RC by DH (English) and DH (Sign) subjects.

Table 6.18 A slash insertion before RC [DH(English) vs. DH (Sign)]

Short RC	DH (English)	DH (Sign)	Long RC	DH (English)	DH (Sign)
Forced HA	64% (16/25)	35% (7/20)	Forced HA	64% (16/25)	30% (6/20)
Forced LA	44% (11/25)	20% (4/20)	Forced LA	52% (13/25)	15% (3/20)
Ambiguous	50% (10/20)	43.8% (7/16)	Ambiguous	60% (15/25)	25% (5/20)

(Total numbers of answers / Total numbers of positions)

The percentage of slash insertions before syntactically forced HA RC sentences was higher than before syntactically forced LA RC sentences by both DH (English) and DH (Sign) subjects. DH (English) subjects inserted a slash before RC more than DH (Sign) subjects did.

Table 6.19 compared the results of hearing, DH (Sign) and DH (English) subjects.

Table 6.19 A slash insertion before RC

Short RC	Hearing	DH (Sign)	DH (English)
Forced HA	26.6% (8/30)	35% (7/20)	64% (16/25)
Forced LA	10% (3/30)	20% (4/20)	44% (11/25)
Ambiguous	8% (2/24)	43.8% (7/16)	50% (10/20)
Long RC			
Forced HA	26% (8/30)	30% (6/20)	64% (16/25)
Forced LA	16% (5/30)	15% (3/20)	52% (13/25)
Ambiguous	10% (3/30)	25% (5/20)	60% (15/25)

(Total numbers of answers / Total numbers of positions)

The percentage of inserted slashes before syntactically forced HA RC sentences was higher than before syntactically forced LA RC sentences for all groups of subjects. It is consistent with the prediction of the Implicit Prosody Hypothesis (Fodor (Fodor 1998, 2002) that the prosodic break occurs before long RC forced to HA. The interesting finding is that the results for the DH (Sign) subjects were closer to those of hearing subjects than DH (English) subjects. This indicates that the different results were not due to the subjects' L1.

6.5 Discussion

Part 1 of the questionnaire was designed to measure whether subjects found processing certain sentences to be difficult. Both DH subjects and hearing subjects answered similarly for Locality Preference (subject-extracted RC vs. object-extracted RC).

Table 6.20 The results for the difficulty judgment for Locality Preference

	DH		Hearing	
sentence	S-extracted RC	O-extracted RC	S-extracted RC	O-extracted RC
(a)-(c)	20%	80%	16.7%	83.3%
(d)	75%	25%	100%	0%

(S-extracted RC: Subject-extracted RC, O-extracted RC: Object-extracted RC)

In these sentence pairs, both DH and hearing subjects found that object-extracted RC sentences were more difficult than subject-extracted RC sentences. There was one sentence pair (d) in Table 6.20 in which both DH and hearing subjects found subject-extracted RC was more difficult than object-extracted RC. Sentence pair (d) is shown in (68).

(68) a. The man who went out with me last year was a poor actor. (subject-extracted RC)
     b. The man who I went out with last year was a poor actor.   (object-extracted RC)

According to the Dependency Locality Theory (DLT) (Gibson 1998, 2000), the integration complexity depends on the distance or locality between the head and dependent being integrated and the distance between the head (*man*) and the dependent (word which needs to integrated to the head, in this case word (*was*), we can see that in those sentences the distances are the same (see (69)). DLT would predict that the difficulty of the two sentences would be equal.

(69) a. The **man** who went out with me last year **was** a poor actor.

     b. The **man** who I went out with last year **was** a poor actor.

However, the results found that the subject-extracted RC was more difficult than the object-extract RC. This can be explained as follows. The distance between the subject-extracted position and the auxiliary verb *was* in the subject-extracted RC is longer than the object-extracted position and the auxiliary verb *was* in the object-extracted RC as is shown in (70).

(70) a. The man who ***e*** went out with me last year **was** a poor actor.

     b. The man who I went out with *e* last year **was** a poor actor.

The integration costs for the word *was* to the word *man* in both sentences are the same, but the integration costs for the word *was* to the empty category from which the word *man* was extracted explains that the costs in the subject-extracted RC are greater than those of object-extracted RC. This, therefore also shows that both DH and hearing subjects preferred the locality based parsing strategy.

Both DH and hearing subjects answered similarly for RC Length Effect (Long RC vs. Short RC). From these results, there is no relationship between the length of RC and the difficulty in processing it.

The results for difficulty judgment for Reanalysis 1 (No Reanalysis vs. Syntactic and Prosodic Reanalyses I), Reanalysis 2 (No Reanalysis vs. Syntactic and Prosodic Reanalyses II), and Reanalysis 3 (No Reanalysis vs. Syntactic Reanalysis) are summarized in Table 6.21.

Table 6.21 Summary for the difficulty judgment for Reanalysis 1, 2, and 3

	DH		Hearing	
	No Reanalysis	Reanalysis	No Reanalysis	Reanalysis
Reanalysis 1	19.6%	80.4%	12.2%	87.8%
Reanalysis 2	32.7%	67.3%	14%	86%
Reanalysis 3	44.4%	55.6%	80%	20%

Both DH and hearing subjects answered similarly for Reanalysis 1 and 2. More than 80% of both DH and hearing subjects found sentences which required both syntactic and prosodic reanalyses were more difficult than sentences which required no reanalysis in Reanalysis 1. 67.3% of the DH subjects and 86% of the hearing subjects found sentences which required both syntactic and prosodic reanalyses were more difficult than sentences which required no reanalysis in Reanalysis 2. Both groups showed that sentences which required reanalysis were more difficult than sentences which required no reanalysis.

For Reanalysis 3, only two subjects found that one of the sentences was more difficult than the other. A majority of subjects answered that sentences in the pairs were equally comprehensible. Thus, it is safe to say on the basis of these data that the subjects did not find any difference between the two sentences in the pairs.

From the results of Reanalysis 1, 2, and 3, both DH and hearing subjects showed that sentences which required both syntactic and prosodic reanalyses were more difficult to process than sentences which required no reanalysis. These results are consistent with the claim of the Prosodic Constraint on Reanalysis (Bader 1998).

The results in part 1 found that both DH and hearing subjects had a locality preference for parsing, they did not find a difficulty difference based on the length of RCs, and they found that the sentences which required syntactic and prosodic reanalyses were difficult.

Part 2 was designed to investigate whether the RC attachment preferences of DH subjects were the same as those of hearing subjects.

Table 6.22 The results for RC-attachment preference [DH vs. Hearing]

	Short RC		Long RC	
	DH	Hearing	DH	Hearing
HA	55.6% (5/9)		66.7% (6/9)	
LA	11.1% (1/9)	83.3% (5/6)	11.1% (1/9)	66.7% (4/6)
No Preference	33.3% (3/9)	16.7% (1/6)	22.2% (2/9)	33.3% (2/6)

In short RC sentences, 55.6% of the DH subjects preferred HA, only 11.1% of them preferred LA, and 33.3% of them did not show any preference. As for hearing subjects, 83.3% of the subjects preferred LA which is consistent with the previous studies (English speakers prefer LA) and 16.7% of them did not show any preference.

In long RC sentences, 66.7% of the DH subjects preferred HA, only 11.1% of them preferred LA, and 22.2% of them did not show any preference. As for hearing subjects, 66.7% of the subjects preferred LA, 33.3% of them did not show any preference, which is consistent with the previous studies (English speakers preference of LA is weaker when it is in long RC than in short RC).

The preferences of RC attachment by DH subjects were different from those of hearing subjects. No hearing subjects preferred HA in both short and long RC sentences. On the other hand, more than 50% of the DH subjects preferred HA in both short and long RC sentences. This can be the result of default prosody according to the Implicit Prosody Hypothesis (Fodor 1998, 2002).

In order to consider the influence of their hearing loss and first languages, the data of the DH subjects were divided into two groups based on their first languages. Comparison between DH (English) and hearing groups is shown in Table 6.23.

Table 6.23 The results for RC-attachment preference [DH (English) vs. Hearing]

	Short RC		Long RC	
	DH (English)	Hearing	DH (English)	Hearing
HA	40% (2/5)		40% (2/5)	
LA	20% (1/5)	83.3% (5/6)	20% (1/5)	66.7% (4/6)
No Preference	40% (2/5)	16.7% (1/6)	40% (2/5)	33.3% (2/6)

In short RC sentences, 40% of the DH (English) preferred HA, 20% of them preferred LA, and 40% of them did not show any preference. On the other hand, 83.3% of the hearing subjects preferred LA, 16.7% of them did not show any preference, and no hearing subjects preferred HA. The difference of HA preference between two groups could be due to the hearing loss of DH (English) subjects.

Comparison between DH (English) and DH (Sign) groups is shown in Table 6.24.

Table 6.24 The results for RC-attachment preference [DH (English) vs. DH (Sign)]

	Short RC		Long RC	
	DH (English)	DH (Sign)	DH (English)	DH (Sign)
HA	40% (2/5)	75% (3/4)	40% (2/5)	100% (4/4)
LA	20% (1/5)		20% (1/5)	
No Preference	40% (2/5)	25% (1/4)	40% (2/5)	

The difference between DH (English) and DH (Sign) subjects was that no DH (Sign) subjects preferred LA in both short and long RC sentences. This could be the influence of their L1 (sign language).

A summary of the results for the all three groups is shown in Table 6.25.

Table 6.25 Summary for RC- attachment preference

	DH (Sign)		DH (English)		Hearing (English)	
	Short RC	Long RC	Short RC	Long RC	Short RC	Long RC
HA	75%	100%	40%	40%		
LA			20%	20%	83.3%	66.7%
No Preference	25%		40%	40%	16.7%	33.3%

	DH (Sign)		DH (English)		Hearing (English)	
	Short RC	Long RC	Short RC	Long RC	Short RC	Long RC
Preference	HA	HA	No preference	No preference	LA	LA

From these results, the hearing subjects preferred LA which is consistent with the previous studies (English speakers prefer LA) and no preference of DH (English) could be the different default prosody because of their hearing loss. The HA preference of DH (Sign) can be influenced by their L1.

Part 3 was designed to investigate whether subjects have conscious knowledge of prosodic breaks. The results for Reanalysis 1 (No Reanalysis vs. Syntactic and Prosodic Reanalyses I) (Table 6.26) shows that the DH subjects inserted a slash in the 'congruent' position less often than the hearing subjects, and the DH subjects inserted a slash in the 'incongruent' position more often than the hearing subjects.

Table 6.26 The break for Reanalysis 1 [DH vs. Hearing]

	DH		Hearing	
	congruent	incongruent	congruent	incongruent
No reanalysis	77.8%	4.4%	96.7%	0%
Reanalysis	40%	20%	90%	6.7%

The comparison of DH (English) and hearing subjects is shown in Table 6.27.

Table 6.27 The break for Reanalysis 1 [DH (English) vs. Hearing]

	DH (English)		Hearing	
	congruent	incongruent	congruent	incongruent
No reanalysis	80%	0%	96.7%	0%
Reanalysis	40%	25%	90%	6.7%

In the sentences which required both syntactic and prosodic reanalyses, DH (English) subjects inserted a slash in congruent positions less often than hearing subjects and more often in incongruent positions than hearing subjects. This indicates that hearing loss influences the judgment of the prosodic phrase boundaries for DH (English) subjects.

The comparison of DH (English) and DH (Sign) subjects is shown in Table 6.28.

Table 6.28 The break for Reanalysis 1 [DH (English) vs. DH (Sign)]

	DH (English)		DH (Sign)	
	congruent	incongruent	congruent	incongruent
No reanalysis	80%	0%	76%	8%
Reanalysis	40%	25%	40%	16%

Because of the similar results from the comparison between DH (English) and DH (Sign) subjects, it does not indicate a clear L1 influence.

The sentences for Reanalysis 2 (No Reanalysis vs. Syntactic and Prosodic Reanalyses II) differed in the length of an AdvP. The results show that both DH and hearing subjects inserted a prosodic break before a long AdvP more often than before a short AdvP. The comparison of DH and hearing subjects is shown in Table 6.29.

Table 6.29 The break before AdvP for Reanalysis 2 [DH vs. Hearing]

	DH	Hearing
No reanalysis (long AdvP)	62.2%	80%
Reanalysis (Short AdvP)	20%	53.3%

Because readers tend not to insert a prosodic break before a short AdvP and therefore erroneously include it into the previous phrase, the sentence requires reanalysis. This means that if the readers do not insert a prosodic break before the short AdvP in the sentence, it is difficult to interpret the sentence. The DH subjects inserted a break before short RC less often than hearing subjects. This suggests that the DH subjects did not find the short AdvP sentences difficult to process.

The comparison of DH (English) and hearing subjects is shown in Table 6.30.

Table 6.30 The break before AdvP for Reanalysis 2 [DH (English) vs. Hearing]

	DH (English)	Hearing
No reanalysis (long AdvP)	64%	80%
Reanalysis (Short AdvP)	12%	53.3%

The results show that DH (English) subjects inserted a prosodic break before both long and short AdvPs less often than hearing subjects. This indicates that hearing loss influences the judgment of the prosodic phrase boundaries for DH (English) subjects.

The comparison of the three groups of subjects is shown in Table 6.31. There is no clear difference between DH (Sign) and DH (English) subjects.

Table 6.31 Summary of the break before AdvP for Reanalysis 2

	DH (Sign)	DH (English)	Hearing
No reanalysis (long AdvP)	60%	64%	80%
Reanalysis (Short AdvP)	30%	12%	53.30%

The results for Reanalysis 3 (No Reanalysis vs. Syntactic Reanalysis) found that hearing subjects did not find any difference in difficulty between the two sentences. As for DH subjects, only one DH subject inserted a break in the incongruent position in two out of five sentences. Although this subject had difficulty processing the sentences which required syntactic reanalysis, other DH subjects did not find any difference in difficulty between the two sentences.

From the results of Reanalysis 1, 2, and 3, both DH and hearing subjects showed that sentences which required both syntactic and prosodic reanalyses were more difficult to process than sentences which required no reanalysis. These results are consistent with the difficulty judgment in Part 1. Thus, these results from the insertion of a prosodic phrase boundary are consistent with the claim of the Prosodic Constraint on Reanalysis (Bader 1998). The comparisons between DH (English) and hearing subjects found that the scores of insertion rate by DH (English) subjects were lower than those of hearing subjects. This result indicates that either the conscious knowledge of prosodic phrase boundaries of DH (English) is influenced by their hearing loss, or they were less dependent on the use of prosody during the parsing.

The prosodic break in the different types of RC sentences is shown in Table 6.32.

Table 6.32 Break before RC [DH vs. Hearing]

	DH	Hearing			DH	Hearing
Forced HA Short RC	49%	26.6%		Forced HA Long RC	58%	26%
Forced LA Short RC	33%	10%		Forced LA Long RC	36%	16%
Ambiguous Short RC	47%	8%		Ambiguous Long RC	44%	10%

(Forced HA: syntactically forced to HA, Forced LA: syntactically forced to LA)

The percentage of insertion of a break before syntactically forced HA RCs was higher than before syntactically forced LA RCs by both hearing and DH subjects. Hearing subjects' break insertion percentages were very low for both forced HA and forced LA RCs. This indicates their default prosodic pattern is not having a break before RCs. This is consistent with the Fodor's (1998, 2002) claim (Implicit Prosody Hypothesis) that a prosodic break before an RC forces HA preference. DH subjects inserted a break before an RC more often than hearing subjects did. This explains their HA preference (the result for Part 2).

The comparison between DH (English) and hearing subjects is shown in Table 6.33.

Table 6.33 Break before RC [DH (English) vs. Hearing]

	DH (English)	Hearing			DH (English)	Hearing
Forced HA Short RC	64%	26.6%		Forced HA Long RC	64%	26%
Forced LA Short RC	44%	10%		Forced LA Long RC	52%	16%
Ambiguous Short RC	50%	8%		Ambiguous Long RC	60%	10%

(Forced HA: syntactically forced to HA, Forced LA: syntactically forced to LA)

The comparison shows a clear difference the prosodic patterns of DH (English) and hearing subjects. DH (English) subjects inserted a break before RCs more often than hearing subjects. These results reflect the RC-attachment preference of the subjects. High percentage of the insertion of a prosodic break before RCs by the DH (English) subjects explains their HA preference. This is consistent with the claim of the Implicit Prosody Hypothesis (Fodor 1998, 2002).

The comparison between DH subjects based on their L1 is shown in Table 6.34.

Table 6.34 Break before RC [DH (English) vs. DH (Sign)]

	DH (English)	DH (Sign)			DH (English)	DH (Sign)
Forced HA Short RC	64%	35%		Forced HA Long RC	64%	30%
Forced LA Short RC	44%	20%		Forced LA Long RC	52%	15%
Ambiguous Short RC	50%	43.8%		Ambiguous Long RC	60%	25%

(Forced HA: syntactically forced to HA, Forced LA: syntactically forced to LA)

There is a clear difference between DH (English) and DH (Sign) subjects. DH (English) inserted a break before an RC much more often than DH (Sign). This difference between DH (English) and DH (Sign) subjects indicates the subjects' L1 influence. However, these results did not reflect their RC-attachment preference. The relationship between default prosody and RC-attachment is summarized in Table 6.35.

Table 6.35 Default prosody (break before RC) and RC-attachment preference

RC	DH (Sign)	preference	DH (English)	preference	Hearing	preference
Short	No break	HA	Flexible break	No preference	No break	LA
Long	No break	HA	Flexible break	No preference	No break	LA

In Part 2, we found that the hearing subjects preferred LA, the DH (Sign) subjects preferred HA for both short and long RCs, and the DH (English) subjects did not have preference for both short and long RCs. According to the Implicit Prosody Hypothesis (Fodor 1998, 2002), if the prosodic break before a RC forces the subject to prefer HA. This explains the LA preference for the hearing subjects and no preference for the DH (English) subjects, but not HA preference for the DH (Sign) subjects. According to the Implicit Prosody Hypothesis, the DH (Sign) subjects should have preferred LA. Possible explanations would be (a) sign language which is the L1 of DH (Sign) is a manual language and the prosody of the manual language cannot be treated the same way as the prosody of the spoken languages, and (b) the combination of hearing loss and L1 influence.

The results for part 3 confirmed that both DH and hearing subjects processed the three types of sentence pairs for Reanalysis 1, 2, and 3 similarly but the scores of DH subjects were lower than those of hearing subjects. This indicates that either the DH subjects are less sensitive to prosodic and syntactic phrase boundaries than hearing subjects and this can be the results of their hearing loss, or that they are less dependent on the use of prosody during the parsing because of their hearing loss. The results for RC sentences found that the default prosodic pattern for hearing subjects is no prosodic break before RC and that they preferred LA. The results also found that the default prosodic pattern for DH (English) subjects is to have a prosodic break before RC more often than hearing subjects and many of DH (English) subjects preferred HA. On the other hand, the relationship between the default prosodic patterns of DH (Sign) subjects and their RC-attachment preference was not clear from the results. This could be the influence of their L1 which is sign language.

In the next chapter, I will report the eye-tracking experiment. The data from the experiment can show the clear influence of hearing loss and the role of prosody in sentence processing.

CHAPTER 7: EXPERIMENT 2 - EYE-TRACKING

7.1 Subjects and Stimuli

Subjects were exactly the same as from experiment 1 (questionnaire study). Sixty stimuli sentences were used in this study from Part 1 in the questionnaire study: Locality Preference (10 sentences of category I), Reanalysis 1 (20 sentences of category III), Reanalysis 2 (20 sentences of category IV), and Reanalysis 3 (10 sentences of category V). In addition, 10 short RC and 10 long RC sentences were also included. These RC sentences were ambiguous (they were not semantically or syntactically forced to LA or HA). These sentences were randomly ordered. In order to find out subjects' RC-attachment preference, each RC sentence was followed by a question asking a preferred noun that RC attaches. In addition, 20 question and answer pairs about the sentences were randomly inserted in order to make readers pay attention to their comprehension of the sentences. All stimuli are provided in the Appendix D.

7.2 Procedure

Subjects were seated in front of an 18-inch computer screen. They wore an SMI EyeLink head-mounted eye-tracker. This study measured only right eye-movement (viewing was binocular). The calibration[35] took about 5 minutes. After the calibration was done, the instructions of the experiment appeared on the screen. The subjects were asked to click a mouse when they finished reading them. The screen does not change unless subjects click the mouse (any button of the

[35] Setting up the eye-tracker to associate screen positions with pupil and corneal reflection positions.

mouse[36]). In order to answer the question, the subjects were asked to left click if the answer was the left one on the screen, and right click if the answer was the right one. The instructions were shown on the computer screen. Subjects were given a trial section after the instructions were given in order to familiarize themselves with the mouse operation and reading sentences on the computer screen while wearing a head-mounted eye-tracker for an actual experiment. Trial section consisted of 6 sentences and 4 questions. The experiment started after the trial section was done. During the experiment, subjects were asked twice whether they wanted to take a break. Total experiment time was 20 minutes to 30 minutes.

7.3 Results

7.3.1 Locality Preference

The sentences which were used for investigating the Locality Preference (Subject-extracted RC vs. Object-extracted RC) are shown in (71). For the later analysis, the same alphabetical labels from the questionnaire study were used.

(71) Subject-extracted RC vs. Object-extracted RC

(a) The reporter who attacked the senator admitted the error.
The reporter who the senator attacked admitted the error.

(b) I met the man who married my mother's friend.
I met the man who my mother's friend married to.

(c) The black cat that chased the white cat was my pet.
The black cat that the white cat chased was my pet.

(d) The man who went out with me last year was a poor actor.
The man who I went out with last year was a poor actor.

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[36] I however recommended to them to click the middle button of the mouse in order to avoid confusion with other operations, such as answering a question (left answer for left click, right answer for right click).

The two sentences in each pair were either exactly (or almost exactly) the same length and composed of exactly (or almost exactly) the same words; word order, however, was different. Thus, reading time differences reflect the difficulty of the sentence processing, not the recognition of the letters and words.

The results are shown in Table 7.1.

Table 7.1 Eye-tracking: Reading Times for Locality Preference (msec.)

	(a)		(b)		(c)		(d)	
	S-RC	O-RC	S-RC	O-RC	S-RC	O-RC	S-RC	O-RC
DH1	1711.37	6818.06	1785.87	9181.96	7763.03	6923.91	3737.76	2518.19
DH2	3404.28	9943.56	5586.13	5335.1	5624.24	6900.34	5209.69	4086.65
DH3	1668.25	3132.39	1320.3	2298.95	1796.11	2271.39	2875.44	2379.26
DH4	2750.92	6126.66	3604.27	5444.46	6782.85	7790.72	4628.72	4950.34
DH5	2268.8	3203.62	1976.46	3425.84	1577.62	3926.41	3064.21	2707.14
DH6	1807.68	7794.1	1489.24	2531.77	565.85	2172.99	2713.61	1813.54
DH7	2623.15	3332.44	1824.81	10828.6	1813.12	1578.24	3493.45	3703.34
DH8	5710.7	8792.55	8023.57	8246.26	4702.41	6732.55	10425.38	8753.38
DH9	2138.76	3092.04	3670.85	4335.23	1863.9	3200	4842.72	2685.27
C1	3680.16	8789.42	5031.53	9488.59	4023.65	6617.6	3990.6	3158.76
C2	2011.74	2953.35	2455.38	2732.24	4219.28	4324.62	2654.52	2794.89
C3	4449.66	7590.67	4070.35	5479.78	4503.4	3688.65	6259.29	4885.98
C4	6898.1	9921.47	7011.5	13682.1	5511.66	8312.61	6520.72	5736.43
C5	4760.6	5120.87	4725.59	4770.59	2768.87	4400.55	4770.75	3256.95
C6	2661.15	3572.17	1941.11	3597.74	2460.1	2848.54	3370.11	3354.48

(S-RC: Subject-extracted RC, O-RC: Object-extracted RC, DH: Deaf and hard of hearing subjects, C: Hearing subjects)

Table 7.2 Eye-tracking: The proportion of longer reading time

		Subject-extracted RC	Object-extracted RC
(a)	DH	0% (0/9)	**100% (9/9)**
	C	0% (0/6)	**100% (9/6)**
(b)	DH	11% (1/9)	**88% (8/9)**
	C	0% (0/6)	**100% (6/6)**
(c)	DH	22% (2/9)	**78% (9/9)**
	C	17% (1/6)	**83% (5/6)**
(d)	DH	**78% (7/9)**	22% (2/9)
	C	**66% (4/6)**	34% (2/6)

(Boldface indicates higher percentages than the other)

Comparison between reading times of two groups was not relevant because reading speed of each subjects was different. Thus, the percentage of subjects who spent a longer time for one sentence than the other was calculated. Except for the sentence pair (d), the percentages of longer reading times of the subjects in object-extracted RC sentences were higher than those of subject-extracted RC sentences. These results are consistent with the results of the Dependency Locality Theory (Gibson 1998, 2000). Thus, both DH and hearing subjects had a locality preference in that object-extracted RC sentences were more difficult to process than subject-extracted RC sentences.

7.3.2 Reanalysis 1: No Reanalysis vs. Syntactic and Prosodic Reanalyses I

Just as I analyzed the congruency of the syntactic phrase boundary and prosodic phrase boundary in Chapter 6.4.3, I will use here the same terms for the different positions. In sentences which require both syntactic and prosodic reanalyses, an “incongruent position” is the position after the subject of the main clause (a double slashed position in (72a)) and a “congruent position” is a position before the subject of the main clause (a slashed position in (71b)).

(72) a. $(_{I}$ $[_{CP}$ In order to help the little boy]) // put down the package he was carrying.)

b. $(_{I}$ $[_{CP}$ In order to help]) / $(_{I}$ the little boy put down the package he was carrying.)
($_{I}$: intonational phrase = prosodic phrase, $_{CP}$: complement phrase = syntactic phrase)

In the sentence which requires no reanalysis, a "congruent position" is the position before the subject of the main clause (a slashed position in (73)) and the other positions are "incongruent positions".

(73) $(_{I}$ In order to help the little boy) / $(_{I}$ Jill put down the package she was carrying).
($_{I}$: intonational phrase = prosodic phrase)

The longer fixation time and the increase of regression indicate an increase in the difficulty of the reading process (Rayner 1995). Although it is not clear that the fixation time also indicates the implicit prosodic break (pause) before a prosodic phrase boundary, I assumed the longer fixation time at the word before prosodic boundary (or a position which is close to the prosodic boundary) would indicate an implicit prosodic break. However, judging a longer fixation time compared to the other fixation times is difficult because many factors influence the fixation time such as the difficulty of the lexical access of the words or word length. Thus, I analyzed whether subjects fixate their eyes on the word before congruent positions in the first pass[37] and whether subjects regress their eye-movement to the earlier position where the subjects already read. If the subject fixated his/her eye on the word before a congruent position, reanalysis would not be needed. It is possible to reanalyze without backtracking as looking at the words in the earlier position of the sentence. However, if the readers go back to the earlier position, it clearly indicates that they are trying to read and analyze the parsed sentence again.

Subjects were given 10 sentences which required no reanalysis and 10 sentences which required both syntactic and prosodic reanalyses. If the subject fixated his or her eye on the word

[37] The first parsing before backtrack and reanalysis of what has been processed.

before congruent positions of all 10 sentences, this would be scored as 10. In order to analyze the reanalysis of the subjects, I chose the second word from the congruent position as the limitation of the backtracking for reanalysis of the prosodic and syntactic phrase boundaries. This two word limit is based on the characteristics of eye-movement. Eyes move forward in reading on average 7 to 9 character spaces (Rayner 1989). Although the average of 7 to 9 character spaces cannot be generalized to two words, and although two words after the congruent position in sentence (74) are shorter than those in other sentences in the same category in this experiment, it is less than three words after the congruent position.

(74) Since Jay always walks / a mile seems like a short distance to him. (/: congruent position)

The results for Reanalysis 1 (No Reanalysis vs. Syntactic and prosodic Reanalyses I) are shown in Table 7.3.

Table 7.3 Eye-tracking: The results for Reanalysis 1 [DH vs. Hearing]

Sentences with no reanalysis

	Fixation	Reanalysis
DH1	8	0
DH2	8	2
DH3	7	1
DH4	9	3
DH5	8	1
DH6	3	2
DH7	9	6
DH8	9	5
DH9	7	4
Average	7.56	2.67

	Fixation	Reanalysis
C1	7	6
C2	7	5
C3	10	4
C4	9	2
C5	8	6
C6	6	4
Average	7.83	4.50

Sentences with both syntactic and prosodic reanalyses

	Fixation	Reanalysis
DH1	10	1
DH2	10	7
DH3	8	4
DH4	7	5
DH5	8	4
DH6	5	6
DH7	10	9
DH8	9	9
DH9	7	9
Average	8.22	6.00

	Fixation	Reanalysis
C1	9	8
C2	6	8
C3	7	9
C4	7	8
C5	7	8
C6	6	7
Average	7.00	8.00

(the numbers of sentences out of 10)

Both hearing subjects and DH subjects increased their reanalysis in the sentences which required both syntactic and prosodic reanalyses, and the average of reanalysis in DH subjects was less than that of hearing subjects. These results can indicate that either DH subjects did not find the sentences were difficult or they did not notice the necessity of the reanalyses.

The comparisons between DH (English) and hearing subjects are shown in Table 7.4.

Table 7.4 Eye-tracking: The results for Reanalysis 1 [DH(English) vs. Hearing]

Sentences with no reanalysis

	Fixation	Reanalysis
DH2	8	2
DH4	9	3
DH6	3	2
DH7	9	6
DH8	9	5
Average	7.6	3.6

	Fixation	Reanalysis
C1	7	6
C2	7	5
C3	10	4
C4	9	2
C5	8	6
C6	6	4
Average	7.83	4.5

Sentences with both syntactic and prosodic reanalyses

	Fixation	Reanalysis
DH2	10	7
DH4	7	5
DH6	5	6
DH7	10	9
DH8	9	9
Average	8.2	7.2

	Fixation	Reanalysis
C1	9	8
C2	6	8
C3	7	9
C4	7	8
C5	7	8
C6	6	7
Average	7	8

(the numbers of sentences out of 10)

Hearing subjects did slightly reanalyze more often than DH (English) subjects in sentences required both syntactic and prosodic reanalayses. Thus, the difference between hearing subjects and DH subjects in Table 7.3 may be due to the DH (Sign) subjects (see Table 7.5).

Table 7.5 Eye-tracking: The results for Reanalysis 1 [DH (Sign) vs. DH (English)]

Sentences with no reanalysis

DH(Sign)	Fixation	Reanalysis
DH1	8	0
DH3	7	1
DH5	8	1
DH9	7	4
Average	7.50	1.50

DH (English)	Fixation	Reanalysis
DH2	8	2
DH4	9	3
DH6	3	2
DH7	9	6
DH8	9	5
Average	7.60	3.60

Sentences with both syntactic and prosodic reanalyses

DH(Sign)	Fixation	Reanalysis
DH1	10	1
DH3	8	4
DH5	8	4
DH9	7	9
Average	8.25	4.50

DH (English)	Fixation	Reanalysis
DH2	10	7
DH4	7	5
DH6	5	6
DH7	10	9
DH8	9	9
Average	8.20	7.20

(the numbers of sentences out of 10)

Although the average of exe-fixation of DH (Sign) was similar to DH (English) and hearing subjects, their reanalysis rate was much lower than DH (English). This could be the influence of the DH (Sign) subjects' L1.

The average of fixation and reanalysis for all groups are summarized in Table 7.6.

Table 7.6 Eye-tracking: The average of the results for Reanalysis 1

	Sentence with no reanalysis		Sentence with reanalysis	
	Fixation	Reanalysis	Fixation	Reanalysis
DH (Sign)	7.5	1.5	8.25	4.5
DH (English)	7.6	3.6	8.2	7.2
C (English)	7.83	4.5	7	8

(the numbers of sentences)

The average of fixations in all three groups was similar. However, the results of reanalysis showed an L1 influence.

7.3.3 Reanalysis 2: No Reanalysis vs. Syntactic and Prosodic Reanalyses II

Subjects were given 10 sentences which required no reanalysis (sentences with long AdvP) and 10 sentences which required both syntactic and prosodic reanalyses (sentence with short AdvP). In these sentence pairs, I analyzed whether subjects fixated their eyes on the word before an AdvP in the first pass and whether subjects regressed their eye-movement to the earlier position where the subjects already read. The scores were measured in the same way as in section 7.3.2.

The results for Reanalysis II (No reanalysis (long AdvP) vs. Syntactic and prosodic reanalyses (short AdvP)) are shown in Table 7.7.

Table 7.7 Eye-tracking: The results for Reanalysis 2 [DH vs. Hearing]

Sentences with no reanalysis

	Fixation	Reanalysis
DH1	9	3
DH2	7	4
DH3	9	1
DH4	10	4
DH5	3	2
DH6	5	2
DH7	8	2
DH8	10	6
DH9	7	6
Average	7.56	3.33

	Fixation	Reanalysis
C1	7	5
C2	6	5
C3	5	6
C4	9	5
C5	7	5
C6	7	2
Average	6.83	4.67

Sentences with both syntactic and prosodic reanalyses

	Fixation	Reanalysis
DH1	9	10
DH2	8	9
DH3	10	9
DH4	10	9
DH5	6	8
DH6	6	9
DH7	10	9
DH8	9	10
DH9	8	10
Average	8.44	9.22

	Fixation	Reanalysis
C1	8	10
C2	9	8
C3	9	10
C4	9	9
C5	10	9
C6	7	8
Average	8.67	9.00

(the numbers of sentences out of 10)

According to the Prosodic Constraint on Reanalysis (Bader 1998), readers tend to insert a prosodic break before long AdvP but not before a short AdvP because it is easy to include it in the previous phrase (see (75)).

(75) a. John will explain to the kids that their grandfather died / after they come home from school.
b. John will explain to the kids that their grandfather died tomorrow/.
(/: prosodic break)

Thus, readers have difficulty interpreting sentences like (75b) because it requires both prosodic and syntactic reanalyses. The results did not indicate this prosodic break differences which Bader predicted. Both DH and hearing subjects fixated more on the word before AdvP when it was short than when it was long. However, the results of reanalysis found that sentences with short AdvP (which were predicted to require both syntactic and prosodic reanalyses) required a high rate of reanalysis by both DH and hearing subjects. These results were consistent with the comparison between DH (English) and hearing subjects (Table 7.8) and the comparison between DH (English) and DH (Sign) subjects (Table 7.9).

Table 7.8 Eye-tracking: The results for Reanalysis 2 [DH (English) vs. Hearing]

Sentences with no reanalysis

	Fixation	Reanalysis
DH2	7	4
DH4	10	4
DH6	5	2
DH7	8	2
DH8	10	6
Average	8.00	3.60

	Fixation	Reanalysis
C1	7	5
C2	6	5
C3	5	6
C4	9	5
C5	7	5
C6	7	2
Average	6.83	4.67

Sentences with both syntactic and prosodic reanalyses

	Fixation	Reanalysis
DH2	8	9
DH4	10	9
DH6	6	9
DH7	10	9
DH8	9	10
Average	8.60	9.20

	Fixation	Reanalysis
C1	8	10
C2	9	8
C3	9	10
C4	9	9
C5	10	9
C6	7	8
Average	8.67	9.00

(the numbers of sentences out of 10)

Table 7.9 Eye-tracking: The results for Reanalysis 2 [DH (English) vs. DH (Sign)]

Sentences with no reanalysis

DH (English)	Fixation	Reanalysis
DH2	7	4
DH4	10	4
DH6	5	2
DH7	8	2
DH8	10	6
Average	8.00	3.60

DH (Sign)	Fixation	Reanalysis
DH1	9	3
DH3	9	1
DH5	3	2
DH9	7	6
Average	7.00	3.00

Sentences with both syntactic and prosodic reanalyses

DH (English)	Fixation	Reanalysis
DH2	8	9
DH4	10	9
DH6	6	9
DH7	10	9
DH8	9	10
Average	8.60	9.20

DH (Sign)	Fixation	Reanalysis
DH1	9	10
DH3	10	9
DH5	6	8
DH9	8	10
Average	8.25	9.25

(the numbers of sentences out of 10)

The average of fixation and reanalysis for all groups are summarized in Table 7.10.

Table 7.10 Eye-tracking: The average of the results for Reanalysis 2

	Sentence with no reanalysis		Sentence with reanalyses	
	Fixation	Reanalysis	Fixation	Reanalysis
DH (Sign)	7.00	3.00	8.25	9.25
DH (English)	8.00	3.60	8.60	9.20
C (English)	6.83	4.67	8.67	9.00

(number: the numbers of sentences out of 10)

The results of fixation and reanalysis in sentences which required both syntactic and prosodic reanalyses were similar in all three groups.

7.3.4 Reanalysis 3: No reanalysis vs. Syntactic Reanalysis

In order to investigate No Reanalysis vs. Syntactic Reanalysis, subjects were given 5 sentences which required no reanalysis and 5 sentences which required only syntactic reanalysis. Syntactic structures of these two types of sentences are shown in (76).

(76) No Reanalysis: Subject + Verb + Object + Adverbial Phrase (or Prepositional Phrase)
Reanalysis: Subject + Verb + Subject + Verb Phrase

(77) a. Peter knew the answer immediately.
b. Peter knew the answer would be false.

In these sentence pairs, I analyzed whether subjects fixated their eyes on the object (e.g., *answer* in (77a)) in sentences which required no reanalysis and the subject (e.g., *answer* in (77b)) of the embedded sentences which required syntactic reanalysis in the first pass. The scores were measured as the same way as in 7.3.2 and 7.3.3. Because all sentences for this analysis were short, they might finish reading without backtracking even if subjects had difficulty reading the sentence. Thus, if the subjects read the sentence more than twice or their eyes moved back to the earlier position in the sentence during the reading or after the reading, I considered that the subjects reanalyzed the sentence.

The results are shown in Table 7.11.

Table 7.11 Eye-tracking: The results for Reanalysis 3 [DH vs. Hearing]

Sentences with no reanalysis

	Fixation	Reanalysis
DH1	3	2
DH2	3	3
DH3	5	4
DH4	5	2
DH5	2	4
DH6	4	3
DH7	5	4
DH8	6	5
DH9	3	5
Average	4.00	3.56

	Fixation	Reanalysis
C1	3	5
C2	4	5
C3	5	4
C4	4	5
C5	4	5
C6	3	1
Average	3.83	4.17

Sentences with syntactic reanalysis

	Fixation	Reanalysis
DH1	5	4
DH2	5	5
DH3	5	4
DH4	4	4
DH5	4	5
DH6	3	5
DH7	5	4
DH8	3	5
DH9	3	5
Average	4.11	4.56

	Fixation	Reanalysis
C1	2	5
C2	3	5
C3	5	5
C4	2	5
C5	4	5
C6	5	3
Average	3.50	4.67

(the numbers of sentences out of 5)

Although DH subjects fixated more often than hearing subjects, the reanalysis results between sentences which required no reanalysis and sentences which required syntactic reanalysis by both DH subjects and hearing subjects were similar. These results were consistent with the results of the comparison between DH (English) subjects and hearing subjects as in Table 7.12 and the results of the comparison between DH (English) and DH (Sign) subjects as in Table 713.

Table 7.12 Eye-tracking: The results for Reanalysis 3 [DH (English) vs. Hearing]

Sentences with no reanalysis

	Fixation	Reanalysis
DH2	3	3
DH4	5	2
DH6	4	3
DH7	5	4
DH8	6	5
Average	4.60	3.40

	Fixation	Reanalysis
C1	3	5
C2	4	5
C3	5	4
C4	4	5
C5	4	5
C6	3	1
Average	3.83	4.17

Sentences with syntactic reanalysis

	Fixation	Reanalysis
DH2	5	5
DH4	4	4
DH6	3	5
DH7	5	4
DH8	3	5
Average	4.00	4.60

	Fixation	Reanalysis
C1	2	5
C2	3	5
C3	5	5
C4	2	5
C5	4	5
C6	5	3
Average	3.50	4.67

(the numbers of sentences out of 5)

Table 7.13 Eye-tracking: The results for Reanalysis 3 [DH (English) vs. DH (Sign)]

Sentences with no reanalysis

DH (English)	Fixation	Reanalysis
DH2	3	3
DH4	5	2
DH6	4	3
DH7	5	4
DH8	6	5
Average	4.60	3.40

DH (Sign)	Fixation	Reanalysis
DH1	3	2
DH3	5	4
DH5	2	4
DH9	3	5
Average	3.25	3.75

Sentences with syntactic reanalysis

DH (English)	Fixation	Reanalysis
DH2	5	5
DH4	4	4
DH6	3	5
DH7	5	4
DH8	3	5
Average	4.00	4.60

DH (Sign)	Fixation	Reanalysis
DH1	5	4
DH3	5	4
DH5	4	5
DH9	3	5
Average	4.25	4.50

(the numbers of sentences out of 5)

The average of fixation and reanalysis for all groups are summarized in Table 7.14.

Table 7.14 Eye-tracking: The average of the results for Reanalysis 3

	Sentence with no reanalysis		Sentence with reanalysis	
	Fixation	Reanalysis	Fixation	Reanalysis
DH (Sign)	3.25	3.75	4.25	4.50
DH (English)	4.60	3.40	4.00	4.60
C (English)	3.83	4.17	3.50	4.67

(the numbers of sentences out of 5)

The results for fixation in sentences which required syntactic reanalysis were different from DH subjects and hearing subjects, but the results for reanalysis were similar in all three groups. These results did not show clear differences among subjects or sentences. This indicates no processing difficulty in the two types of sentences by all subjects.

7.3.5 RC-Attachment Preference

The results of RC-attachment preference during the eye-tracking experiment are shown in Table 7.15.

Table 7.15 Eye-tracking: RC-Attachment Preference [DH vs. Hearing]

Short RC

	HA	LA
DH1	**8**	2
DH2	**8**	2
DH3	**10**	0
DH4	**9**	1
DH5	5	5
DH6	2	**8**
DH7	5	5
DH8	**8**	2
DH9	5	5

	HA	LA
C1	2	**8**
C2	3	**7**
C3	6	4
C4	1	**9**
C5	1	**9**
C6	3	**7**

Long RC

	HA	LA
DH1	**8**	2
DH2	**10**	0
DH3	**10**	0
DH4	**9**	1
DH5	**8**	2
DH6	4	6
DH7	5	5
DH8	4	6
DH9	5	5

	HA	LA
C1	1	**9**
C2	**8**	2
C3	1	**9**
C4	3	**7**
C5	3	**7**
C6	4	6

(number: the numbers of sentences out of 10, boldface: over 2/3 of all sentences)

Five out of six hearing subjects preferred LA for short RC sentences, however only one DH subject preferred LA in short RC sentences. Five DH subjects preferred HA in short RC sentences. The results for four DH subjects and one hearing subject did not indicate any preference in short RC sentences. Four out of six hearing subjects preferred LA and one hearing subject preferred HA for long RC sentences. Five DH subjects preferred HA in long RC sentences. Most of hearing subjects preferred LA in both short and long RC sentences. On the other hand, more than half of the DH subjects preferred HA for both short and long RC sentences.

In order to find out the influence of hearing loss, the results for DH (English) and hearing subjects were compared. The results are shown in Table 7.16.

Table 7.16 Eye-tracking: RC-Attachment Preference [DH (English)] and Hearing]

	Short RC		Long RC	
	HA	LA	HA	LA
DH2	**8**	2	**7**	0
DH4	**9**	1	**9**	1
DH6	2	**8**	4	6
DH7	5	5	5	5
DH8	**8**	2	4	6

	Short RC		Long RC	
	HA	LA	HA	LA
C1	2	**8**	1	**9**
C2	3	**7**	**8**	2
C3	6	4	1	**9**
C4	1	**9**	3	**7**
C5	1	**9**	3	**7**
C6	3	**7**	4	6

(the numbers of sentences out of 10, boldface: over 2/3 of all sentences)

No hearing subjects preferred HA for short RC sentences, however 3 out of 5 DH (English) subjects preferred HA in short RC sentences.

In order to find out the influence of the L1, the results for DH (English) and DH (Sign) were compared. The comparison is shown in Table 7.17.

Table 7.17 Eye-tracking: RC-Attachment Preference [DH (English)] and DH (Sign)]

	Short RC		Long RC	
DH (English)	HA	LA	HA	LA
DH2	**8**	2	**7**	0
DH4	**9**	1	**9**	1
DH6	2	**8**	4	6
DH7	5	5	5	5
DH8	**8**	2	4	6

	Short RC		Long RC	
DH (Sign)	HA	LA	HA	LA
DH1	**8**	2	**8**	2
DH3	**10**	0	**9**	0
DH5	5	5	**7**	2
DH9	5	5	5	5

(the numbers of sentences out of 10, boldface: over 2/3 of all sentences)

One finding from these results was that no DH (Sign) subjects showed LA preference, but one DH (English) subject preferred LA in short RC.

7.3.6 Eye-Fixation in RC

In order to investigate whether subjects inserted an implicit prosodic break before RCs, eye-fixation on the word before RCs in the first pass were analyzed. The results are shown in Table 7.18.

Table 7.18 Eye-tracking: Fixation before RC [DH vs. Hearing]

	Short RC	Long RC
DH1	8	9
DH2	10	9
DH3	9	9
DH4	10	7
DH5	9	8
DH6	1	5
DH7	10	8
DH8	8	10
DH9	4	5
Average	7.67	7.78

	Short RC	Long RC
C1	7	6
C2	7	8
C3	9	7
C4	3	6
C5	6	6
C6	5	2
Average	6.17	5.83

(the numbers of sentences out of 10)

The averages of occurrence of eye-fixation before both short and long RC by DH subjects were higher than by hearing subjects.

In order to find out the influence of hearing loss, the results for DH (English) and hearing subjects were compared. The comparison is shown in Table 7.19.

Table 7.19 Eye-tracking: Fixation before RC [DH (English) vs. Hearing]

	Short RC	Long RC
DH2	10	9
DH4	10	7
DH6	1	5
DH7	10	8
DH8	8	10
Average	7.80	7.80

	Short RC	Long RC
C1	7	6
C2	7	8
C3	9	7
C4	3	6
C5	6	6
C6	5	2
Average	6.17	5.83

(the numbers of sentences out of 10)

DH (English) subjects fixated before both short and long RC more often than hearing subjects. This indicates the difference is influenced by the hearing loss of DH (English) subjects. These results can explain the preference of HA by some DH (English) subjects.

In order to find out the influence of the L1, the results for DH (English) and DH (Sign) were compared. The comparison is shown in Table 7.20.

Table 7.20 Eye-tracking: Fixation before RC [DH (English) vs. DH (Sign)]

DH (English)	Short RC	Long RC
DH2	10	9
DH4	10	7
DH6	1	5
DH7	10	8
DH8	8	10
Average	7.80	7.80

DH (Sign)	Short RC	Long RC
DH1	8	9
DH3	9	9
DH5	9	8
DH9	4	5
Average	7.50	7.75

(the numbers of sentences out of 10)

The results did not indicate any clear difference between DH (English) and DH (Sign) subjects. This indicates that there was no L1 influence for the DH (Sign) subjects.

The averages of fixation before RCs for all groups are summarized in Table 7.21.

Table 7.21 Eye-tracking: The average of the fixation before RC

	Short RC	Long RC
DH (Sign)	7.50	7.75
DH (English)	7.80	7.80
C (English)	6.17	5.83

(the numbers of sentences out of 10)

These results found that hearing loss influenced the prosodic break before both short and long RCs. The contrast the data to the RC-attachment preference during the eye-tracking experiment (see Table 7.15), a high rate of insertion of a prosodic break before RC by DH subjects can explain their high rate of HA preference.

7.4 Discussion

We noted that the reading times of subject-extracted RCs and object-extracted RCs were similar for both DH and hearing subjects. Both DH and hearing subjects spent longer when reading object-extracted RCs in three of the pairs. This longer reading time indicates the sentence is more difficult to process than the other sentence in the pair.

Table 7.22 Eye-tracking: The longer reading times for Locality Preference

	DH		Hearing	
sentence	S-extracted RC	O-extracted RC	S-extracted RC	O-extracted RC
(a)-(c)	11.3%	88.7%	5.7%	94.3%
(d)	78%	22%	66%	34%

(S-extracted RC: Subject-extracted RC, O-extracted RC: Object-extracted RC)

One sentence pair (d) (shown in (78)) had the opposite results to those predicted for both DH and hearing subjects. This pattern is the same as for the results from the questionnaire study. Subjects spent longer reading the subject-extracted RC than the object-extracted RC.

(78) a. The man who went out with me last year was a poor actor. (subject-extracted RC)
b. The man who I went out with last year was a poor actor. (object-extracted RC)

This is explained in Section 6.5. Therefore, the results of the eye-tracking experiment also found that both DH and hearing subjects preferred the locality based parsing strategy.

The results for Reanalysis 1 (No Reanalysis vs. Syntactic and Prosodic Reanalyses I) (Table 7.23) found that both DH and hearing subjects reanalyzed (backtracked) on the sentences which required syntactic and prosodic reanalyses more often than on the sentences which did not require reanalysis. The numbers of fixations were similar to DH (English) and DH (Sign) and hearing subjects. However, the number of reanalyses by the hearing subjects were the greatest for both sentences which required no reanalysis and sentences which required both syntactic and prosodic reanalyses. The number of reanalyses by the DH (English) was slightly less than those of hearing subjects. This could be due to their hearing loss. On the other hand, the number of reanalyses by the DH (Sign) subjects was almost half of the number by DH (English) and hearing subjects. This indicates a clear L1 influence.

Table 7.23 Eye-tracking: The results for Reanalysis 1

	Sentence with no reanalysis		Sentence with reanalysis	
	Fixation	Reanalysis	Fixation	Reanalysis
DH (Sign)	7.5	1.5	8.25	4.5
DH (English)	7.6	3.6	8.2	7.2
C (English)	7.83	4.5	7	8

(the numbers of sentences out of 10)

The results for Reanalysis 2 (No Reanalysis vs. Syntactic and Prosodic Reanalyses II) (Table 7.24) found that both DH and hearing subjects reanalyzed (backtracked) on the sentences which required syntactic and prosodic reanalyses more often than the sentences which did not require reanalysis. This pattern is the same found in the result for Reanalysis 1 (No Reanalysis vs. Syntactic and Prosodic Reanalyses I) in the above. However, the results for DH (English) and DH (Sign) subjects were very close. This does not indicate any L1 influence.

Table 7.24 Eye-tracking: The results for Reanalysis 2

	Sentence with no reanalysis		Sentence with reanalyses	
	Fixation	Reanalysis	Fixation	Reanalysis
DH (Sign)	7.00	3.00	8.25	9.25
DH (English)	8.00	3.60	8.60	9.20
C (English)	6.83	4.67	8.67	9.00

(the numbers of sentences out of 10)

The results for Reanalysis 3 (No Reanalysis vs. Syntactic Reanalysis) (Table 7.25) found that both DH and hearing subjects reanalyzed (backtracked) on the sentences which required syntactic reanalysis slightly more often than on the sentences which did not require reanalysis. This small difference indicates that subjects did not find a difficulty difference between the two types of sentences.

Table 7.25 Eye-tracking: The results for Reanalysis 3

	Sentence with no reanalysis		Sentence with reanalysis	
	Fixation	Reanalysis	Fixation	Reanalysis
DH (Sign)	3.25	3.75	4.25	4.50
DH (English)	4.60	3.40	4.00	4.60
C (English)	3.83	4.17	3.50	4.67

(the numbers of sentences out of 5)

From the above analyses, we can see that both DH and hearing subjects had difficulty in processing sentences which required both syntactic and prosodic reanalyses but not sentences which required only syntactic reanalysis. This means that DH subjects are also using prosody during silent reading. However, the reanalysis rate of the DH subjects was lower than that of the hearing subjects in Reanalysis 1. This might indicate that (a) they are less sensitive to the prosodic boundary compared to the hearing subjects, (b) they are less sensitive to the syntactic boundary compared to the hearing subjects, or (c) they are less dependent on the prosody during parsing. However the results for Reanalysis 2 and 3 showed that DH subjects' knowledge of

English prosody and the use of prosody were the same as the hearing subjects'. The difference between sentences in Reanalysis 1 and 2 was syntactic structures. Sentences in Reanalysis 1 consist of a preposed constituent, while sentences in Reanalysis 2 consist of an AdvP. The movement of the constituent to the beginning of the sentence might give DH subjects difficulty. Thus, the lower scores of DH subjects in Reanalysis 1 might be due to the analysis of the syntactic structures.

The data of eye-fixation indicate that all subjects fixated their eyes on the word before the congruent position with a high rate. Thus, the relationship between an eye-fixation and a prosodic break is not clear from the results.

The results for the RC-attachment preference task of the eye-tracking experiment are shown in Table 7.26.

Table 7.26 Eye-tracking: RC-Attachment Preference [DH vs. Hearing]

	Short RC		Long RC	
	DH	Hearing	DH	Hearing
HA	55.6% (5/9)		55.6% (5/9)	16.7% (1/6)
LA	11.1% (1/9)	83.3% (5/6)		66.7% (4/6)
No Preference	33.3% (3/9)	16.7% (1/6)	44.4% (4/9)	16.7% (1/6)

Except for one hearing subject who preferred HA in a long RC sentence, the results are consistent with the previous studies (English speakers prefer LA (Cuetos and Mitchell 1988, Maynell 1999)). As for the DH subjects, half of them preferred HA in both short and long RC sentences.

The comparison of the three groups: DH (Sign), DH (English), and hearing subjects is shown in Table 7.27.

Table 7.27 Eye-tracking: RC-Attachment Preference

	DH (Sign)		DH (English)		Hearing (English)	
	Short RC	Long RC	Short RC	Long RC	Short RC	Long RC
HA	50%	75%	60%	40%		16.7%
LA			20%		83.3%	66.7%
No Preference	50%	25%	20%	60%	16.7%	16.7%

	DH (Sign)		DH (English)		Hearing (English)	
	Short RC	Long RC	Short RC	Long RC	Short RC	Long RC
Preference	No preference	HA	No preference	No preference	LA	LA

The results show that DH (English) subjects preferred had no preference in both short and long RC sentences while hearing subjects preferred LA in both short and long RC sentences. This difference indicates the influence of hearing loss of DH (English) subjects. The comparison between DH (English) and DH (Sign) subjects found that although both groups did not prefer LA in both short and long RC sentences, DH (Sign) subjects preferred HA in long RC sentences while DH (English) subjects had no preference. This could be the influence of their L1.

The results for the eye-fixation of RC sentences are shown in Tables 7.28 and 7.29.

Table 7.28 Eye-tracking: Fixation occurrence on the word before an RC [DH (English) vs. Hearing]

DH (English)	Short RC	Long RC
DH2	10	9
DH4	10	7
DH6	1	5
DH7	10	8
DH8	8	10
Average	7.80	7.80

Hearing	Short RC	Long RC
C1	7	6
C2	7	8
C3	9	7
C4	3	6
C5	6	6
C6	5	2
Average	6.17	5.83

(the numbers of sentences out of 10)

Table 7.29 Eye-tracking: Fixation occurrence on the word before an RC [DH (English) vs. DH (Sign)]

DH (Sign)	Short RC	Long RC
DH1	8	9
DH3	9	9
DH5	9	8
DH9	4	5
Average	7.50	7.75

DH (English)	Short RC	Long RC
DH2	10	9
DH4	10	7
DH6	1	5
DH7	10	8
DH8	8	10
Average	7.80	7.80

(the numbers of sentences out of 10)

The two groups of DH subjects fixated their eyes before an RC on more than seven out of ten RC sentences in both short and long RCs. On the other hand, the hearing subjects fixated their eyes before the RC less often than the DH subjects. According to the Implicit Prosody Hypothesis (Fodor 1998, 2002), if the default prosody of the reader's language provides a prosodic break before an RC, then the readers will prefer HA. Thus, the low numbers of breaks before RCs by the hearing subjects (average 6.17 for short RC, 5.83 for long RC) indicates that the default prosodic pattern in English is not to have a prosodic break before an RC and, therefore, their preference is LA. However, the similar numbers of breaks before RCs by two groups of DH subjects did not indicate a different preference for their RC-attachments.

In order to further investigate the RC-attachment preferences, the eye-fixation patterns before an RC are compared in Tables 7.30, 7.31 and 7.32. Table 7.30 shows the data for the hearing subjects.

Table 7.30 Eye-tracking: Fixation occurrence on the word before an RC, and RC-attachment preference [Hearing]

	Short RC			Long RC		
	Fixation	Preference		Fixation	Preference	
Hearing		HA	LA		HA	LA
C1	**7**	2	**8**	6	1	**9**
C2	**7**	3	**7**	**8**	**8**	2
C3	**9**	6	4	**7**	1	**9**
C4	3	1	**9**	6	3	**7**
C5	6	1	**9**	6	3	**7**
C6	5	3	**7**	2	4	6
Average	6.17			5.83		

(the numbers of sentences out of 10, boldface: over 2/3 of all sentences)

Three hearing subjects fixated their eyes before short RCs with a high rate and none of them had a strong HA preference. Although two hearing subjects fixated their eyes before long RCs with a high rate, only one of them had a strong HA preference. Thus, the high eye-fixation rate before RCs did not indicate hearing subject's HA preference. From these results, the relationship between eye-fixation and a prosodic break is not clear.

Table 7.31 is the data of DH (English) subjects.

Table 7.31 Eye-tracking: Fixation occurrence on the word before an RC, and RC-attachment preference [DH (English)]

	Short RC			Long RC		
	Fixation	Preference		Fixation	Preference	
DH (English)		HA	LA		HA	LA
DH2	**10**	**8**	2	**9**	**7**	0
DH4	**10**	**9**	1	**7**	**9**	1
DH6	1	2	8	5	4	6
DH7	**10**	5	5	**8**	5	5
DH8	**8**	**8**	2	**10**	4	6
Average	7.8			7.8		

(the numbers of sentences out of 10, boldface: over 2/3 of all sentences)

Four DH (English) subjects fixated their eyes before short RCs with a high rate and three of them had a strong HA preference. Four DH (English) subjects fixated their eyes before long RCs with a high rate and two of them demonstrated a strong HA preference.

Table 7.32 is the data of DH (Sign) subjects.

Table 7.32 Eye-tracking: Fixation occurrence on the word before an RC, and RC-attachment preference [DH (Sign)]

	Short RC			Long RC		
	Fixation	Preference		Fixation	Preference	
DH (Sign)		HA	LA		HA	LA
DH1	**8**	**8**	2	**9**	**8**	2
DH3	**9**	**10**	0	**9**	**9**	0
DH5	**9**	5	5	**8**	**7**	2
DH9	4	5	5	5	5	5
Average	7.5			7.75		

(the numbers of sentences out of 10, boldface: over 2/3 of all sentences)

Three DH (Sign) subjects fixated their eyes before short RCs with a high rate and two of them strongly preferred HA. Three DH (Sign) subjects fixated their eyes before long RCs with a high rate and all of them showed a strong HA preference.

The relationship between fixation rate and RC-attachment preference from eye-tracking is summarized in Table 7.33.

Table 7.33 Average fixation and RC-attachment preference

RC	DH (Sign)	preference	DH (English)	preference	Hearing	preference
Short	7.5	No preference	7.8	No preference	6.17	LA
Long	7.75	HA	7.8	No preference	5.83	LA

Compared to hearing subjects, the high eye-fixation rate before RCs indicates the DH subjects' HA preference. Hearing subjects had LA preference even though they fixated their eyes before RCs, regardless of their length. However, this did not apply to the DH subjects. The similar fixation rate and different preference between DH (Sign) and DH (English) subjects (HA vs. no preference in long RC) may be the result of L1 influence.

From the eye-tracking experiment, the relationship between eye-fixation and prosodic break is not clear. However, the subjects' eye-movements reflected the difficulty of sentence processing in their backtracking phenomena. These reanalysis processes confirmed the claim of the Prosodic Constraint on Reanalysis (Bader 1998) which states that the sentences which required both syntactic and prosodic reanalysese are more difficult to process than sentences which required only syntactic reanalysis or no reanalysis.

CHAPTER 8: SUMMARY AND IMPLICATIONS

In Chapter 6 and 7, I reported on two experiments designed to investigate the role of prosody in silent reading. In this final chapter, I will summarize the results from the two experiments and the findings from them. In addition, I will discuss directions for future research.

8.1 General findings and implications

The investigation of the role of locality in parsing from both the questionnaire and the eye-tracking studies found that the results for both DH and hearing subjects were very similar. The questionnaire study found that both DH and hearing subjects found object-extracted RC sentences more difficult than the subject-extracted RC sentences. The reading times for the eye-tracking study found that the reading times for the object-extracted RC sentences were longer than those for the subject-extracted RC sentences by both DH and hearing subjects. Thus, I can conclude that the locality preference of DH subjects is not influenced by their hearing loss.

The investigation of the RC-length effect in the questionnaire study also found that the results for both DH and hearing subjects were very similar. The length of the RC did not influence the difficulty to process the sentences by either DH or hearing subjects.

The investigation of the difficulty in sentence processing in both the questionnaire and the eye-tracking studies found that the results for both DH and hearing subjects were very similar. Both DH and hearing subjects demonstrated in the questionnaire study that sentences which required both syntactic and prosodic reanalyses were more difficult to process than sentences which required either syntactic reanalysis alone or no reanalysis. The eye-tracking study found that sentences which required both a syntactic and prosodic reanalysis required more backtracking than sentences which required either syntactic reanalysis alone or no reanalysis. These findings support the claim of the Prosodic Constraint on Reanalysis (Bader 1998) which states that sentences which require both syntactic and prosodic reanalyses are more difficult to process than sentences which require either no reanalysis or only syntactic reanalysis. Although the eye-fixations from the eye-tracking experiment did not show a prosodic break difference between the two different types of sentence, the questionnaire study found that subjects inserted a break where the prosodic phrase boundary matched the syntactic phrase boundary in order to process the sentence naturally (easily). The results of this task showed that DH subjects inserted a break in a position where the prosodic boundary is not congruent with the syntactic boundary more often than hearing subjects did, especially when the sentences required both syntactic and prosodic reanalyses. This suggests that hearing loss influences the conscious knowledge of the prosodic phrase boundary of DH subjects.

The results concerning RC-attachment preference in the questionnaire study were similar to the results for the eye-tracking study.

Table 8.1 RC-attachment preference [Questionnaire vs. Eye-tracking]

RC	DH (Sign)		DH (English)		Hearing	
	Questionnaire	Eye-tracking	Questionnaire	Eye-tracking	Questionnaire	Eye-tracking
Short	HA	None	None	None	LA	LA
Long	HA	HA	None	None	LA	LA

(None: No preference)

The hearing subjects preferred LA and the DH (English) subjects had no preference. The difference may be the influence of hearing loss. However, DH (Sign) subjects had opposite preferences to the hearing subjects. They clearly preferred more HA than DH (English) subjects. This indicates that the results of DH (Sign) subjects could be the influence of their hearing loss and their L1 which is different from other two groups of subjects.

The investigation of the default prosodic pattern in RCs in the questionnaire found that DH subjects inserted a break before short RCs more often than hearing subjects did. According to Fodor (1998, 2002), a short RC is included into the previous prosodic phrase as a result of the phonological constraint on the size (optimal length) of prosodic phrase (a major phrase in Selkirk 2000). However this was not the case for DH subjects. The different RC-attachment preferences which occur in long RCs are based on the default prosodic pattern of the language in question. The higher rate of insertion of the break before short RCs by DH subjects may have been influenced by their hearing loss. For the long RCs, the hearing subjects inserted a break before the RCs 10 to 26.6% of the time; the DH (English) subjects inserted a break before the RCs 52 to 64% of the time; and the DH (Sign) subjects inserted a break before the RCs 15 to 30% of the time. These results indicate that the default prosodic pattern of the hearing and DH (Sign) subjects was to not have a break before long RCs, while the default prosodic pattern of the DH (English) subjects is more flexible. The results for the hearing subjects were not completely consistent with the results for the English speakers in Fodor (2002). Not many hearing subjects inserted a break before long RCs when they were forced to a HA interpretation. However the results from prosodic break insertion before RCs and their preferences of RC-attachment support the claim of the Implicit Prosody Hypothesis (Fodor 1998, 2002). The Implicit Prosody Hypothesis explains (a) the LA preference of the hearing subjects because their default prosodic pattern is to not have a break before RCs, and (b) the lack of clear preference of the DH (English) subjects because their prosodic pattern with respect to breaks is flexible. This different prosodic pattern between hearing and DH (English) subjects may reveal the influence of hearing loss for DH (English) subjects. On the other hand, the DH (Sign) subjects' HA preference contradicts the prediction of the Implicit Prosody Hypothesis because the default prosodic pattern of DH (Sign) subjects is to not have a break before RCs. Possible explanations are (a) the influence of the L1 (which is sign language) as the prosody of a manual language cannot be treated the same way as the prosody of a spoken language, and (b) the influence of the combination of L1 and hearing loss.

The eye-fixation data from the eye-tracking study found that fixation rates for hearing subjects were lower than both DH (English) and DH (Sign) subjects. This suggests that the eye-fixation on the word before RCs does reflect a prosodic break before an RC. DH (English) subjects had fewer numbers of fixations on the target word. Thus, they had fewer prosodic breaks before an RC and their preference of (mild) HA are correctly predicted by the Implicit Prosody Hypothesis. However the eye-fixation for the two DH subject groups did not reflect the difference of RC-attachment preference between them.

The difference between the DH (English) subjects and the hearing subjects in RC-attachment preference and their prosodic break during parsing is summarized in Table 8.2.

Table 8.2 Default prosody, eye-fixation and RC-attachment preference [DH (English) vs. Hearing]

	DH (English)			Hearing		
RC	Default prosody	Eye-fixation	Preference	Default prosody	Eye-fixation	Preference
Short	Flexible break	7.8	No preference	No break	6.17	LA
Long	Flexible break	7.8	No preference	No break	5.83	LA

Table 8.2 shows that although eye-fixation difference is small, the Implicit Prosody Hypothesis (Fodor 1998, 2002) correctly predicted the RC-attachment preference for the DH (English) and the hearing subjects. The more prosodic breaks for the DH (English) subjects found in the questionnaire study (as evidenced by default prosody) and in the eye-tracking study (as measured by eye-fixation) leads to their flexible RC-attachment preference. The default prosodic pattern for the hearing subject is to not have a break before an RC and the low rate of eye-fixation

suggests fewer prosodic breaks and hence their RC-attachment preference is LA.

However, the results for the DH (Sign) subjects contradicted the prediction of the Implicit Prosody Hypothesis (Fodor 1998, 2002). The relationship between default prosodic pattern, eye-fixation before RC, and RC-attachment preference is summarized in Table 8.3.

Table 8.3 Default prosody, eye-fixation and RC-attachment preference

	DH (Sign)			DH (English)			Hearing		
RC	Default prosody	Eye-fixation	Preference	Default prosody	Eye-fixation	Preference	Default prosody	Eye-fixation	Preference
Short	None	7.5	HA*	Flexible	7.8	None	None	6.17	LA
Long	None	7.75	HA	Flexible	7.8	None	None	5.83	LA

(* None (No preference) in the Eye-tracking study)

The default prosodic pattern for the DH (Sign) subjects is to not have a break before RC, thus according to the Implicit Prosody Hypothesis they should have preferred LA, but their preference is HA. If the eye-fixation before RC indicates a prosodic break the DH (Sign) subjects should have had no RC-attachment preference as the DH (English) subjects did. Therefore, the results for the DH (Sign) subjects may be influenced by their L1 (sign language).

Sign languages are natural languages. Although there is a modality difference between signed language and spoken language (manual-visual vs. oral-aural modalities), the phonological phrase[38] in a signed language is also marked by a phonetic (gesturral) cue, such as lengthening the sign, pausing between signs, or reiteration of the sign (Sandler and Lillo-Martin 2006). An RC in ASL is indicated by agreement with the head via spatial marking (Lillo-Martin, Hanson, and Smith 1992). For example, signed sentences (79) and (80) are RC sentences. Words written in capital letters are signs (English gloss). Subscripts indicate the spatial locations. Superscript 'rc' indicates RC.

[38] Phonological phrase: Major phonological phrase in Selkirk (2000), Phonological phrase in Nespor and Vogel (1986).

$$\overset{rc}{\overline{{}_{a}\text{WOMAN HAVE BOX}}}\ {}_{a}\text{THAT}\ {}_{a}\text{KISS}_{b}\ {}_{b}\text{MAN.}$$

(79) ${}_{a}$WOMAN HAVE BOX ${}_{a}$THAT ${}_{a}$KISS${}_{b}$ ${}_{b}$MAN.
"The woman who has the box kissed the man." (Lillo-Martin, et al. 1992)

$$\overset{rc}{\overline{{}_{b}\text{MAN}\ {}_{b}\text{KISS}_{a}}}\ {}_{a}\text{WOMAN}\ {}_{a}\text{THAT HAVE BOX.}$$

(80) ${}_{b}$MAN ${}_{b}$KISS${}_{a}$ ${}_{a}$WOMAN ${}_{a}$THAT HAVE BOX.
"The woman who the man kissed has the box." (Lillo-Martin, et al. 1992)

Suppose 'a' is left and 'b' is right. Then sentence (79) is interpreted in the following manner: 'a' is "the woman", 'a' is "who", and 'a' kiss 'b' means "the woman … kiss the man". Because of head marking via spatial marking, RC in ASL is unambiguous. Thus, whether or not there is a prosodic break before an RC, the noun to which the RC attaches in ASL is spatially unambiguous. This means that in ASL, spatial expressions explain RC-attachment, not the Implicit Prosody Hypothesis. In addition, the prosodic pattern for DH (Sign) subjects found in the questionnaire study also did not support the Implicit Prosody Hypothesis. Therefore a possible explanation could be that the DH (Sign) subjects' prosodic pattern reported in the questionnaire study was not, in fact, a prosodic break (prosodic phrase boundary). It might have been a syntactic phrase boundary. Whether DH (Sign) subjects used prosodic analysis during parsing RC sentences, and why their RC-attachment preference was HA requires more study about the syntactic and prosodic structure of RC sentences in ASL and English by DH (Sign) subjects.

The comparison between subject-extracted RC and object-extracted RC sentences found that DH subjects showed a locality preference. However, DH subjects did not apply the locality preference for ambiguous short RC sentences. If they used only the locality parsing strategy (not prosodic analysis during parsing), their RC-attachment preference should have been LA. This could be explained by the role of prosody in sentence processing. The processing of subject-extracted RC and object-extracted RC sentences does not involve prosodic analysis during parsing while the processing of ambiguous RC sentences involves prosodic analysis during parsing. The results for the sentence processing difficulty show that DH subjects revealed a difficulty difference less often than the hearing subjects did. From these results, we can conclude that hearing loss may be correlated with the DH subjects' sentence processing in sentences which involve prosodic analysis. This influence of hearing loss on the processing of sentences which involve prosodic analysis seemed to confirm the assumptions (51) in section 5.1 (shown in as (81) again).

(81) Assumptions

- Hearing-loss readers also use phonological coding but their phonological coding is less close to actual speech than hearing readers' phonological coding.
- The implicit prosody of hearing-loss readers is different from hearing readers' implicit prosody.
- Implicit prosody influences the parsing process in silent reading.

From the results of the two studies, the hypothesis (52) in section 5.1 (shown in as (82) again) is also confirmed.

(82) Hypothesis

The parsing process (the use of parsing strategies and preferences for parsing strategies) during silent reading of hearing-loss readers could be different from hearing readers.

8.2 Directions for future research

This thesis has tried to investigate the relationship between sentence processing and prosody. The study of sentence processing cannot avoid the influence of certain prosodic factors. Although the sample of deaf and hard of hearing subjects in this study is small, the results found that the possible correlation between hearing loss and prosodic analysis in sentence processing during silent reading. However, in order to provide more solid data, we would require more study of sentence processing by hearing-loss readers. As I discussed in section 5.2.1, the ideal research design would involve hearing-loss subjects who have the same hearing levels, the same language background, and the same reading levels. The subjects in this study have different hearing levels, different language backgrounds, and I did not assess the subjects' reading levels of English (as their reading levels were high enough to read the questionnaire of this study). Thus, it is not clear whether their reading levels were similar or not. In future studies, it will be important to find sufficient numbers of subjects who meet these criteria for inclusion.

It is also necessary to reconsider the experimental materials and the analysis of the data. I drew the RC sentences from Fernández (2003) and modified them. An example of a modification is shown below. I changed the sentence "Someone shot the **servant** of the actress that was on the balcony with her husband." to "Someone shot the **maid** of the actress that was on the balcony with her husband." This modification was based on the comments from my pilot study. Some readers found that the word *servant* gave the impression of a male, thus the RC could modify only *actress* and the sentence was not ambiguous. It is also worth noting that some hearing-loss subjects found some sentences were difficult to process because they contained the complementizer *that* instead of a relative pronoun *who*. Their difficulty in processing *that* might have influenced the eye-fixation around that word.

In order to investigate the position of a prosodic break, I measured the eye-fixation on certain words in the eye-tracking study. The results did not give any clear indication of a relationship between a prosodic break and eye-fixations for the sentences which required both syntactic and prosodic reanalysis. On the other hand, there was an indication of this relationship for RC sentences. This could have been the result of the use of the complementizer *that* instead of the relative pronoun *who*. In order to investigate the position of prosodic breaks by hearing-loss readers, the investigation of overt prosody should be conducted in a future study, as Quinn et al. (2000) and Lovrić (2003) chose as a measurement of the implicit prosody.

This study is the first step in the investigation of sentence processing and prosody in silent reading by both hearing-loss and hearing readers. The role of prosody in sentence processing is important as we attempt to understand the nature and structure of the parsing mechanism. If problems in prosody are underlying problems in sentence processing for deaf and heard of hearing people, then this may be one of the reasons for their depressed reading abilities. Perhaps instruction which focused on aspects of prosody would be able to bring about a change in their reading proficiency. Thus, this study might contribute to improving the future education of deaf and hard of hearing students. Above all, the study of sentence processing in silent reading by deaf and hard of hearing people provides evidence for the influence of prosody on the parsing mechanism.

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APPENDIX A: PROFILE FOR DEAF AND HARD OF HEARING SUBJECTS

Your profile

(For use only in data analysis. This information will be treated as confidential. Your anonymity will be retained in any presentation of results).

1. Age: ______ years old
2. Gender: Male ☐ / Female ☐
3. You are: deaf ☐ / hard-of-hearing ☐
4. At what age did you lose your hearing? ______ years old
5. Your hearing level:

   ______dB loss (left ear), ______dB loss (right ear)

   (Comments: ....)
6. Are you using hearing aid? Yes ☐ / No ☐
7. What kind of hearing aid are you using? (..............)
8. If you are using hearing aid, what is your hearing level with hearing aid?

   ______dB loss (left ear), ______dB loss (right ear)

   (Comments: ....)
9. First language: ___________________
10. Do you speak or sign other language(s)? _____
11. Do you lipread? Yes ☐ / No ☐
12. Did you learn English-based sign language? Yes ☐ / No ☐
13. At what age did you first start learning Sign language? ______ years old
14. Do you speak English? Yes ☐ / No ☐
15. If your first language is not English, have you learned how to speak/pronounce English? Yes ☐ / No ☐

16.Do you speak English when you sign? Yes ☐ / No ☐

17. If the answer of 16 is 'Yes', how often do you speak English with signing?

______

18.At what age did you first start learning English? ______ years old

19.At what age did you first start learning speaking English? ______ years old

20.Education (highest level completed): Graduate ____________________

21.Do you watch TV or movie (with subtitle)? ____________________

22.Do you read books, magazines, or newspaper? ____________________

23.Do you picture inner sign (or imagine sign) when you read? Yes ☐ / No ☐

24.Do you hear an inner voice or sound when you read? Yes ☐ / No ☐

25.When reading a letter, have you ever experienced the sensation of picturing the sign (or imaging sign) of the person who wrote it as you read the words?

Yes ☐ / No ☐

26.When reading a letter, have you ever experienced the sensation of hearing the voice or sound of the person who wrote it as you read the words?

Yes ☐ / No ☐

27.Your family:

Father: ____________, Mother: ____________
Husband: ____________, Wife: ____________
Sibling 1: ____________, Sibling 2: ____________
Sibling 3: ____________, Sibling 4: ____________
Other family member (_____): ____________
Other family member (_____): ____________
Other family member (_____): ____________
Other family member (_____): ____________

28.How do you communicate with your family?

Father: ____________, Mother: ____________
Husband: ____________, Wife: ____________
Sibling 1: ____________, Sibling 2: ____________

Sibling 3: ____________, Sibling 4: ____________
Other family member (_____): ____________
Other family member (_____): ____________
Other family member (_____): ____________
Other family member (_____): ____________

29.Other information:
(e.g., If you had a cochlear implant, when did you have it?)

....

30.Name, address, and postal code (if you want to receive a questionnaire by mail):

....

Thank you for your cooperation. If your profile fits my study, I will ask you to participate in a questionnaire study. I will inform you as soon as I analyze your profile.

The questionnaire consists of some Drop-Down forms. The choices are followings.

Question 9: ASL, English-based sign, English, Other

Question 17: Always, Sometimes, Rarely, Never

Question 20: Junior high school, High school, College, University, Junior high school for the deaf and hard of hearing, High school for the deaf and hard of hearing, College for the deaf and hard of hearing, University for the deaf and hard of hearing

Question 21: Everyday, Sometimes, Rarely, Never

Question 22: Everyday, Sometimes, Rarely, Never

Question 27: hearing, deaf, hard of hearing

Question 28: ASL, English-based sign, English, Other

APPENDIX B: PROFILE FOR HEARING SUBJECTS

Profile for hearing participants

Your profile

(For use only in data analysis. This information will be treated as confidential. Your anonymity will be retained in any presentation of results).

1. Age: _____ years old
2. Gender: Male ☐ / Female ☐
3. Where are you from?
4. First language: _____
5. Second language(s): _____
6. At what age did you first start learning your second Language? _____ years old
7. Do you hear an inner voice when you read? Yes ☐ / No ☐
8. When reading a letter, have you ever experienced the sensation of hearing the voice of the person who wrote it as you read the words?

   Yes ☐ / No ☐
9. Education (highest level completed):

   Graduate: high school ☐ / college ☐ / university ☐
10. Occupation: _____

APPENDIX C: QUESTIONNAIRE

Questionnaire

Please do not use a dictionary!

There is no correct answer, so feel free to answer what you think.
If you do not understand, please skip the questions.

Part 1: Which sentence is more difficult? Check the difficult sentence.
If you think that both answers are equally difficult, check 'same'.

Example
a. The horse raced past the barn fell. ☒ ← difficult
b. The horse taken past the barn fell. ☐ (same ☐)

(1) a. Tom will give you the cat that my dog chased after he buys a cage for it. ☐
b. Tom will give you the cat that my dog chased tomorrow. ☐ (same ☐)

(2) a. I gave the valuable book that was extremely difficult to find to Mary. ☐
b. I gave the valuable book to Mary that was extremely difficult to find. ☐ (same ☐)

(3) a. Lisa couldn't find the refills for the pens that were on sale. ☐
b. Lisa couldn't find the refills for the pens that were in the lower desk drawer. ☐ (same ☐)

(4) a. You will hear from Lisa that Mike's wife fainted after Lisa comes back to town. ☐
b. You will hear from Lisa that Mike's wife fainted tomorrow. ☐ (same ☐)

(5) a. Mike heard the story was boring. ☐
b. Mike heard the story yesterday. ☐ (same ☐)

(6) a. Jack will tell you that you have failed tomorrow. ☐
b. Jack will tell you that you have failed after he comes back to the office. ☐ (same ☐)

(7) a. Without her contributions the funds would be inadequate. ☐
b. Without her contributions would be inadequate. ☐ (same ☐)

(8) a. In case you haven't eaten breakfast sandwich is on the table. ☐
b. In case you haven't eaten breakfast is on the table. ☐ (same ☐)

(9) a. Patricia saw the teacher of the student that was in the zoo. ☐
b. Patricia saw the teacher of the student that was in the library the other day. ☐ (same ☐)

(10) a. Tom found the book yesterday. ☐
b. Tom found the book was boring. ☐ (same ☐)

Questionnaire

(11) a. Mike will know that his mother was very sick after he sees her pictures. ☐
b. Mike will know that his mother was very sick tomorrow. ☐ (same ☐)

(12) a. The reporter who the senator attacked admitted the error. ☐
b. The reporter who attacked the senator admitted the error. ☐ (same ☐)

(13) a. Whenever the dog obeyed the little girl showed her approval. ☐
b. Whenever the dog obeyed the little girl she showed her approval. ☐ (same ☐)

(14) a. Every time Harry calls his mother she is out. ☐
b. Every time Harry calls his mother is out. ☐ (same ☐)

(15) a. We will see the movie that was famous in China after our teacher gets the video. ☐
b. We will see the movie that was famous in China tomorrow. ☐ (same ☐)

(16) a. According to her studies predict the volcano would erupt in less than one year. ☐
b. According to her studies the volcano would erupt in less than one year. ☐ (same ☐)

(17) a. Although I called John didn't come to the party. ☐
b. Although I called John he didn't come to the party. ☐ (same ☐)

(18) a. I believe you with all my heart. ☐
b. I believe you are innocent. ☐ (same ☐)

(19) a. You will believe that Jack told us the truth tomorrow. ☐
b. You will believe that Jack told us the truth after you watch the news. ☐ (same ☐)

(20) a. I met the man who my mother's friend married to. ☐
b. I met the man who married my mother's friend. ☐ (same ☐)

(21) a. Julia saw the secretary of the lawyer that was speaking on the phone all morning. ☐
b. Julia saw the secretary of the lawyer that was on vacation. ☐ (same ☐)

(22) a. The man who went out with me last year was a poor actor. ☐
b. The man who I went out with last year was a poor actor. ☐ (same ☐)

(23) a. The plumber adjusted the pipe of the sink that was installed before I moved in this apartment. ☐
b. The plumber adjusted the pipe of the sink that was cracked. ☐ (same ☐)

(24) a. Harry will inform you that Tom failed the mission tomorrow. ☐
b. Harry will inform you that Tom failed the mission after he returns next week. ☐ (same ☐)

(25) a. In order to help the little boy Jill put down the package she was carrying. ☐
b. In order to help the little boy put down the package he was carrying. ☐ (same ☐)

(26) a. Peter knew the answer would be false. ☐
b. Peter knew the answer immediately. ☐ (same ☐)

Questionnaire

(27) a. Because many students failed the exam it was made easier this year. ☐
b. Because many students failed the exam was made easier this year. ☐ (same ☐)

(28) a. Mary will know his sister is cute. ☐
b. Mary will know his sister sooner or later. ☐ (same ☐)

(29) a. The black cat that chased the white cat was my pet. ☐
b. The black cat that the white cat chased was my pet. ☐ (same ☐)

(30) a. John will explain to the kids that their grandfather died after they come home from school. ☐
b. John will explain to the kids that their grandfather died tomorrow. ☐ (same ☐)

(31) a. Someone shot the maid of the actresses that was on the balcony with her husband. ☐
b. Someone shot the maid of the actress that was on the balcony. ☐ (same ☐)

(32) a. Since Jay always walks a mile it seems like a short distance to him. ☐
b. Since Jay always walks a mile seems like a short distance to him. ☐ (same ☐)

(33) a. He will hear from Mary that she broke her leg tomorrow. ☐
b. He will hear from Mary that she broke her leg after he goes to a hospital. ☐ (same ☐)

(34) a. Because of her contributions would be adequate. ☐
b. Because of her contributions the funds would be adequate. ☐ (same ☐)

(35) a. Mary will tell you that Peter danced after everyone comes to school. ☐
b. Mary will tell you that Peter danced after tomorrow. ☐ (same ☐)

Part 2: Choose the preferable answer.

Example
Linda wrote to the manager of the actor that was late.
Who was late? the manager ☒ / the actor ☐

(36) Julia saw the secretary of the lawyer that was on vacation.
Who was on vacation? the secretary ☐ / the lawyer ☐

(37) Someone shot the maid of the actress that was on the balcony.
Who was on the balcony? the maid ☐ / the actress ☐

(38) The plumber adjusted the pipe of the sink that was cracked.
What was cracked? the pipe ☐ / the sink ☐

(39) Patricia saw the teachers of the students that were in the zoo.
Who was in the zoo? the teachers ☐ / the students ☐

Questionnaire

(40) Lisa couldn't find the refills for the pens that were on sale.
What was on sale? the refills ☐ / the pens ☐

(41) My friend met the assistant of the detective that was fired.
Who was fired? the assistant ☐ / the detective ☐

(42) Maria met the son of the president that was smoking.
Who was smoking? the son ☐ / the president ☐

(43) My mother finally found the button of the shirt that was brown.
What was brown? the button ☐ / the shirt ☐

(44) The chef couldn't find the lid of the pan that was clean.
What was clean? the lid ☐ / the pan ☐

(45) The thief found the key of the safe that was gorgeous.
What was gorgeous? the key ☐ / the safe ☐

(46) Julia saw the secretary of the lawyer that was speaking on the phone all morning.
Who was speaking on the phone all morning? the secretary ☐ / the lawyer ☐

(47) Someone shot the maid of the actress that was on the balcony with her husband.
Who was on the balcony with her husband? the maid ☐ / the actress ☐

(48) The plumber adjusted the pipe of the sink that was installed before I moved in this apartment.
What was installed before I moved in this apartment? the pipe ☐ / the sink ☐

(49) Patricia saw the teachers of the students that were in the library the other day.
Who was in the library the other day? the teachers ☐ / the students ☐

(50) Lisa couldn't find the refills for the pens that were in the lower desk drawer.
What was in the lower desk drawer? the refills ☐ / the pens ☐

(51) My friend met the assistant of the detective that was in the police station near my house.
Who was in the police station near my house? the assistant ☐ / the detective ☐

(52) Maria met the son of the president that was watching television in the living room.
Who was watching television in the living room? the son ☐ / the president ☐

(53) My mother finally found the button of the shirt that was missing for long time.
What was missing for long time? the button ☐ / the shirt ☐

(54) The chef couldn't find the lid of the pan that was in the cupboard on the left.
What was in the cupboard on the left? the lid ☐ / the pan ☐

(55) The thief found the key of the safe that was in the closet in the hall.
What was in the closet in the hall? the key ☐ / the safe ☐

Questionnaire

Part 3: Insert at most 2 slashes (/) in the following sentences to read easily.
(If you think it is not necessary, you don't need to insert any slash.)

> **Example**
> **In order to help the little boy Jill put down the package she was carrying.**
>
> **In order to help the little boy / Jill put down the package she was carrying.**

(56) Peter knew the answer immediately.

(57) Julia saw the secretary of the lawyers that was on vacation.

(58) Someone shot the maid of the actress that was on the balcony with her husband.

(59) Without her contributions the funds would be inadequate.

(60) Tom will give you the cat that my dog chased after he buys a cage for it.

(61) Someone shot the maid of the actress that was on the balcony.

(62) Peter knew the answer would be false.

(63) Julia saw the secretaries of the lawyer that was on vacation.

(64) Without her contributions would be inadequate.

(65) Someone shot the maids of the actress that was on the balcony with her husband.

(66) The plumber adjusted the pipe of the sink that was cracked.

(67) Someone shot the maid of the actresses that was on the balcony.

(68) Julia saw the secretary of the lawyers that was on vacation.

(69) Tom found the book was boring.

(70) Jack will tell you that you have failed after he comes back to the office.

(71) Since Jay always walks a mile it seems like a short distance to him.

(72) The plumber adjusted the pipes of the sink that was cracked.

(73) John will explain to the kids that their grandfather died tomorrow.

(74) Mike heard the story yesterday.

Questionnaire

(75) Patricia saw the teachers of the students that were in the zoo.

(76) Lisa couldn't find the refills for the pen that were on sale.

(77) The plumber adjusted the pipe of the sink that was installed before I moved in this apar tment.

(78) Patricia saw the teachers of the student that were in the library the other day.

(79) Someone shot the maids of the actress that was on the balcony.

(80) Julia saw the secretary of the lawyer that was speaking on the phone all morning.

(81) Patricia saw the teacher of the students that were in the library the other day.

(82) Tom found the book yesterday.

(83) The plumber adjusted the pipes of the sink that was installed improperly since last week.

(84) You will hear from Lisa that Mike's wife fainted after Lisa comes back to town.

(85) Whenever the dog obeyed the little girl she showed her approval.

(86) John will explain to the kids that their grandfather died after they come home from scho ol.

(87) I believe you are innocent.

(88) Patricia saw the teacher of the students that were in the zoo.

(89) The plumber adjusted the pipe of the sinks that was installed before I moved in this apa rtment.

(90) Julia saw the secretary of the lawyers that was speaking on the phone all morning.

(91) Mary will tell you that Peter danced after everyone comes to school.

(92) In order to help the little boy Jill put down the package she was carrying.

(93) According to her studies predict the volcano would erupt in less than one year.

(94) You will hear from Lisa that Mike's wife fainted tomorrow.

(95) I believe you with all my heart.

(96) Lisa couldn't find the refills for the pens that were on sale.

(97) Patricia saw the teachers of the students that were in the library the other day.

Questionnaire

(98) Whenever the dog obeyed the little girl showed her approval.

(99) Tom will give you the cat that my dog chased tomorrow.

(100) Mike heard the story was boring.

(101) In order to help the little boy put down the package he was carrying.

(102) Lisa couldn't find the refills for the pens that were in the lower desk drawer.

(103) Jack will tell you that you have failed tomorrow.

(104) Patricia saw the teachers of the student that were in the zoo.

(105) Lisa couldn't find the refills for the pen that were in the lower desk drawer.

(106) The plumber adjusted the pipe of the sinks that was cracked.

(107) Julia saw the secretaries of the lawyer that was speaking on the phone all morning.

(108) Mary will know his sister is cute.

(109) According to her studies the volcano would erupt in less than one year.

(110) Lisa couldn't find the refill for the pens that were in the lower desk drawer.

(111) Mary will know his sister sooner or later.

(112) Since Jay always walks a mile seems like a short distance to him.

(113) Mary will tell you that Peter danced tomorrow.

(114) Lisa couldn't find the refill for the pens that were on sale.

(115) Someone shot the maid of the actresses that was on the balcony with her husband.

Thank you for your cooperation. If the results of this questionnaire fit my study, I will ask you to participate in an eye-tracking experiment. I will inform you as soon as I analyze your questionnaire.

If you have any comments, please feel free to write down.

....

APPENDIX D: STIMULI FOR THE EYE-TRACKING EXPERIMENT

PRACTICE SENTENCES

- Tom hit Mike.
- Mary slapped Mike.
- Who slapped Mike?

  Susan / Mary
- Jack slept for 8 hours and Tommy slept for 6 hours last night.
- Did Jack sleep for 7 hours last night?

  yes / no
- The cat chased the mouse.
- The mouse chased the cat.
- What is chased?

  the mouse / the cat
- Bill speaks English and French, but Jason speaks only English.
- Does Jason speak French?

  yes / no

EXPERIMENT SENTENCES

- Tom will give you the cat that my dog chased after he buys a cage for it.
- Who will give you the cat?

  Mary / Tom
- Without her contributions the funds would be inadequate.
- I believe you with all my heart.
- I gave the valuable book that was extremely difficult to find to Mary.
- What did I give to Mary?

  Valuable book / difficult book
- The man who went out with me last year was a poor actor.

- Since Jay always walks a mile seems like a short distance to him.
- Does Jay always swim a mile?

  yes / no
- I met the man who my mother's friend married to.
- He will hear from Mary that she broke her leg tomorrow.
- In order to help the little boy put down the package he was carrying.
- What was the little boy carrying?

  books / package
- Tom will give you the cat that my dog chased tomorrow.
- Julia saw the secretary of the lawyer that was on vacation.
- Who was on vacation?

  the secretary / the lawyer
- Someone shot the maid of the actress that was on the balcony.
- Who was on the balcony?

  the actress / the maid
- The plumber adjusted the pipe of the sink that was cracked.
- What was cracked?

  the pipe / the sink
- Patricia saw the teachers of the students that were in the zoo.
- Who was in the zoo?

  the teachers / the students
- Lisa couldn't find the refills for the pens that were on sale.
- What was on sale?

  the pens / the refills
- Mary will tell you that Peter danced after everyone comes to school.
- The man who I went out with last year was a poor actor.
- Who did I go out with last year?

  singer / actor
- In order to help the little boy Jill put down the package she was carrying.
- Because of her contributions the funds would be adequate.

- Although I called John didn't come to the party.
- Did John come to the party?

  yes / no
- The reporter who the senator attacked admitted the error.
- Peter knew the answer would be false.
- Every time Harry calls his mother she is out.
- Who calls his mother?

  Tom / Harry
- You will believe that Jack told us the truth tomorrow.
- I met the man who married my mother's friend.
- Did I meet my mother's friend?

  yes / no
- Without her contributions would be inadequate.
- I believe you are innocent.
- I gave the valuable book to Mary that was extremely difficult to find.
- Who did I give the book?

  Mary / Jane
- We will see the movie that was famous in China after our teacher gets the video.
- John will explain to the kids that their grandfather died tomorrow.
- Since Jay always walks a mile it seems like a short distance to him.
- Does Jay always walk a mile?

  yes / no
- You will hear from Lisa that Mike's wife fainted after Lisa comes back to town.
- Harry will inform you that Tom failed the mission tomorrow.
- Did Tom fail the mission?

  yes / no
- Mary will know his sister is cute.
- Whenever the dog obeyed the little girl she showed her approval.

- Julia saw the secretary of the lawyer that was speaking on the phone all morning.
- Who was speaking on the phone all morning?

  the lawyer / the secretary
- Someone shot the maid of the actress that was on the balcony with her husband.
- Who was on the balcony with her husband?

  the maid / the actress
- The plumber adjusted the pipe of the sink that was installed before I moved in this apartment.
- What was installed before I moved in this apartment?

  the sink / the pipe
- Patricia saw the teachers of the students that were in the library the other day.
- Who was in the library the other day?

  the teachers / the students
- Lisa couldn't find the refills for the pens that were in the lower desk drawer.
- What was in the lower desk drawer?

  the refills / the pens
- Mary will tell you that Peter danced after tomorrow.
- You will hear from Lisa that Mike's wife fainted tomorrow.
- Who did faint?

  Lisa / Mike's wife
- He will hear from Mary that she broke her leg after he goes to a hospital.
- The reporter who attacked the senator admitted the error.
- In case you haven't eaten breakfast a sandwich is on the table.
- What is on the table?

  cake / sandwich
- Because of her contributions would be adequate.
- We will see the movie that was famous in China tomorrow.
- Tom found the book yesterday.
- When did Tom find the book?

  Last month / yesterday
- According to her studies the volcano would erupt in less than one year.

- My friend met the assistant of the detective that was fired.
- Who was fired?

  the detective / the assistant
- Maria met the son of the president that was smoking.
- Who was smoking?

  the son / the president
- My mother finally found the button of the shirt that was brown.
- What was brown?

  the button / the shirt
- The chef couldn't find the lid of the pan that was clean.
- What was clean?

  the pan / the lid
- The thief found the key of the safe that was gorgeous.
- What was gorgeous?

  the safe / the key
- Harry will inform you that Tom failed the mission after he returns next week.
- Did Tom succeed the mission?

  yes / no
- Mike heard the story was boring.
- Because many students failed the exam it was made easier this year.
- Did many students fail the exam?

  yes / no
- Every time Harry calls his mother is out.
- Although I called John he didn't come to the party.
- Tom found the book was boring.
- The black cat that chased the white cat was my pet.
- Which one was a chaser?

  black cat / white cat
- In case you haven't eaten breakfast is on the table.
- Mike heard the story yesterday.

- Peter knew the answer immediately.
- My friend met the assistant of the detective that was in the police station near my house.
- Who was in the police station near my house?

  the detective / the assistant
- Maria met the son of the president that was watching television in the living room.
- Who was watching television in the living room?

  the son / the president
- My mother finally found the button of the shirt that was missing for long time.
- What was missing for long time?

  the shirt / the button
- The chef couldn't find the lid of the pan that was in the cupboard on the left.
- What was in the cupboard on the left?

  the pan / the lid
- The thief found the key of the safe that was in the closet in the hall.
- What was in the closet in the hall?

  the key / the safe
- Mary will know his sister sooner or later.
- Does Mary know his sister?

  yes / no
- Mike will know that his mother was very sick tomorrow.
- You will believe that Jack told us the truth after you watch the news.
- According to her studies predict the volcano would erupt in less than one year.
- Did the volcano erupt last year?

  yes / no
- The black cat that the white cat chased was my pet.
- Jack will tell you that you have failed tomorrow.
- Whenever the dog obeyed the little girl showed her approval.
- John will explain to the kids that their grandfather died after they come home from school.
- Is their grandfather dead?

  yes / no

- Mike will know that his mother was very sick after he sees her pictures.
- Because many students failed the exam was made easier this year.
- Jack will tell you that you have failed after he comes back to the office.

APPENDIX E: ETHICS APPROVAL

UNIVERSITY OF
CALGARY

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CERTIFICATION OF INSTITUTIONAL ETHICS REVIEW

This is to certify that the Conjoint Faculties Research Ethics Board at the University of Calgary has examined the following research proposal and found the proposed research involving human subjects to be in accordance with University of Calgary Guidelines and the Tri-Council Policy Statement on *"Ethical Conduct in Research Using Human Subjects"*. This form and accompanying letter constitute the Certification of Institutional Ethics Review.

File no:	**5096**
Applicant(s):	**Seiko Sagae**
Department:	**Linguistics**
Project Title:	**Sentence Processing in Deaf Readers: Do Deaf Readers Use Prosody During Silent Reading?**
Sponsor (if applicable):	

Restrictions:

This Certification is subject to the following conditions:

1. Approval is granted only for the project and purposes described in the application.
2. Any modifications to the authorized protocol must be submitted to the Chair, Conjoint Faculties Research Ethics Board for approval.
3. A progress report must be submitted 12 months from the date of this Certification, and should provide the expected completion date for the project.
4. Written notification must be sent to the Board when the project is complete or terminated.

Janice Dickin

Janice Dickin, Ph.D, LLB,
Chair
Conjoint Faculties Research Ethics Board

26 January 2007
Date:

Distribution: (1) Applicant, (2) Supervisor (if applicable), (3) Chair, Department/Faculty Research Ethics Committee, (4) Sponsor, (5) Conjoint Faculties Research Ethics Board (6) Research Services.