LEXICAL QUANTITY IN JAPANESE AND FINNISH

Toshiko Isei-Jaakkola

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Department of Phonetics
University of Helsinki
P. O. Box 35 (Vironkatu 1 B)
00014 University of Helsinki

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Abstract

Despite the fact that Finnish and Japanese differ from each other typologically, remarkable similarities between them can be heard. The most obvious common phonetic feature may be the linguistically distinctive quantity in both vowels and consonants. In the present study I investigated the similarities and differences of lexical quantity in Finnish and Japanese. So far, no large systematic phonetic comparative study on these two languages exists.

As background, I discuss the sound systems of each language, including segments, phonotactics, syllable structures, as well as rhythm and timing issues, all being closely related to quantity. The major experiments were concentrated on production and perception of quantity: (1) the segmental, syllabic and word durational ratios of bisyllabic nonsense words with /$C^1V^1(V^1)C^1(C^1)V^1(V^1)$/ structure (2-5 moraic words) were measured and (2) using synthetic speech stimuli, the perceptual boundary ranges in equivalent structures were compared and correlated with three fundamental frequency and intensity patterns in order to observe their influence on quantity perception. In addition, I conducted perception tests on the Finnish /(C)Vn$C^1(C^1)$V/ structure with the Japanese speakers, and compared the durational ratios of the nasal consonant in the /CV-n/N-$C^1(C^1)$V/ structure both in isolation and a sentence. I also discuss the durations of /h/ in Japanese and the Finnish /hV/ and /CV1hCV2/ structures. In each experiment, the syllable concept was used for both languages, but the ‘linearity’ or ‘isochronicity’ based on the Japanese mora hypothesis was also taken into consideration.

In Chapter 3, utilising the structure /$C^1V^1(V^1)C^1(C^1)V^1(V^1)$/, the results showed that (1) the segmental ratios were smaller in Finnish, and the durational variations were relatively narrower and more stable in Finnish than in Japanese; (2) in both languages, the segmental durations depended not only on the syllable structure but also on the syllable position in the word; (3) both languages showed similar stepwise patterns in increasing ratios, but Japanese showed greater linearity (isochronicity), according to the number of syllables/morae, regardless of the number of phonemes, while Finnish showed a greater dependence on the number of phonemes within the comparable syllable structure; (4) the segmental durational ratios within the word showed negligible differences between the languages. In Chapter 4, I used the short/long vowels/consonants in /$C^1V^1(V^1)C^1(C^1)V^1(V^1)$/ and created stimuli with 8 types of syllable structure and variable prosodic patterns. The results revealed that (1) the Japanese perceptual boundary ranges were shorter in duration, but the Finnish counterparts were more stable in differentiating between short/long segments; (2) the Finnish reached the minimum durational point of long vowels and consonants in less time than the Japanese, but the Finnish had wider prosodically conditional variations than the Japanese; (3) the word structural differences had more effect than the prosodic conditional differences in differentiating short segments from long segments in both Finnish and Japanese. In Chapter 5, the findings were that (1) the Japanese mostly perceived the Finnish /CVn$C^1(C^1)$V/ as trimoraic words in both listening and transliteration; (2) the durations of /n/ were much shorter in the /CVnCCV/ structure than in /CVnCV/ in Finnish, and (3) the durational patterns showed similarities in /CV-n/N-CV/ for both Finnish and Japanese. In Chapter 6, /h/ was defined as an approximant, not as a fricative. The duration of the Japanese /h/ was longer than in Finnish, but the durations of /h + V/ were similar in both languages. The Finnish /CV-h-CV/ did not show an isochronic durational pattern.

Key words: *Japanese and Finnish lexical quantity, speech production and perception, durational patterns, temporal control, syllable structure and quantity, prosody in relation to quantity.*

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Toshiko Isei-Jaakkola

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Contents

List of Figures

List of Tables

List of Appendices

Abbreviations

J.	Japanese
F.	Finnish
V	vowel(s)
C	consonant(s)
S	segment(s)
W	word(s)
CV1	CV in the first syllable
CV2	CV in the second syllable
V1	vowel in the first syllable
V2	vowel in the second syllable
C1	consonant in the first syllable
C2	consonant in the second syllable
SS	syllable structure(s)
PC	prosodic condition(s)
D	difference
BR	perceptual boundary range, boundary range area
PSE	point of subjective equality
S	short segment(s)
L	long segment(s)
U	uncertain area
Me	median
n	the number of subjects/informants
N	the number of data

R	range(s)
SD	standard deviation(s)
‘a1’	[ɑ] in the first syllable
‘a2’	[ɑ] in the second syllable
‘aa1’	[ɑː] in the first syllable
‘aa2’	[ɑː] in the second syllable
‘m1’	word-initial [m]
‘m2’	word-medial [m]
‘p1’	word-initial [p]
‘p2’	word-medial [p]
‘s1’	word-initial [s]
‘s2’	word-medial [s]
‘mm’	word-medial [mː]
‘pp’	word-medial [pː]
‘ss’	word-medial [sː]
/ /	phonological description
[ ]	phonetic notation
##	sentence boundary
#	word boundary
+	morpheme boundary
.	syllable boundary
|	mora boundary
-	segmentation boundary

Meaningful Japanese and Finnish example words in italics; ‘ ’ for English and nonsense words.

1 Introduction: Aims of the study

1.1 Purpose

When I first encountered Finnish, I observed auditive similarities to Japanese. How can we verify this impression empirically? This question led me to start a comparative phonetic study between Japanese and Finnish applying acoustic methods. I also found that no comparative phonetic studies (including basic studies) of these two languages exist – perhaps with only one exception[1] (provided with experimental data) to my knowledge.

Finnish and Japanese have short/long durational contrasts in both vowels and consonants, and these are phonemically distinctive.[2] This distinction, i.e., quantity differentiation, might be the most outstanding common feature to Japanese and Finnish.[3] The primary purpose of my study is to clarify how similar (or different: language-specific) the use of quantity is between these two languages (Ch. 3 – 4). The secondary purpose is to compare some special cases of temporal organisation (Ch. 5 – 6).

1.2 Problems

Some terminological problems combined with the notion of quantity are pointed out and some other aspects of quantity are discussed.

Since the term quantity is often used as an equivalent for an abstract length to denote differentiation of durational proportion, either short or long (or half-long), etc., 'quantity' does not refer simply to a durational dichotomy, but also to other relational, systematic and rule-governed lengths.

The term 'quantity' is often used for phonetic/phonological short/long distinctions at

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[1] Aoyama (2001) used two words – *hana* and *hanna* – for both Finnish and Japanese and measured the durational differences of /n, nn/ and tested their perceptual differences for both language speakers. In addition, she investigated when the children acquire their durational differentiation in these languages.

[2] Ladefoged (1982:226) states that probably one of the most interesting languages in the way that it uses length is Japanese.

[3] Karlsson (1987) states that the most difficult feature of pronunciation of Finnish (for second language speakers) is the length differentiation in that distinguishes separate words. However, this is not the case for Japanese speakers because of the common features of quantity.

the segmental level. Lehtonen (1970:15) states that the traditional concept of quantity should be understood as three distinct phenomena at different levels of speech processing: as (1) linguistic distinction, (2) subjective, auditory length, or (3) objective, measurable duration. Hence the levels of language, perception, and production (production meant as measurable speech output) influence the interpretation of the term. Crystal (1980) defines 'quantity' as a term used in phonology to refer to the relative durations of sounds and syllables when these are linguistically distinctive and are also referred to as length. He states that the term is particularly used in historical studies of vowel and syllable length. Laver (1994:436) quotes from Daniel Jones the terms 'chrone' to denote particular degree of phonetic duration and 'chroneme' to denote a distinctive degree of phonological length. Laver (1994:431-449) refers to other aspects of speech sound duration: intrinsic, allophonic, and positional.

These definitions seem to be mainly phonological and their classifications are mainly based on a dichotomy, and the domain at the segmental and syllabic level. The domain of quantity is often considered to be a phoneme or segment (short or long), syllable, or word (Lehtonen 1970, Magga 1984).[4] Quantity also denotes the phonetic duration within various domains and across morae, syllables, word boundaries, or even sentence boundaries.

Quantity can exist as a dichotomy or trichotomy,[5] the degree of duration, in a number of languages, while some do not have such distinctions. A quantity dichotomy cannot exist in all word positions.

Quantity differs not only at the level of phonemic contrast, but also at the syntagmatic level, i.e., in phonotactics (cf. Iivonen 1974a, 1974b).[6] With regard to the relationship between quantity and syllable structure, for example, Abercrombie (1967:82) points out that a difference in vowel length that makes a difference in syllable structure is called a difference in vowel quantity. Quantity can be related to temporal control such as speech rhythm and timing and may relate to fundamental frequency (F0)

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[4] Magga (1984:11-12) states that the syllable seems to be very important in explaining quantity in various languages, although quantity seems to be a highly language-specific phenomenon, and the domain of the quantity patterns is the word, the building blocks of which are syllables and possibly certain bisyllabic sequences.

[5] Quantity trichotomy exists in Saami and Estonian, for example.

[6] Lehtonen (1970:60-61) claims, in terms of intrinsic duration characteristics of segmental phoneme units, that paradigmatic factors affect the duration of phonemes caused by the particular characteristics of each segmental phoneme, while syntagmatic factors are those which depend on the structure of a larger phonological unit (e.g., the syllable, measure or word) regardless of which vowel and consonant phonemes of the paradigm appear in various positions within the structure.

and/or intensity (amplitude, dB).

Thus quantity refers to all systematic, proportional ways of using duration in a language, not just its distinctive quantity (distinguishing word meanings).

A great number of phoneticians of Japanese (Han 1962a, 1962b, 1992, 1994, Beckman 1982, Homma 1981, Sato 1992, 1993, 1995, 1998, and many others – see also Warner and Arai's review (2001)) and Finnish (Wiik 1965, Lehtonen 1970, and others) have conducted experiments on (phonologically distinctive) quantity. The Finnish studies preferred to use quantity rather than mora, but most of them have been related to phonemic length differentiation. The Japanese studies have tended to verify or neglect isochronity by mora-hypothesis, according to which each mora is isochronous. These experiments have been conducted with the test words in isolation, or carrier sentence or both and in the read speech, or recitation, or nowadays more often spontaneous speech. Most of these studies are on production, studies on perception being fewer. Perceptual boundaries have been investigated in each language, e.g., Fujisaki and Sugitou (1977) (and others) for Japanese, Lehtonen (1970) (and others) for Finnish, Aoyama (2001) for Finnish and Japanese. But there might be very little research on focusing boundary range areas.

In my work the study of rhythm is no central issue, but because different rhythm or timing types might be important for understanding some phenomena of durational ratios of quantity, some reference to rhythm and timing is necessary.

Concerning Finnish quantity, there are several phonological interpretations presented in the literature (reviewed in Harrikarri 2000:2-3).

My use of 'lexical quantity' in this study means that quantity is phonologically distinctive. Quantity is the paradigmatic duration of segments (categorically short or long, vowel or consonant), which occurs within words and which can occur syntagmatically in certain positions in words. However, for the phonologically short vowels or consonants the notations /V/ or /C/ have been applied, for the long ones /V^1V^1/ or /C^1C^1/. 'Single' or 'singleton' for the short category and 'geminate (consonants)' or 'double' for the long category will be used as equivalent terms.

1.3 Goals of the study

One of my focal points is whether there are similarities and differences of quantity, based on the quantity dichotomy and also considering tripartite concept for perception taking into account the perceptual uncertainty aspect and using different types of syllable structures for the experiments.

I took into consideration the common syllable structures to Finnish and Japanese with the same phonemic combinations /$C^1V^1(V^1)C^1(C^1)V^1(V^1)$/ except for /CVVCCVV/ and /CV-n/N-CV/, and different phonotactic combinations (/CVhCV/) and different syllable structures (Finnish /CVnCCV/), in order to measure not only segmental durations but also word durations. /CVVCCVV/ structure does not exist in Japanese but the Japanese speakers were tested in its production and perception. Variable prosodic conditions have not very much been tested in the perception of quantity. In addition, since the perception tests have been in general conducted by binary concept, choosing short or long, I adopted tripartite concept for choices of tests words and focused on perceptual boundary areas in quantity. Moreover, I considered temporal organisations of a phoneme, mora and syllable within the word using the same (/CV-n/N-CV/) and different phonotactic combinations (/CVhCV/) and different syllable structures (Finnish /CVnCCV/). These syllable structures represent bisyllabic words in Finnish and bimoraic to five moraic words in Japanese.

1.4 Outline

This study consists of seven chapters. In Chapter 2, I compare the similarities and differences of sound systems between Finnish and Japanese – vowels and consonants, phonotactics, and syllable structures. In addition, I discuss quantity and timing. I also compare the Japanese mora and the Finnish syllable, and their rhythm and timing issues in relation to quantity. In Chapter 2 I also include such basic phonetic and phonological descriptions as might help Finnish learners of Japanese and Japanese learners of Finnish improve their practical skills, because such an approach is very limited in textbooks.

Chapters 3 – 6 comprise the experimental part of this study. Chapters 3 and 4 form the main part. The comparison between Japanese and Finnish can be carried out only using exactly the same experimental set-up; otherwise the result may reflect differences in the test arrangements.

In Chapter 3, I report on the durational ratios of short and long quantity, segmental variations, word durations, durational patterns and segmental durational distributions within the word in different syllable structures having the same phonological combinations of vowels and consonants in /$C^1V^1(V^1)C^1(C^1)V^1(V^1)$/ structure. This study tries to answer whether there is linearity in relation to mora-counting, dependent on word durations.

In Chapter 4, I discuss the perceptual boundary range areas (BR) of vowel and consonantal quantity, utilising eight types of syllable structures and variable prosodic conditions (F0 and intensity) attached to them in order to compare if and which conditions affect the quantity. In my experiments, I use tripartite concept – short, long and uncertainty. Also, I compare the minimum long segments for vowels and consonants using the same conditions as in BR between Finnish and Japanese, which have in general been studied by many phoneticians in order to determine the distinctive ratios between short and long segments in perception.

In Chapter 5, I describe how the Japanese speakers perceive Finnish /CVnCV/ and /CVnCCV/ words by listening and writing tests. The /CVnCCV/ structure does not exist in Japanese. The durations of /N/ in Japanese /CVNCV/ and of /n/ in Finnish /CVnCV/, uttered in isolation and in a sentence and the syllabic/moraic durational patterns were compared. Finnish /CVnCCV/ were used for comparison.

In Chapters 5 and 6, syllable structures, different from those used in Chapters 3 and 4 are studied. They concentrate of special segmental durations which might be systematic, language-specific temporal patterns which are not distinctive, but yet regular and rule-governed.

In Chapter 6, I discuss the definitions of /h/ and report on the durations of /h/ and surrounding vowels in Japanese and Finnish /hV/ structure. The intensity of /h/ was also compared to test our impression. In addition, the duration of /h/ in Finnish /CVhCV/ was measured to compare it to the /h/ in /hV/, since this structure – /CVCCV/ exists in Japanese but not /CVhCV/ structure. The measurement of zero-crossings in /CVhCV/ was added to observe whether the /h/ has a fricative quality.

In Chapter 7, the final chapter, I summarise the major findings concerning similarities and differences between Finnish and Japanese, and discuss these results on quantity in relation to syllable structure, phonotactics, the influence of other prosodic parameters beside duration, and rhythm and timing.

Since accentuation and intonational differences, in addition to word expressions, distinguish a wide variety of dialects in Japanese, some dialects may not be mutually intelligible. In my study I recorded the contemporary standard norm for both Finnish and Japanese, used in formal situations and close to the written norm. I excluded dialectal variation as much as possible. In this study I selected Tokyo dialect speakers, who are closest to the standard Japanese, and speakers from the Helsinki and its surrounding area, for Finnish.

2 Sound systems and quantity

Both Finnish and Japanese include many words with the same or similar pronunciation and the same or very similar sequences of segments although the meaning is different. The following examples are taken from the lexicon.

me	(F. 'we', J. 'eye')[7]
te	(F. 'you' pl., J. 'hand')
osa	(F. 'part', J. 'chief')
kai	(F. 'probably', J. 'shell')
hana	(F. 'tap', J. 'nose')
koko	(F. 'size', J. 'here')
hanki	(F. 'a sort of snow', J. 'half term')
kappa	(F. 'pelmet', J. 'animal name')

Finnish and Japanese differ from each other typologically. Finnish is a Uralic language, while Japanese is considered to be isolated (Takeuchi 1999:5). Finnish and Japanese are agglutinative languages, but differ morphologically. The similarities and differences in morphotactics and loan words, and the relationship between the orthographic system and pronunciation between Japanese and Finnish are explained in Notes (1) and (2).

In this chapter I discuss the sound systems of each language: segments, phonotactics, syllable structures, and rhythm and timing issues, all being closely related to quantity.

2.1 Vowels

Standard Japanese has five vowel phonemes: /i, e, ɑ, o, ɯ[8]/. The Japanese vowel may be nasalised when followed by the moraic nasal /N/. Finnish has eight vowels: /i, y, u, e, ø, o, æ, ɑ/. It should be noted that Finnish /u/ has a lip protrusion and lip rounding, while Japanese /ɯ/ has lip compression (cf. Vance 1987) with no spreading and with very little lip-protrusion and is more centralized. The Finnish phoneme system is relatively limited (Wiik 1965, Karlsson 1983, Leino 1986) compared to, say, English, which has

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[7] Since there is no plural in Japanese, my English translation does not have articles or suffixes to imply plurality.

[8] The Japanese /ɯ/ is not exactly that of cardinal vowel [ɯ]. The timbre is different from cardinal vowel 16 [ɯ] where lips are pulled aside.

18 vowels according to Wells (1990). However, the Japanese vowel system is still more limited.

2.1.1 Vowel quality

The phonemic quality of Japanese[9] and Finnish vowels does not seem to be greatly affected by stress or accent, unlike English in which a vowel phoneme (strong form) can change into a different vowel phoneme (weak form) and the extrinsic or intrinsic duration changes largely, depending on whether it is stressed/accented or not.

Fujisaki and Sugitou (1977:72) measured the vowel formants – F1, F2 and F3 of six males, all of who are Tokyo dialect speakers.[10] De Graaf and Koopmans-van Beinum (1982/3) measured the Japanese vowel formants (F1 and F2) of three male informants in three ways: at the segmental (in isolation), lexical (in words) and sentential (in conversation) levels respectively. Their data seems to be taken from broader categories than Fujisaki and Sugitou's (1977). (See Appendix 1) In terms of the Finnish vowel formants, Wiik (1965:57)[11] measured the F1, F2 and F3 of monophthongs and "double" vowels (Wiik's term) produced by five Finnish male informants. (See Appendix 2) De Graaf and Koopmans-van Beinum's (1982/3) and Wiik's (1965) values were translated into Figure 2.1.

This formant chart (and the smaller inventory size) might suggest that each Japanese vowel can be more clearly pronounced than Finnish vowels. The /ɑ/ vowels in Japanese and Finnish seem to be the closest of the vowels on the vowel formant chart.

The Finnish /y, ø, æ/, which do not exist in Japanese, are particularly difficult for the Japanese to articulate, especially in a sequence of these sounds occurring in the same word. The Japanese may confuse /u/ and /y/, /ɑ/ and /æ/, and /o/ and /ø/ in perceiving Finnish, and thus may replace them by Japanese sounds, i.e., /y/ by /u/, /æ/ by /ɑ/, and /ø/ by /o/ in production.

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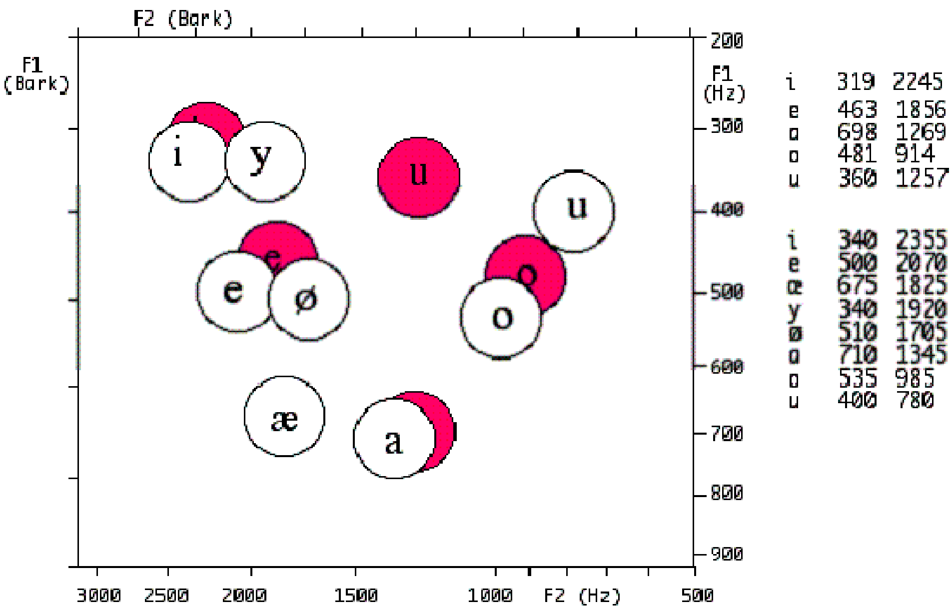
[9] See Keating and Huffman (1984) more about vowel variation in Japanese.

[10] Hattori et al. (1980) and Homma (1985) also measured the vowel formants. De Graaf and Koopmans-van Beinum's data seemed to be the best to quote. Han (1962a) showed the differences between the adult Japanese male's, adult female and children's vowel formants in her work. The vowel formants F1 (the first formant) and F2 (the second formant) of a female have higher values than those of a male and those of a child are higher still. Homma (1985), a Japanese female, measured her Japanese vowels and the data show that all of her vowel formants had very high frequencies, compared, for example, to the data from de Graaf and Koopmans-van Beinum (1982/3).

[11] See in http://www.helsinki.fi/hum/hytt/projektit/vokaali, produced by A. Iivonen (2000), also for the Finnish vowels.

The frequency ratio of Finnish five vowels, /ɑ, e, i, o, u/, is approximately 93% of all eight vowels (100%) (Karlsson 1983:75). These vowel phonemes form the Japanese vowel system.



The grey color shows the five Japanese vowels and the white the eight Finnish vowels. The formant values, quoted from de Graaf and Koopmans-van Beinum (1982/3) for Japanese and Wiik (1965) for Finnish, are shown on the right side of this figure. The Japanese and Finnish ‘a’ in this figure represents [ɑ], and Japanese ‘u’ stands for [ɯ].

Figure 2.1 Vowel Formant Chart for Japanese and Finnish vowels.

2.1.2 Vowel devoicing and duration

Finnish vowels can become devoiced in the sentence-final position in particular. Japanese vowel devoicing,[12] which occurs as a phonological rule, is not observed in Finnish. Typically, the high vowels /i/ and /ɯ/ devoice when they occur between voiceless consonants and more often in (pitch-) accented position than not. The vowel /ɯ/ also gets devoiced in word-final and sentence-final position, because a polite

[12] In her book *Japanese Phonology*, Han (1962a) uses the term “unvoicing” for ‘devoicing’ and “unvoiced” for ‘devoiced’. Her interpretation may be phonological. The term “devoicing” is usually used for this phonetic phenomenon in Japanese. It should be noted that in Japanese devoicing, the vowel does not necessarily become devoiced completely and the voicing degree may be partial.

affirmative statement always ends with /ɯ/. Let us take some examples,

/i/	[i̥]	*kiku*	[ki̥kɯ]	('(to) hear', LH)
/ɯ/	[ɯ̥]	*susuki*	[sɯ̥sɯ̥ki][13]	('Japanese pampas grass')
/sɯ#/		*garasu*	[gɑɹɑsɯ̥]	('glass', loan word)
/sɯ##/		*Soodesu.*	[soːdesɯ̥]	('That's right.').

Vowel devoicing can occur in an environment in which the surrounding consonants are voiced, e.g., *hajime* [hɑdʑ̥ime] 'the beginning', and even /o/ can devoice in *kokoro* 'heart' (Arai 1999). In such cases, the vowel can be physically deleted as a result of devoicing, but the phonological length remains. After deletion of a vowel in a word, the deleted vowel is replaced by the same consonant as the following adjacent mora, and consequently becomes geminated. Let us take an example.

/kɑtsɯte/ [kɑtsɯ̥te] ('once') → /kɑtte/ [kɑtːe].

In both cases each word has three morae. This example illustrates a phonological process (cf. Shibatani 1990) in which the affricate [ts] in /kɑtsɯte/ becomes a plosive, /t/, and that plosive is combined with the other /t/ and forms the geminate consonant /tt/.

2.1.3 Vowel quantity

Homma (1985:109) used 267 disyllabic words with the same phonemes but with different types of accent, and measured the durations of the Japanese five vowels. The linguistic content is not described.[14] They were on average 117.5 ms for /o/, 112 ms for /e/, 110 ms for /ɑ/, 95 ms for /i/, and 94.5 ms for /ɯ/ from the longest to the shortest. The durations of the vowels in Homma's data were different from Han's (1962a), which were /ɑ, e, i, o, ɯ/ from the longest to the shortest. Han's data (1962a) were calculated in a nonsense-word series and in a meaningful sentence with the syllable structures of the /CV/ series where V was always surrounded by the same C: /kVk/, /pVp/, etc. She

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[13] This example shows consecutive devoicing. The elision of consecutive vowels is also common in spontaneous speech, e.g., /to#omoQte/ surfacing as [tomotːe] (Arai 1999:616), where the word initial /o/ in /omotte/ is deleted. In addition Arai (op. cit.) adds "glide formation" where, for example, /e/ in /dɑke#ɑttɑɹɑ/ becomes /j/ in /dɑk#jɑttɑɹɑ/ These two cases – elision and glide formation – occur at the word boundary.

[14] She does not indicate whether the test words were read in isolation or in a carrier sentence.

used the consonants /p, b, m, t, d, n, k, g, n, s, z, h, r/ (op. cit.:16). Unfortunately, Han does not describe the absolute durational values. In Arai et al.'s spontaneous speech (2001) the order was /e, ɑ, o, i, ɯ/ (/e/ = 85.7 ms, /ɑ/ = 82.3 ms, 75.4 ms, /o/ = 75.4 ms, /i/ = 67.5 ms, /ɯ/ = 56.8 ms) from the longest to the shortest as the mean values of 30 speakers (tokens = 5368). The order of the long vowels were /ii (123 ms), ɑɑ (122 ms), ee (121 ms), oo (116 ms), ɯɯ (110 ms)/ (tokens = 407). The durational ratio between short and long vowels was 1:53 (117 ms:76.4 ms). They used the consonants /p, pp, t, tt, k, kk, b, d, g, s, ss, ç, çç, h, ɸ, ts, tɕ, dz, dʑ, ɹ, w, t, m, mm, n, nn, ɴ/.

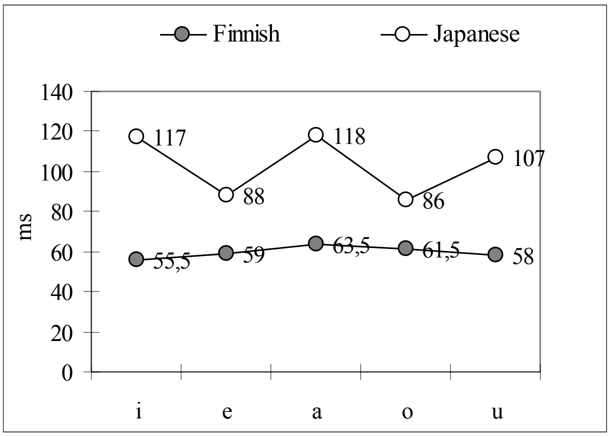
Homma (1981) measured the vowel /ɑ/, using 24 bimoraic (/CV|CV/) and trimoraic (/CV|C|CV/) real and nonsense words. Her results showed that the durational difference varied from 69 ms to 114 ms in the first syllable and from 79 ms to 112 ms in the second in /CVCV/ and /CVCCV/ (C = /p, pp, b, bb, t, tt, d, dd, k, kk, g, gg/). This indicates that the vowel duration is shorter in the first syllable than in the second, and also that the variation in the vowel largely depends on its consonantal environment. In Lehtonen (1970), the same was 79 ms in the first syllable and 48 ms in the second syllable. These results will be compared with my results in Chapter 3 of this study.

Lehtonen (1970:64-5) conducted experiments to acquire Finnish vowel and consonant quantity in a carrier sentence. His results for Finnish showed that the durational order of individual vowels was /æ, ɑ, u, o, y, ø, e, i/, beginning from the longest, in nonsense-word frames with the /pVVpV/ and /pVppVV/ syllable structures. Wiik (1965) measured the Finnish vowels in isolated words and in a carrier sentence. According to Wiik (1965:113), the mean durational ratio between single and double Finnish vowels was 1:2.3. That of Lehtonen's was approximately 1:2.2. Marjomaa (1982) compared vowel durational ratios under varying tempo conditions, his results being 1:2.3 in slow speech. Kukkonen's (1990) mean data for three normal adult speakers was 1:2.17. According to Homma (1985), the short vowel durations in the first syllable (V1 = 92 ms) were longer than those in the second (V2 = 120 ms) using the words with distinctive tonal difference (HL or LH).[15] This result is the reverse of Lehtonen's data (V1 = 76 ms, V2 = 44 ms respectively). In Finnish the first syllable is stressed, which may be why there is so much difference in the vowel duration between the first and second syllable. There has been quite a lot of research on the question of whether pitch accent may influence the vowel durational difference between the first and second syllable in Japanese. The effect of pitch accent has been reported to be negligible (e.g., Homma, 1985).

[15] She used 134 bimoraic word tokens, containing /p, t, k, s, n, j/.

Iivonen (1998:313) states that it has been difficult to find stable microprosodic pitch differences combined with the single/double contrast in vowels. The only difference observed by Aulanko (1985) was a greater F0 movement in the double (long) vowels. Vihanta (1988) concludes that the systematic F0 movements observed in connection with the single-double contrasts in vowels and consonants might depend on word structure or sentence intonation, but they might also have some function as an acoustic cue for quantity opposition (Iivonen 1998:313). The absolute value of a segment varies depending on its environment of occurrence. Nevertheless, it may be worth comparing overall ratios as language-specific durations. Sagisaka et al.'s (1984:631) and Lehtonen's data (1970:64) are compared as in Figure 2.2, where there are only five vowels because of the missing cognates for three vowels, /æ, y, œ/, in Japanese. Sagisaka and Tohkura (1984) measured the durations of the five Japanese vowels in both meaningful and nonsense words at the word, phrasal and sentence level in read speech, utilising 17 consonants (*n*: 1, *N*: 4 x 310).

The overall mean duration of the Japanese short vowels was much longer (103 ms) than those of Finnish (60 ms). The mean durational difference in the vowels between the first and second syllable was shorter in Japanese (28 ms) than in Finnish (32 ms). Sagisaka et al.'s mean duration of the five vowels was obtained from the mean values of 310 word tokens. Homma's data (1985) showed close durations for five Japanese vowels to Sagasaka et al.'s (103 ms), although Homma used her own speech alone. Lehtonen had 10 informants. Speech durations can be speaker-dependent. It must also be noted that the contextual difference can affect duration. Nevertheless, we can observe the vowel durational patterns between Finnish and Japanese. These data will be compared with my results for five vowels in Chapter 6, although my experimental purpose there was not to compare the vowel durations between Finnish and Japanese. With regard to the Japanese vowels, it must be noted that the duration of devoiced vowels are often phonetically shorter than their voiced counterparts (cf. Beckman 1982), an effect which must be taken into consideration in comparing the vowel durations between Finnish and Japanese. Vowel devoicing does not mean that the devoiced vowel is deleted; e.g., /sɯsɯki/ does not become /sski/, regardless of whether or not they are allophones or in complementary distribution (Bloch 1950:337, cf. Nagano-Madsen 1994).



Data are quoted from Lehtonen (1970) for Finnish and Sagisaka et al. (1984) for Japanese.

Figure 2.2 Durational comparison of five Finnish and Japanese short vowels.

Lehtonen (1970) states that the duration of a vowel can be a vital cue in perception of the stress of a syllable, but that his experiments show that it is not possible to state directly the modifying effect of stress on the sound durations (vowels and consonants, noted by the author) in Finnish nor can one show the significance durations and durational relations have in the perception of stress. This will be compared in Chapter 4.

2.2 Consonants

2.2.1 Japanese consonants

Table 2.1 shows the Japanese consonants. [ŋ] occurs as an allophone of /g/. [β, ɣ] can occur as allophones of /b, g/ respectively. /t/ is a laminal dento-prealveolar and can be phonetically notated as [t̪]. The affricate [ts] occurs only before /ɯ/. /d, n/ can be also dento-prealveolar, depending on its environments. *W*[16] is phonetically closer to /ɰ/ than [w] when it occurs before /ɑ/. In *w̲a* 'harmony' there is a slight lip rounding without lip protrusion, a sound which can be transcribed as [ʷɰ]. The [w], a sound which can be transcribed [ʷ], is also used as a glide for loan words[17]. The Japanese *r* is often transcribed as a voiced alveolar flap or tap like [ɾ], but is rather closer to a voiced

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[16] Akamatsu (1997) uses [ɰ] for *w* in his book *Japanese Phonetics*.

[17] In loanwords *w* is combined with the vowels /i, e, o/, e.g., *wi*, *we*, *wo* *U<u>wi</u>suki* ('whisky'), *Su<u>we</u>eden* ('Sweden'), *u<u>wo</u>kka* ('vodka').

postalveolar lateral flap [ɺ]. In rapid speech [ɺ] can become [ɾ]. The allophones of /dz, dʑ/: [z, ʑ] occur word-medially. Japanese /h/ has often been described as having the following allophones:

/h/ → [ç]/__ [i]
→ [ɸ]/ __ [ɯ][18]
→ [ɦ]/ V__V
→ [h]/ elsewhere.

However, Japanese /ç/ is a phoneme since there are minimal pairs[19] such as *haku* [hɑ ⌈kɯ][20] ('to put on') as against *hyaku* [çɑ⌈kɯ] ('hundred').[21] The allophone [ɦ] of /h/ occurs only intervocalically. In IPA [h, ɦ] are classified as fricatives but I define them as approximants. In Table 2.1, the place of /h/ is not specified because its place may vary. I shall discuss the definitions of /h/ in Chapter 6 providing acoustic experiments.

/Cʲ/[22] in Japanese is one phoneme, while the consonant sequence /Cj/[23] in Finnish (e.g., *ketju* /ketju/ ('chain')) consists of two separate consonantal phonemes, two phonemes being clearly pronounced.

2.2.2 Finnish consonants

Finnish has traditionally been described as having 13 consonants: (1) /p, t, k, s, h, m, n, ŋ[24], l, r,[25] j, ʋ, d[26]/ (Lehtonen, 1970:24). If the phonemes appearing in loanwords, (2) /b,

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[18] In loanwords [ɸ] can be combined with /ɑ, i, e, o/, e.g., *Finrando* 'Finland,' *famirii* 'family,' *feen* 'Föhn, G.,' *fookasu* 'focus'. N. B. The letter *f* is used in *roomaji* for [ɸ].

[19] For the definition, see Pike (1945).

[20] The accent notation [⌈] means the accent rise and [⌉] accent fall. I shall use these notations only where necessary.

[21] Traditionally, it has often been interpreted as an allophone (cf. Tsujimura 1996).

[22] These consonants regularly occur before the vowels /ɑ, ɯ, o/. Some of these may be palatals.

[23] This consonantal sequence does not occur in the word-initial position in Finnish, but only in the word-medial position.

[24] It occurs before /k/ within words, e.g., aurinko 'sun', and at the word boundary: e.g., pojan# kello ('boy's watch').

[25] Ladefoged & Maddieson (1996:237) states that single rhotics are taps and geminates are trilled, but in Finnish even single rhotics are trilled [often not, commented on by the author] and geminate rhotics are just longer trills. This phoneme may be tap in certain circumstances. It seems that there are two kinds of realisation of short /r/: [ɾ] and [r] in Finnish.

[26] It is adopted from Swedish as the phonetic realization of a weak form of /t/ in consonant gradation.

g, f, š[27]/, are added to these (Karlsson 1983, Lieko 1992), and the total becomes 17. The Finnish labio-dental approximant /ʋ/ can be the voiced fricative [v]. The Finnish /t/ is laminal dento-prealveolar. /h/ has the allophone [ɦ]. /r/ has the allophone [ɾ]. /l/ may have its dark and light allophones, depending on its environment. Some Finnish people do not distinguish between voiceless /p, k/ and their voiced counterparts /b, g/. These variations do not occur in Japanese. The Finnish /d/ is apical medioalveolar[28] In particular, /d/ has many substitutions depending on the dialect. The distinctions between the Finnish rhotic sounds /l, ll, r, rr/ are extremely difficult for Japanese to produce, because no such distinction exists.

Since the place of articulation of /h/ is not stabilised, its column has no indication for this place in Table 2.2. Some issues on /h/ will be discussed in Chapter 6 together with the experimental results as I mentioned earlier. The insertion of a glottal stop can occur between vowels at a word boundary, e.g., *Anna omena*! /ɑnnɑʔomenɑ/ (‘Give (me) an apple!’), or at the word- (or sentential) initial position: /(#)#ʔV-/. A doubling of a consonant occurs at the word boundary when preceded by certain words ending with /e/ or /i/ or by some word forms, e.g., *Tule̱ tänne!* /tulettænne/ (‘Come here!’) (Karlsson 1983, Lieko 1992).

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[27] This is not exactly [ʃ] or [ɕ] or [s].

[28] It can be slightly retroflex [ɖ] depending on the speaker.

Table 2.1 Japanese consonant chart.

Place / Manner	Bilabial	Dento-prealveolar	Alveolar	Alveolo-palatal	Palato-alveolar	palatal	Velar	Uvular	|
Plosive	p b pʲ bʲ	t	d				k g kʲ gʲ		
Fricative			s	ɕ		ç			
Affricate			dz	tɕ dʑ					
Nasal	m mʲ		n nʲ					ɴ	
Approximant						j	ɰ		h
Lateral flap					ɺ ɺʲ				

Table 2.2 Finnish consonant chart.

Place / Manner	Bilabial	Labio-dental	Dento-prealveolar	Alveolar	Alveolo-palatal	palatal	Velar	|
Plosive	p (b)		t	d			k (g)	
Fricative		(f)		s	(ʃ)			
Nasal	m			n			ŋ	
Approximant		ʋ				j		h
Lateral				l				
Trill/tap				r				

( ) = loan consonants.

2.2.3 Common consonants

The common consonants of Japanese and Finnish seem to be at most 12: [p, t, k, b, d, g, s, m, n, ŋ, j, h]. [ɦ], an allophone of /h/, is not included in this inventory. These are shown in the following Table 2.3.[29] Since the place of articulation of /h/ is not stabilised, its column has no indication for this place in Table 2.3. I explained the reason for this in the sections above.

Table 2.3 The consonants common to Japanese and Finnish.

Place / Manner		Bilabial	Dento-prealveolar	Alveolar	Palatal	Velar	–
Obstruent	Plosive	p b	t	d		k g	
	Fricative			s			
Sonorant	Nasal	m		n		ŋ	
	Approximant				j		h

2.2.4 Consonant quantity

Quantity can be lexical and morphological. In the structure of both languages, gemination is a frequent process in the system of derivation and inflection. Japanese and Finnish have word-medial geminate consonants. A difference between the two languages is that word-final geminates can occur in Japanese emphatic expressions; i.e., word-final /Q/. In Finnish, initial doubling of a consonant under certain word boundary circumstances can occur (Karlsson 1983). For example, "*Tule pas*!" becomes /tuleppɑs/ [tulepːɑs]. Such a case is phonologically described as /tuleQpɑs/ in Japanese.

According to Han (1962a), the durational ratio between short and long consonants is

29 Although not all consonants are common to both languages, the place of articulation of all consonants in Finnish and Japanese is mostly from labial to velar (except for the Japanese uvular nasal [ɴ]).

1:2.6 and often 1:3.0.[30] Later, Han (1994) measured the durational contrast between /p, t, k/ and /pp, tt, kk/. She suggests that the duration of medial consonants may vary according to the presence of an initial consonant in the previous syllable. This indicates that temporal compensation works within the word. Sato (1992) measured the duration of nasals that occur between a vowel and a consonant, obtaining 58 – 62 ms for /-Nɑ-/ structures and 123 – 130 ms for /-NCV-/. Phonetically, not all morae have the same duration, a claim substantiated by a number of experiments (e.g., Sagisaka and Toukura 1984, and others). /N/ and /Q/ are generally regarded as having one mora, but their duration can in fact vary according to phonological environment. For example, Sato (1992) revealed that the duration of the mora nasal (/N/) in Japanese is not always the same, and that it is short when followed by a voiceless consonant, which has a relatively long duration, while it is long when followed by a voiced consonant, which has a relatively short duration, and that the duration of the moraic nasal depends on the length of the following consonants. Homma (1981:275) measured the Japanese short and long plosives /p:pp, b:bb, t:tt, d:dd, k:kk, g:gg/ and their VOT and closure part in a carrier sentence. The absolute durational contrasts were 77:183 ms (the ratio = 1:2.38), 55:159 ms (1:2.89), 62:170 ms (1:2.74), 35:144 ms (1:4.11), 61:175 ms (1:2.87), 41:134 ms (1:3.27) respectively. The VOT of the initial stops ranged from 14 ms to 61 ms and that of the medial stops from 0 ms to 28 ms (Homma (1981:276). Beckman (1982) reports that the mean duration of the Japanese short consonants was 89 ms when VOT was included and 64 ms when not, and that that of geminates was 195 ms when VOT was included and 171 ms when not. According to Beckman, the VOT of the Japanese plosives is 25 ms (89 - 64) for a short consonant and 24 ms (195 - 171). Shimizu (1989) compared the VOT of five languages. The durations of the Japanese VOT of plosives were /t/ (27 ms), /p/ (44 ms) and /k/ (68 ms) from shortest to longest (*N*: 27 for bilabials and alveolars, *N*: 45 for velars). Arai et al. (2001) measured the absolute durational differences between short and long consonants: /p:pp, t:tt, k:kk, s:ss, m:mm, n:nn/ in spontaneous speech (see Table 2.4). Their results show that the durational ratios of these six combinations were 1:1.77 and thus smaller than those in the other past studies. The durational and durational ratio contrasts and VOT of plosives will be compared with my results for /p, pp/ in Ch. 3.

Lehtonen's data (1970) seem to be reliable regarding the syllable structures and the number of subjects (n = 10). The mean durations of the Finnish short and long

[30] Because of these ratios, she proposed using [kkk] phonetically and /k:kk/ phonologically to represent the geminate. Since there seems to be no re-articulation during the occlusion of the plosive, Han's phonetic transcription is not correct.

consonants are quoted in Table 2.7. The overall mean durations for the 13 Finnish short consonants were 77 ms and 162.5 ms for 10 long consonants, making the durational ratio between singleton and geminates 1:2.11. Suomi (1980) compared Finnish word-initial, -medial and -final /p, t, k, pp, tt, kk/ and the English counterparts /p, t, k/. According to his results, the order of the duration of VOT was /p/ < /t/ < /k/ from the shortest to longest.

Comparing the durations between Finnish and Japanese short and long consonants /p:pp, t:tt, k:kk/ (see Table 2.4), the absolute values were mostly longer in Finnish than in Japanese. It must be, however, noted that Lehtonen (1970) and Homma's (1981) data was measured in read speech and Arai et al.'s (2001) in spontaneous speech, and that there are numerical differences between Homma's and Arai et al.'s data.

The consonants /p:pp, s:ss, m:mm/ will be compared with my results in Ch. 3.

Table 2.4 The mean durations of short and long Finnish and Japanese consonants.

	Finnish[1]		Japanese[2] (Homma 1981, Arai et al. 2001)	
	Short (ms)	Long (ms)	Short (ms)	Long (ms)
p/pp[3]	106	191	77 (H) 74(A)	183 (H) 140 (A)
t/tt	99	197	62 (H) 77 (A)	170 (H) 149 (A)
d/dd	55	168	35 (H)	144 (H)
k/kk	104	205	61 (H) 83 (A)	175 (H) 172 (A)
s/ss	93	190	106 (A)	114 (A)
m/mm	73	142	61 (A)	92 (A)
n/nn	59	134	53 (A)	114 (A)

1: from Lehtonen (1970). 2: from Homma (1981) = (H) and Arai et al. (2001) = (A).
3: plosives contain VOT.

Iivonen (1998:313) states that the ratio between single and double consonants C/CC seems to vary according to the major consonantal classes and might somehow be related to stress/accented signalisation.

2.3 Phonotactics

Since the Finnish syllable structure is more complicated than that of Japanese, the number of combinations of vowels and consonants within syllable and word frames in

Finnish is much larger than in Japanese. Phonologically, the languages are very different in other respects.

There are many words with the same sound segments, the meanings of which, however, are different in Japanese and Finnish. The greatest differences are in phonotactics. In Japanese one vowel phoneme can make one word. Four vowels out of five can be lexical on their own as follows.

/i/	‘stomach’
/ɯ/	‘cormorant’
/e/	‘picture’
/o/	‘tail’

There are no standard Finnish words with only one short vowel phoneme. One vowel- (monomoraic) words do not exist in Finnish, except for colloquial expressions, such as *ei ole* → *ei o* (‘is not’, 3rd sg. pres. neg.) or *en ole* → *e o* (‘not am’, 1st sg. pres. neg.). A Finnish word requires at least two phonemes, one of which must be a vowel. The examples of the shortest word structures thus are:

CV	*me*	/me/	(‘we’)	*he*	/he/	(‘they’)
VC	*en*	/en/	(‘not’, 1st sg.)	*on*	/on/	(‘is’),

Like Finnish, Japanese has CV and VC word structures that have the same segmental sequence:

CV	*me*	/me/	[me]	(‘eye’)	*he*	/he/	[he]	(‘fart’)
VC	*en*	/en/	[eɴ]	(‘yen’)	*on*	/on/	[oɴ]	(‘favour’),

Although there are no word structures with the two identical vowels in Finnish, i.e., V^1V^1, except for letter names and one place name (e.g., *Ii*), Japanese has

V^1V^1	*ii*	/ii/	[iː]	(‘good’)	*ee*	/ee/	[eː]	(‘yes’).

In Finnish, V^1V^2 is the shortest vowel sequence required to form a basic word.

V^1V^2	*yö*	[yø]	(‘night’)

Japanese has words of more than two morae.

aoi[31] /ɑoi/ [ɑ꜔oi] ('geranium') *ao+i* [32] [ɑ꜔o˥i] ('blue')
aioi /ɑioi/ [ɑ꜔ioi] ('two being born together and growing')

Apart from the discussion of whether Japanese may be mora-timed or syllable-timed, it is true that a large percentage of the morae or syllables of Japanese are so-called open-syllables in which the mora/syllable ends with a vowel. If there were closed syllables, they would always end with only one C: /N/ or /Q/. The Japanese morae number 100 and, if moraic consonants (Q and N) are added, it would be 102. If moraic consonants or a lengthened symbol R for a vowel are taken as syllable-final constituent, the number of syllable in Japanese would be more. On the other hand, there can be over 3,000 syllables in Finnish (Karlsson 1983).

2.3.1 Vowels

2.3.1.1 Double/long vowels

All five short vowels in Japanese have their long counterparts (V^1V^1). For comparison, words with the same segment but with length differentiation are listed.

[ɑ/ɑː]	*obasan*	[obɑsɑɴ]	('aunt')
	obaasan	[obɑːsɑɴ]	('grandmother')
[i/iː]	*ojisan*	[odʑisɑɴ]	('uncle')
	ojiisan	[odʑiːsɑɴ]	('grandfather')
[ɯ/ɯː]	*kuki*	[kɯ̥ki]	('stalk')
	kuuki	[kɯːki]	('air')
[e/eː]	*tema*	[temɑ]	('a lot of work')
	teema	[teːmɑ]	('theme')
[o/oː]	*sato*	[sɑto]	('home village')
	satoo	[sɑtoː]	('sugar')

[31] Its tonal structure is phonologically LHH where L represents the lower pitch and H the higher. I omitted the (phonological) tonal representation of H or L as much as possible in this study; instead I use the Japanese symbols to illustrate tonal accent rise/fall, but only where necessary.
[32] Its tonal structure is LHL.

In Finnish, all eight vowels have a short/long contrast (/V^1V^{1}/) as follows:[33]

[ɑ/ɑː]	*varat*	[ʋɑrɑt]	('funds')
	vaarat	[ʋɑːrɑt]	('danger', pl. nom.)
[i/iː]	*sika*	[sikɑ]	('pig')
	siika	[siːkɑ]	('whitefish')
[u/uː]	*puro*	[puro]	('brook')
	puuro	[puːro]	('porridge')
[e/eː]	*te*	[te]	('you', pl.)
	tee	[teː]	('tea')
[o/oː]	*polo*	[polo]	('poor')
	poolo	[poːlo]	('polo')
[æ/æː]	*värin*	[ʋærin]	('colour', gen.)
	väärin	[ʋæːrin]	('wrongly')
[ø/øː]	*mökki*	[møkːi]	('cottage')
	töötti	[tøːtːi]	('siren')
[y/yː]	*ryppy*	[rypːy]	('wrinkle')
	ryyppy	[ryːpːy]	('a drink')

2.3.1.2 The diphthongs – /V^1V^2/

The Japanese diphthongs[34] are probably limited to seven: /ɑi, ie, io, ɯe, ɯo, ei, oi/. Examples are:

/ɑi/	*kai*	[kɑi]	('seashell')
/ie/	*ie*	[ie]	('house')
/io/	*iori*	[ioɹi]	('hermitage')
/ɯe/	*ue*	[ɯe]	('above')
/ɯo/	*uo*	[ɯo]	('fish')
/ei/	*ei*	[ei]	('ray')

[33] Quoted from http://www.helsinki.fi/hum/hyfl/Finnish Phonetics (Iivonen, 2000).

[34] It should be noted that there is a mora boundary and sometimes an accent rise/fall within diphthongs in Japanese. For these reasons it is difficult to determine whether Japanese has (genuine) diphthongs.

/oi/ *k<u>oi</u>* [koi] ('carp').

Finnish does not have diphthongs /io, ue/ (because they are interpreted vowel sequences /i.o, u.e/), but the other five Japanese diphthongs have a cognate in Finnish. The 18 Finnish diphthongs are: /ɑi, ɑu, ie, iu, iy, ui, uo, ei, eu, ey, oi, ou, æi, æy, øi, øy, yi, yø/ (Karlsson, 1983:83). Four of these, /ɑu, iu, ui, ou/, are found in Japanese, but are interpreted as vowel sequences. Eight diphthongs, /iy, ey, æi, æy, øi, øy, yi, yø/, do not occur in Japanese.

2.3.1.3 The vowel sequences

In Japanese a vowel sequence with a maximum of four vowel phonemes is possible as listed in the above section. Since the Japanese *aoi* does not have a morphological boundary, there may be triphthongs in Japanese. A sequence of four identical vowels is exemplified as follows:[35]

T<u>oooo</u> /to|o.o|o/ ('Eastern Europe')
H<u>oooo</u> /ho|o.o|o/ ('Pope').

Finnish has 16 different vowel sequences at the border of the first and the second syllable (/ɑe, ɑo, eɑ, eo, iɑ, io, iæ, oɑ, oe, uɑ, ue, ye, yæ, æe, æø, øæ/) and even more, if other positions are taken into account (Karlsson, 1983:91-5). Of these, the Japanese have no cognate for /eo, iɑ, iæ, oɑ, uɑ, ye, yæ, æe, æø, øæ/, /eɑ/ being found only in a loanword in Japanese *kea* ('care').

2.3.2 Consonants

There are no consonant clusters in Japanese although there are consonant sequences, while in Finnish there are consonant clusters and consonant sequences. Consonant sequences occur with only two consecutive consonants (CC) in Japanese, while Finnish allows a maximum of four consecutive consonants (CCCC), except in loanwords. I shall discuss the relationship between consecutive consonants and consonant clusters in the following section 2.3.2.5. Japanese does not allow word-initial CC and neither does

[35] These examples were quoted from Akamatsu (1997).

Finnish, except for loan words. When CC is allowed in Japanese, it is only when /N/ and /Q/ are combined with another consonant. In addition, /N/ occurs word-finally and /Q/ can occur word-finally in emphatic expressions. They do not occur adjacently combined. The only consonant that occurs sentence-finally in Japanese is /N/. This means that most of the morae or syllables are open, ending with a vowel, and so does a sentence. The word-final occurrence of /Q/ is marginal and limited to emphatic expressions only. /N/ and /Q/ are termed a moraic nasal and moraic obstruent. The reason for using the term moraic consonants is that each segment has the same moraic length (V, CV). I shall discuss this relation to rhythmic issues in section 2.5.

2.3.2.1 Geminate consonants

In the literature, geminates, double consonants and long consonants are used to refer the same phenomenon.

It seems that there is no convincing theory differentiating gemination from quantity. One distinction is that the word 'geminate' traditionally usually denotes only consonants. In reviewing some definitions of 'geminate' suggested in the literature, many authors often seem to adopt more purely phonological criteria (Catford 1977, 1988, Crystal 1980, Katamba 1989, Ladefoged 1982). Of these, only Ladefoged refers to "vowel" geminates (1982:226).

Ladefoged (1982:226) says that geminate consonants in English can occur only across word boundaries[36] as in 'white tie', or in a word containing two morphemes as in 'unknown'. In contrast, Catford says "the term 'geminate' is not usually employed with reference to such English examples, where each of the two consonants belongs to a separate word…or to separate meaningful segments of a word, to separate morphemes" (1988:112).

The term 'geminate' can be defined as adjacent to or a sequence of identical segments that necessarily differentiate the linguistic meaning from the same singleton by its length at a word level. Estonian[37] and a handful of other languages have three

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[36] This type may be called 'junctural geminates'. (Cf. Lehiste et al., 1973.)

[37] Estonian has short (single), long (short geminate) and overlong (long geminate) consonants and vowels (Lehiste 1973:146). In this language, however, as has been pointed out by Lehiste (1970), the significant differences in quantity are not simply lexical, but are related to the structure of the word. Ladefoged & Maddieson (1996: 320) state that the only language that we know of that has persuasively been shown to use three degrees of length to contrast lexical items is Mixe (Hoogshagen 1959 in Ladefoged & Maddieson, 1996:320). Saami has to be added to this group (cf. Harrikarri 2000). Engstrand and Krull (1994) report that the duration contrasts are maintained more consistently by Finnish and Estonian than by Swedish speakers, and that

degrees of length that are differentiated semantically from each other. ‘Geminate’ means literally ‘twin’. From this reason, it may not be appropriate to apply the term geminate to these languages.

Concerning Finnish, Karlsson (1969) interprets the long vowels and consonants as phonologically a sequence of two identical phonemes. Similarly, Lehtonen (1970:26) states that “long quantity” is phonemised as a sequence of two identical segmental phonemes.

There is also a problem as to whether geminates are long consonants or double consonants. From an articulatory point of view, it has been debated whether a distinction should be drawn between long consonants and geminates in terms of production. The crucial point is that some phoneticians have maintained that long consonants should be distinguished from geminates because the production of the latter involves a rearticulation of the consonant, which would then consist of two phases (cf. Lehiste 1970 and 1973). Lehiste (1973:147) bases her claim that articulation of geminates is a language specific phenomenon for Estonian on her electromyographic observation.

In terms of rearticulation, some of the studies have focused on the acoustic (articulatory) properties of quantity (Sawashima & Miyazaki 1968, 1973 for Japanese, and Iivonen 1975, 1981 for Finnish). I have investigated the question by observing electropalatograph (EPG) data (Isei 1995), in order to observe whether rearticulation may occur in Japanese geminate consonants. EPG provides evidence as to whether the first part of Japanese geminates may be released partially or completely, and thus is relevant to the question of whether geminates are double consonants or long consonants. I was able to confirm that the Japanese geminate seems to be phonetically a long consonant and not a double consonant, except for one example out of 28. The decrease (in the case of plosives an affricates) or increase (in the case of fricatives) of the tongue contact with the alveolar ridge during the long consonant may however indicate a potentially “bi-segmental nature” (Catford 1977:210). As regards transcription, in this study I use the symbol [ː] for representing both a long consonant and vowel, and two identical symbols, e.g., /ɑɑ/ to show that it is a phonological description.

In Japanese ‘moraic’ nasals and ‘moraic’ obstruents must be considered separately. With regard to obstruents, it has been suggested that the first part of geminate stops and affricates is usually pronounced with a wide-open glottis (Sawashima & Miyazaki 1973,

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this is attributed to the unusually complex structure of the Finnish and Estonian quantity systems, and to the fact that Finnish and Estonia, in contrast to Swedish, do not use vowel quality or diphthongisations as correlates to quantity distinctions.

etc.). The same was confirmed in Finnish stops as well (Iivonen 1975).

Another approach was made in an attempt to gain some insight into the matter of the maintenance of phonation during the articulatory closure of stopped, fricative and affricate geminates in Japanese. A largyngographic (Lx) analysis of the geminates was carried out (Isei 1994), result confirming that the Lx waveform provided no evidence for the postulation of a glottal stop accompanying the first part of the consonant. However, in the waveforms, not only does the amplitude decrease but the valleys between the peaks are also relatively broad, which suggests breathy phonation, unlike impressionistic analysis by some phoneticians or linguists. Thus the results supported Sawashima & Miyazaki's (1973) direct observation of the glottis.

2.3.2.2 Japanese geminates

There are 14 Japanese geminates: [pː, tː, kː, k^{j}ː sː, ɕː, mː, m^{j}ː, nː, n^{j}ː, ŋː, p^{j}ː, tːs, tːɕ]. The voiced geminates could be added to this inventory but, because they occur only in loanwords, I have not considered them here. In this way we count 14 kinds of geminate consonant in Japanese.

The Japanese geminate consonantal segments (C^1C^1) are listed below. For comparison, the words with the same segment but the short length (singletons) are also given.

Plosives

[t]	[oto]	('sound')	[tː]	[otːo]	('husband')
[k]	[sɑkɑ]	('slope')	[kː]	[sɑkːɑ]	('writer')
[k^{j}]	[ik^{j}oː]	('gentile')	[k^{j}ː]	[ik^{j}ːoː]	('good fun')

The following two examples do not constitute members of minimal pairs.

[pː]	[hɑpːɑ]	('blast')
[p^{j}ː]	[ip^{j}ːoː]	('a vote')

Nasals

[m]	[sɑmɑ]	('appearance')	[mː]	[sɑmːɑ]	('(Pacific) saury')
[n]	[ɑnɑ]	('hole')	[nː]	[ɑnːɑ]	('that kind of')
[ŋ]	[hoŋki]	('earnest')	[ŋː]	[hoŋːi]	('core meaning')

[m^j] [m^{j}ɑkɯ] ('pulse') [m^{j}ː] [sɑm^{j}ːɑkɯ] ('mountains')
[n^j] [hɑn^{j}ɯː] ('place name') [n^{j}ː] [hɑn^{j}ːɯː] ('carrying in')

Fricatives
[s] [iso] ('beach') [sː] [isːo] ('rather')
[ɕ] [iɕi] ('medical doctor') [ɕː] [iɕːi] ('one child')

Affricates
[ts] [jɑtsɯ] ('guy') [tːs] [jɑtːsɯ] ('eight pieces')
[tɕ] [itɕi] ('location') [tːɕ] [itːɕi] ('agreement')

The example [dːʑ] in /bɑQdʑi/ ('badge') occurs only in loanwords from English, and will be excluded from the long consonants. The other consonants can occur only as long consonants in emphatic expressions, and thus will also be excluded from the inventory.

2.3.2.3 Finnish geminates

There are 11 possible Finnish geminates: [pː, tː, kː, sː, mː, nː, ŋː, rː, lː, (hː, ʋː)].[38]

Examples of the Finnish long consonantal segments are given below. The words with the similar segment but shorter length are also given for comparison.

Plosives
[p] [nupi] ('tack') [pː] [nupːi] ('button')
[t] [kɑto] ('dearth') [tː] [kɑtːo] ('roof')
[k] [kukɑ] ('who') [kː] [kukːɑ] ('flower')

Nasals
[m] [sɑmɑ] ('same') [mː] [homːɑ] ('job')
[n] [kɑnɑ] ('chicken') [nː] [kɑnːɑ] ('Kanna!' (= to carry, pres. imp.))
[ŋ] [helsiŋki] ('Helsinki') [ŋː] [helsiŋːin] ('of Helsinki')

[38] The geminates [hː, vː] are very marginal. Their example words are *hihhuli* 'holy roller' and *livvi* 'Aunus dialect'. They do not occur in minimal pairs but are phonetically and phonologically long consonants, which are contrastive with their short counterparts, [h, ʋ].

Fricatives

[s] [kisɑ] ('game') [sː] [kisːɑ] ('cat')

Liquids

[r] [ʋɑrɑs] ('thief') [rː] [ʋɑrːɑs] ('spit')

[l] [tuli] ('fire') [lː] [tulːi] ('customs')

2.3.2.4 Common geminates

Seven common geminate consonants are shared between Japanese and Finnish: three plosives [pː, tː, kː], one fricative [sː], and three nasals [mː, nː, ŋː], as listed in Table 2.5.

Table 2.5 The geminate consonants common to Japanese and Finnish.

Manner \ Place	Bilabial	Dental	Alveolar	Velar
Plosive	p	t		k
Fricative			s	
Nasal	m		n	ŋ

2.3.2.5 Consonant sequences and consonant clusters

Consonant sequences include a syllable boundary and consonant clusters belong to the same syllable. Finnish has at most four consecutive consonants (CCCC) and three consecutive consonants (CCC) for consonant clusters, e.g., *lomps.ka* 'wallet, coll.', but this case is very rare. In loanwords, consonant clusters occur not only word-initially but also syllable-finally. In general, Finnish has no more than three word-medial consecutive consonants (CCC), and two word-medial consonant clusters (CC), e.g., *pank.ki*, 'bank'. These are limited to: (1) the combinations of liquids /l, r/ + the geminates /pp, tt, kk, ss/ and (2) /n/ + /pp, tt, kk, ss, sk, st, ts, ps, ks/. The combinations /l, r/ + the geminates /pp, tt, kk, ss/ and /n/ + /pp, tt, kk, ss/ are difficult for the Japanese to perceive whether or not there is a geminate consonant after a liquid or a nasal consonant, and neither is it not easy to produce such consonant sequences, since there are no such phonotactical combinations or such long consonant sequences.

As stated earlier, producing geminate consonants is not difficult. Japanese may adopt vowel devoicing in such voiceless consonantal combinations as /sk, st, ts, ps, ks/ and produce /sVk, sVt, pVs, kVs/ where interconsonantal V gets devoiced as a phonological rule. Japanese has an affricate [ts].

2.4. Quantity and syllable structures

2.4.1 The unit of length

The mora is a unit of length. Traditionally, there are three kinds of morae in Japanese: V, CV, and C (Q, N). All these consist of one mora. The moraic consonant /Q/ represents part of an obstruent (voiceless) geminate consonant and /N/ part of a nasal geminate consonant[39]. /N/ is termed a moraic nasal and /Q/ a moraic obstruent. /N/ is represented as *n* in *roomaji*. /N/ and /Q/ are represented by only one *kana, respectively*. In *roomaji*, /Q/ is represented as the first part of two *roomaji* letters, e.g., *o<u>t</u>to* /oQto/ 'husband', (see the following explanation of /Q/ and in thus various *roomaji* letters). /N/ is pronounced as a uvular nasal [ɴ] in isolation. /Q/ does not have such a particular pronunciation in isolation. (See also Notes (3)). Thus /Q/ contains [s, ɕ, t, k, p, k^j, p^j, ts, tɕ] and may also contain a part of the voiced geminate consonants [d] of /beddo/ ('bed'), [g] of /bɑggɯ/ ('bag'), [dʑ] /bɑddʑi/ ('badge'), and [dz] /moddzɯ/ in loanwords, but such cases are marginal. Akamatsu (1997)[40] includes [ɸ, ɕ, h] as /Q/. However, these can appear only in emphatic expressions and, based on Akamatsu's interpretation, even the other consonants can be geminated in the same way.

Neither Q or N form monomoraic words. The following two examples show monomoraic words consisting of V or CV.

Monomoraic words
V <u>*i*</u> [i] ('stomach')
CV <u>*ki*</u> [ki] ('tree')

The Japanese mora has been interpreted as a phonological, linguistic, and

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[39] Except the one occurring word-finally.
[40] He calls it "moraic non-nasal" and counts /Q/ as 14: [p, p', b, t, d, k, g, k', g', ɸ, ɕ, s, h, c].

psychological unit (cf. Kubozono 1992, 1993 and many others). MaCawley (1978) claims that the mora serves as a temporal unit in accent assignment. Kubozono (1985, 1989) attempted to verify the Japanese mora unit by analysing speech errors.[41] I shall discuss the Japanese mora related to linguistic timing issues in Section 2.5.

2.4.2 Syllable weight

Using the terms of syllable weight or syllable quantity, Kubozono (1993) argues Japanese synchronic phonetic/phonological phenomena from the syllable structural point of view. These notions are explained as follows based on his theory.

(1) Light syllable (one mora)
V, CV E.g., *e* (‘picture’), *ki* (‘tree’)
(2) Heavy syllable (two morae)
V^1V^2 (V^2 = J),
V^1V^1(2^{nd} V^1 = R), VC, CVC (C = N, Q)
E.g., *ai* (‘love’), *kai* (‘shell’), *en* (‘yen’), *hon* (‘book’)
(3) Super-heavy syllable (three morae)
$V^1V^2V^3$, V^1V^1C (2^{nd} V^1 = R, C = N, Q), CV1V^2C (C = N, Q)
E.g., *aoi* (‘geranium’), *iin* (‘clinic’), *koin* (‘coin’)

This concept may be applicable to Finnish as well. Kubozono did not include V^1V^2 V^3.

2.4.3 Mora and syllable, syllable structure

‘Mora’ and ‘syllable’ are used to interpret rhythmic units and also for the timing concept. Otake et al. (1993) state that the rhythm of Japanese is based on a sub-syllabic unit, the mora. Shibatani (1999:159) states that both morae and syllables play an important role in the Japanese accentual system from a phonological point of view. Pitch change occurs at the mora level (except in some dialects) but not always in long

[41] Isei (1994) attempted to determine whether the phonological unit of Finnish could be a moraic or syllabic unit in speech errors in Finnish “Nihongo to Finrando go no bishiin no hikaku – rizumu to taimingu ni kansuru ichikoosatsu” [A study on rhythm and timing – a comparison of nasal consonants in Japanese and Finnish]. Presented at the 21st Annual Meeting of The Uralic Society of Japan.

segments.

There are other problems concerning the timing concepts of Japanese – is Japanese mora-timed or syllable-timed (e.g., Kubozono 1989 and others)? The presumption that Japanese can be syllable-timed is based on the premise that there is no morpheme boundary in a particular sequences of segments within a word, and these are (1) /Q, N/ combined with preceding mora (C)V to form (C)VC or (C)VN, and (2) /V/ combined with another preceding /(C)V/ to form (C)VV class. Class (2) includes diphthongs, V^1V^2, and long (or double) vowels V^1V^1. In V^1V^2, V^2 can be described as VJ in which J means the second part of a diphthong (Joo'o 1977). In V^1V^1, the second V^1 can be described as R, in which R means the second part of a double vowel (Joo'o 1977). Q and N occur only in the coda position. When a word contains Q, the word has at least three morae, except for (C)VQ structures such as interjections (e.g., /ɑQ/ ('Oh, dear me', etc.)) or emphatic expressions (e.g., /i|tɑ|Q/ from *itai* ('Ouch!')). Thus bimoraic words of the (C)VQ, (C)VN, (C)R pattern have the same number of morae as CVCV in the mora-counting concept, while these are counted as monosyllabic words in the syllable-counting concept. The following examples illustrate this claim:

(1) VC (C = N) <u>*en*</u> /e|N/ [eɴ] ('yen')
VC (C = Q) <u>*at*</u>. *to* /ɑ|Q/ + /*to*/ [ɑtːo] (state of surprise, *to*, adverbial particle))
<u>*ot*</u>.*to* /o|Q| to/ [otːo] ('husband')

(2) CVC (C = N) <u>*kin*</u> /ki|N/ [kiɴ] ('gold')
CVC (C = Q) <u>*kat*</u>.*to* /kɑ|Q/ + /*to*/ [kɑtːo] ('furious')
<u>*mot*</u>.*to* /mo|Q|to/ [motːo] ('more')

In this concept, the symbol /J/ (V^2) can be used for part of diphthongs, V^1V^2, and the symbol /R/ (V^1) for the second part of the same long vowel, V^1V^1.

Bimoraic words containing /J, R/ = monosyllabic words:

(3) VV (V1V2) <u>*ai*</u> /ɑ|J/ [ɑi] ('love')
(4) VV (V1V1) <u>*ii*</u> /i|R/ [iː] ('good')
(5) CVV (CV1V2) <u>*hai*</u> /hɑ|J/ [hɑi] ('ash')
(6) CVV (CV1V1) <u>*soo*</u> /so|R/ [soː] ('so', 'yes', 'no', etc.)

If the definition of a syllable requires that there be no syllable boundary in a sequence of segments within a word, the following combinations of segments form one syllable.

(7) CVVC (CVVN)[42] *boin* /bo|i|N/ [boiɴ] (‘vowel’)
CVVC (CVVQ)[43] <u>*koot*</u>*.ta* /ko|R|Q|tɑ/ [koːtːɑ] (‘froze’, v. pt.)

(8) VVC (RQ)[44] <u>*eet*</u>*.to* /e|R|Q|to/ [eːtːo] (‘let’s see’)

(9) CVCC (CVQN) *Lon* ・<u>*donk*</u> ・*ko* (‘Londoner’) /ɹo|N|do|N|Q|ko/
[ɹondoŋkːo]

In the consonant sequence CC, the combination of consonants is only N + Q. These syllable structures can be termed “super-syllable weight”.

The example word *Lon* ・<u>*donk*</u> ・*ko* is sometimes quoted as having a CVCC syllable structure. However, /ɹoNdoNQko/ is counted as having six morae. However, this is a loan word and can also be pronounced as [ɹondoŋko] /ɹoNdoNko/ (five-mora word). There are no Sino- or native Japanese words containing of the CVCC structure. Thus this marginal case allows us to exclude the possibility that the phonological interpretation of *Londonkko* might employ the -*kko*- /-Qko-/ (*ko* ‘-er’) of *Nyuuyookukko* [nʲɯːjoːkɯ̥kːo] (‘New Yorker’) and support the claim that a CVCC syllable structure can exist.[45]

Although the following example may exist, it can usually be omitted from consideration of Japanese syllable structures.

(10) VVV <u>*a|o|i*</u> (‘geranium’) [ɑoi]

It is not certain whether a word consisting of a sequence of four vowels like the following Japanese example word can form one syllable.

(11) VVVV <u>*a|i|o|i*</u> (‘place name’)[ɑioi]

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42 Trimoraic words = monosyllabic words.
43 Four moraic words = bisyllabic words
44 N. B. This syllable structure can occur only in emphatic expressions.
45 Takeuchi (1999:44) seems to agree to this.

Since I only can find one example of a VVVV syllable in Japanese, this would appear to be extremely marginal. This example word may also be comprised two VVs. Finnish has words with a sequence of four vowels:

ai.oin ('I aimed')
oi.oin ('I made straight')

Finnish, on the other hand, has 11 different syllable types, type (11) being rare.

(1)	CV	*ja*	('and')		
(2)	CVC	*kun*	('when')		
(3)	CVV	*suu*	('mouth')	*suo*	('moor')
(4)	CVVC	*puut*	('trees')	*noin*	('about')
(5)	VC	*on*	('is', 3rd. sing. Pre.)		
(6)	V	*i.kä*	('age')		
(7)	VV	*ei*	('no')		
(8)	VVC	*ään.tää*	('(to) pronounce')	*ais.ti*	('sense')
(9)	CVCC	*pank.ki*	('bank')		
(10)	VCC	*ank.ka*	('duck')		
(11)	CVCCC	*lomps.ka*	('wallet')		

Japanese is compared to Finnish because these two languages share quantity differences between vowels and consonants, which are linguistically distinctive, as a common feature. However, their speech rhythms have been claimed to be different. In these languages the syllable structures are different. In Japanese there are only three kinds of mora (V, CV, C), while it seems that there are 11 types of syllables in Finnish, although Karlsson (1983:139) describes ten.

Eleven kinds would seem to be a maximum with regard to Japanese syllable structure. However, two syllable structures (CVCC and VVVV) can at least be eliminated from the above mentioned types in Japanese, and probably VVV because of its tonal rise/fall between morae. The syllable structures common to both Finnish and Japanese (if the concept of syllable is adopted) would total eight at most:

(1) CV
(2) CVC
(3) CVV

(4) CVVC
(5) VC
(6) V
(7) VV
(8) VVC.

So far the discussion has shown that many syllable structures are common in both Finnish and Japanese. However, it is not phonetically guaranteed that the pronounced syllables in these combinations of segments are of approximately the same duration.

2.5 Quantity and timing

2.5.1 Timing and rhythm in relation to quantity

The linguistic rhythm and timing were explained by earlier non-experimental theories as a dichotomy: syllable- and mora-counting (Trubetzkoy 1969:177 [1939])[46] and syllable-timed and stress-timed rhythm (Pike 1945). Trubetzkoy[47] includes Japanese and Finnish in the mora-counting languages. Pike (1945) defines the mora as “a minimum unit of timing, usually comprising a short vowel or half a long vowel”. This trichotomy of types of rhythm, syllable-timed, stress-timed and mora-timed, has been traditionally a tripartite linguistic rhythmic concept. In addition, the foot-timing concept has been discussed in relation to these categorisations. It seems that there is no clear-cut difference between ‘rhythm’ and ‘timing’. These notions are mainly based on whether the isochronical timing unit of regular recurrence is mora (mora-timed), syllable (syllable-timed) or stress-group (stress-timed). This simple classification has since been challenged. (Dauer 1983, 1987, and others). Lehtonen (1970) considers foot-timing in Finnish, in which he uses the term ‘measure’. Nagano-Madsen (1992) reviews language rhythm in relation to mora and pitch. Barry and Andreeva (2001) quote newer rhythmic types.

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[46] He includes Japanese in the mora-counting languages (op. cit.: 8)

[47] He analyses the mora by categorizing it into five criteria, according to which Finnish is a mora-counting language because a long vowel contains a morpheme boundary, and Japanese because long vowels make a phonemic distinction between two types of accent. He attempted to classify languages depending on whether syllable nuclei can be interpreted in terms of an ‘arithmetic conception of quantity’.

Warner and Arai (2001) review the hypotheses, the means of testing them and the results of nearly 40 years of experimental work on mora-timing in Japanese. Their summary mentions a huge literature by linguists, phonologists and phoneticians, introducing the early non-experimental claim of mora-timing (e.g., Jinbo (1980 (1927)) in Warner and Arai (2001), and many others until recently) and so on. These authors have grouped the contributions into five categorisations, subdividing them as follows (the numeral shows the number of papers quoted in each group):

(1) The tendency toward the isochrony mora-timing hypothesis
  a. Durational ratios – 9,
  b. Tests of correlation between duration of adjacent segments – 13,
  c. The problem of correlation across mora boundaries - 7,
(2) Mora-timing at a higher level
  a. A new definition of mora-timing – 5,
  b. Further test of high-level mora-timing – 12,
(3) Cross-linguistic comparisons
  a. Looking for Japanese effects in stress- or syllable-timed languages – 6,
  b. Looking for English effects in Japanese - 5,
  c. Looking for mora-timing effects in other mora languages – 4,
(4) Alternative definitions of mora-timing
  a. Mora-timing as underlying isochrony - 10,
  b. The vowel centre of gravity model – 6,
  c. Articulatory definitions of mora timing – 4,
  d. Mora-rhythm rather than mora-timing – 23,
  e. Perceptual mora-timing – 3,
(5) Acquisition of timing patterns – 8

This review covers studies of mora-timing up to 2000. Han's *Japanese Phonology* (1962a) is to be added to this list. Auer's work (1989) does not include Japanese, but should be noted regarding the mora notion. Aoyama's work (2001) may be unique in belonging to groups (1)a., (3)c., and (5).

Warner and Arai (2001) thoroughly described mora timing and the problems in its studies, and show that mora hypotheses are necessarily related to the isochronity concept. They state that Japanese is still very often described as mora-timed, but evidence is increasing that the mora plays a structural role in Japanese and influences duration only indirectly, rather than being a temporal unit itself, and that the restricted syllable structure of Japanese, the statistical prevalence of light syllables over the few possible heavy syllables, prevent pitch accent affecting duration, variability in the number of syllables occurring between pitch accents, durational distinctions without concomitant quality differences. Even such abstract factors as the lack of allophonic alternations conditioned by pitch accent make relatively regular timing of morae more likely, but experimental work has yet to establish which of these factors actually do contribute to mora rhythm, and how.

Linguistic rhythm is an impressionistic phenomenon and does not always accord with acoustic experiments. There have been discussions on whether Finnish speech rhythm is mora-, syllable-, or stress-timed, or even foot-timed. Foot-timing in Japanese has been relatively well described phonologically. On the other hand, the arguments over timing issues in Japanese have been only about whether it is mora-timed or syllable-timed. The crucial problem is probably how to deal with long consonants containing moraic consonants (Q, N) and consecutive vowels V^1V^1 and V^1V^2 (diphthongs), particularly long vowels in Japanese. This problem is also relevant to Finnish, over which there has been argument about whether it is syllable-, stress-, foot - or mora-timed.

It appears that Japanese linguistic timing has been discussed in relation to quantity quite seldom, although it does not seem that there is a significant discrepancy between mora and quantity concepts. In Japanese, numerous studies on quantity have involved the Japanese mora hypothesis - isochronity. There have been discussions about whether Japanese timing is based on the mora or syllable in relation to quantity (e.g., Otake 1989, and others). Nagano-Madsen (1992) also reviewed the literature discussing mora, focusing on the relationship between the mora and prosodic features (see also Nagano-Madsen 1988, 1989a, 1989b, 1990a, 1990b). It is rare for Japanese linguistic timing to be discussed using the term quantity, though it does not seem that there is a great discrepancy between mora and quantity concepts. Finnish quantity studies, however, have seldom been discussed in terms of the mora hypotheses.

The basis of the stress-timed, syllable-timed, or mora-timed language is length based on isochronicity. Japanese is said to be a mora-timed or mora-counting language. This concept is based upon the notion that each mora of a (C)V or C (/Q/ and /N/) unit is a rhythmic unit and has a phonological function, and that each mora is approximately isochronal.

Thus the main problems in assessing the linguistic timing of these two languages may have been focused on (1) coordination between isochronity and syllables with different length recurring for Finnish and (2) treatment of the moraic consonants of C /Q, N/ or V /R, J/ for Japanese. Of course, if Japanese were a syllable-timed language, then it would have the same problem as Finnish, i.e., coordination between isochronity and syllables of different length.

2.5.2 Timing and rhythmic units

Lehtonen (1970:150-1) discusses the syllable/mora concepts and stress and mora, stating that a prosodic unit smaller than a measure (foot) is a syllable. He considers that CCVCV, CVV and CVC(C) are of equal value, each having two morae. He also claims that in a temporal analysis of Finnish, various larger and smaller units should be distinguished as well as the broader rhythm sequence, the speech measure or stress group, the measure, the sequence of two morae and the syllable.

Tajima (1998:15) states that in Japanese a wide variety of morphonological processes appear to prefer groups of two or four morae over groups of other numbers of morae. He reports that four-mora words were found to be most numerous (44%), followed by trimoraic words (27%) and that 82% of all four-mora words consisted of two bimoraic morphemes; this was 36% of the entire word list. His informal analysis was based on an outline word list of 34,086 nouns from a pronunciation dictionary of Japanese (NHK 1998). Poser (1990) claims that a bimoraic foot serves as a prosodic template for many word-formation processes. This can be taken into consideration as part of the Japanese timing unit – probably a measure or foot.

Such moraic consonants as /Q/ and /N/ may also exist in Finnish, assuming that the mora concept is applied to Finnish. However, these have never been treated as independent syllabic consonants. Although /Q/ and /N/ are independent as moraic consonants and phonologically counted as a moraic unit, /Q/ and /N/ are not independent linguistic units, unlike the other moraic units. For these reasons, it has been claimed that /Q/ or /N/ is combined with the other mora (V, CV) and that it contributes to a syllabic word, e.g., CVN *kan* ('insight') /kɑN/ [kɑɴ], CVQCV *motto* ('more') /moQto/ [motːo].

Such terms as mora, syllable, or foot are used to interpret linguistic timing units; for example, in the Japanese words *Nippon* /niQpoN/ ('Japan') [48] or /kookoo/ ('high school'), the bimoraic /niQ/, /poN/, /koo/ can be one syllable and one foot. These words can be counted as two feet. The mora can be considered to be a subdivision of a syllable.

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[48] Ladefoged (1982:226) describes it as [nippoŋ].

In this hierarchical concept, whether /niQ/ (CVC) or /poN/ (CVC) has two morae and is counted as one syllable is the crux of the argument concerning the Japanese rhythmic unit.

Researchers usually agree that adult Japanese speakers have acquired mora-counting unit based on the *kana* unit through education and their Finnish counterparts syllabification. The mora is thus a psychological unit in Japanese and the syllable is a psychological unit in Finnish. Linguistic rhythm can be based on such a unit, but linguistic timing may be based on more temporal control by such units as the mora, syllable, or measure. Thus linguistic rhythm may be different from linguistic timing.

Researchers usually agree that adult Japanese speakers have acquired a mora-counting unit based on the *kana* unit through education and their Finnish counterparts syllabification based on a syllable. Therefore, the mora is a psychological unit in Japanese and the syllable is a psychological unit in Finnish. Linguistic rhythm can be based on such a unit, but linguistic timing may be based rather on more temporal control by such units as the mora, syllable, or measure. Thus linguistic rhythm can be different from linguistic timing.

3 Production of lexical quantity

3.1 Introduction

In this chapter I shall investigate the similarities and differences of quantity in production between Finnish and Japanese in various word structures. (Isei-Jaakkola 2003c).

It seems that Aoyama (2001) was the first to compare Japanese and Finnish from the phonetic and psychophonetic point of view, although there were only two test words. Aoyama (2001) measured the durational differences between Finnish and Japanese /n/ and /nn/ using two words, *hana* and *hanna*, for both languages. In measuring these segments, she eliminated the word-initial /h/ and measured the relative durational values of *a-n-a* and *a-nn-a*. Her results showed that the durational distinction between /n/ and /nn/ was clearer in Finnish than in Japanese.

Finnish consonantal sequences can contain no more than four phonemes and there is much more variety in forming bisyllabic words: CV$\underline{C^1.C^1}$V (e.g., *katto* 'roof') or CV$\underline{C^1.C^2}$V (e.g., *kanta* 'base; viewpoint'), but also CV$\underline{C^1C^2.C^2}$V (e.g., *kanssa* 'with'), CV$\underline{C^1C^2.C^3}$V (e.g., *kansleri* 'Chancellor'), and CV$\underline{CCC.C}$V[49] (e.g., *lompska* 'wallet'). In terms of vowel sequence in forming bisyllabic words, Japanese can have four vowel sequences, e.g., C$\underline{V|V|V|V}$ *toooo* ('Eastern Europe'), as can Finnish; C$\underline{VVVV}$ tauoissa 'in pauses' from *tauko* 'pause; a rare case with two long vowels: *niiaa* ('curtsy', 3rd sing. pres.). Finnish can have meaningful bisyllabic words which represent eight different syllable structures as the combination of the phonologically short/long vowels and the short/long consonants – /CVCV, CVCVV, CVVCV, CVCCV, CVVCVV, CVCCVV, CVVCCV, CVVCCVV/. On the other hand, Japanese can have seven of these, i.e., excluding /CVVCCVV/. Japanese bisyllabic words can contain only intervocalic consonant sequences which have two segments at most: CV$\underline{C^1.C^1}$V (e.g., *motto* 'more') or CV$\underline{C^1.C^2}$V (e.g., *tanki* 'short term'). Table 3.1 shows examples of meaningful bisyllabic words in Finnish and Japanese that contain only the same intervocalic short/long consonants.

These eight kinds of word structure are counted as having two to five morae in the Japanese mora counting as in Table 3.2. Table 3.2 also shows how Japanese counts

[49] This structure is a rare case.

Table 3.1 Different syllable structures and bisyllabic meaningful words in Finnish and Japanese.

Syllable structure	Finnish meaningful words	Japanese meaningful words
CVCV	*kato* (‘crop failure’)	*kato* (‘process’)
CVCVV	*katoo* (‘disappears’, 3rd sing. pres.)	*katoo* (family name)
CVVCV	*kaato* (‘overturn’, n.)	*kaato* (‘cart’)
CVVCVV	*kaataa* (‘overturn’, v.)	*kootoo* (‘oral’)
CVCCV	*katto* (‘roof’)	*katto* (‘furious’, ‘cut’)
CVCCVV	*kattaa* (‘cover’, v.)	*kattoo* (‘conflict’)
CVVCCV	*kiitti* (‘thanked’, 3rd sing. pt.)	*kaatto* (‘very furious’)
CVVCCVV	*kiittää* (‘thank’, v.)	—

Table 3.2 Different syllable structures and number of morae in Japanese.

Syllable structure	Number of morae	Moraic Model
CVCV	2	100%
CVCVV	3	150%
CVVCV	3	150%
CVVCVV	3	150%
CVCCV	4	200%
CVCCVV	4	200%
CVVCCV	4	200%
CVVCCVV	5	250%

these syllable structures by mora (number of morae), and the increasing ratio (moraic model, hereafter 'Model') of each structured word when the bimoraic CVCV is 100%. The concept of this model is based on the Japanese mora hypothesis in which every mora is approximately isochronous and has nearly the same length.

Neither language has the words that have the combinations of exactly the same short/long vowels and consonants having eight different structures as in Table 3.1. Thus, in the experiments, I decided to use bisyllabic nonsense-words containing short /ɑ/ and long /ɑɑ/, and short /m, p, s/ and long /mm, pp, ss/, in which Finnish and Japanese both have a contrast between short and long segments. In terms of consonants, I chose one phoneme = /p/ for plosives, one = /m/ for nasals and one = /s/ for fricatives (see also Table 2.5) and /ɑ/ for vowels. The quality of the Japanese and Finnish vowel /ɑ/ is similar by vowel formant chart as illustrated in Figure 2.1 in Chaper 2.

In this chapter, the following language-specific questions were asked:

(1) Are there differences in the durational ratios between short and long segments?
(2) Are there differences in the segmental variations according to the environments?
(3) Are there differences in word durations dependent on syllable structures?
(4) Are there differences in word-durational ratios dependent on syllable structures?
(5) Are there differences in segmental distributional ratios within each syllable structure?

In the experiments, I measured each segmental duration, and then calculated segmental ratios, variations in segments, word durations, word-durational ratios, and segmental distributional ratios based on the measurements. These questions pertain to the relationship between syllable structures and its linearity (Warner and Arai, 2001) in terms of word duration. Since my main concern does not include the individual differences in this study, I do not describe them.

3.2 Experimental designs

3.2.1 Materials

Test words with eight different syllable structures and combinations of the vowel /ɑ/ and the consonants /m, p, s/ are shown in Table 3.3.

Table 3.3 Test words used for experiments.[50]

Syllable Structure	‘ma(a)m(m)a(a)’	‘pa(a)p(p)a(a)’	‘sa(a)s(s)a(a)’
CVCV	mama	papa	sasa
CVCVV	mamaa	papaa	sasaa
CVVCV	maama	paapa	saasa
CVVCVV	maamaa	paapaa	saasaa
CVCCV	mamma	pappa	sassa
CVCCVV	mammaa	pappaa	sassaa
CVVCCV	maamma	paappa	saassa
CVVCCVV	maammaa	paappaa	saassaa

These nonsense words[51] were embedded in a carrier sentence for each language.

Finnish: “*Sanokaa_____ kahdeksan kertaa*.” (‘Please say ___ eight times.’)
Japanese: “*Mooikkai _____ to itte kudasai*.” (‘Please say ___ once more.’)

The plosives /k/ (for Finnish) and /t/ (for Japanese) after the test word were chosen in order to facilitate finding the boundary between the word-final /ɑ/ and the plosive.

3.2.2 Informants

The informants were three Tokyo dialect speakers and three southern Häme dialect speakers, who are from Helsinki and its surrounding area. Speakers of each language had little or no knowledge of the other language. The test words, embedded in a carrier sentence, were read five times by the informants. The test words and carrier sentence were written according to the writing system of each language. Japanese test words

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50 I use single quotation marks ‘ ’ for nonsense words, not italics. And in graphs and charts, I do not use either of them.

51 For example, ‘pappa’ [pɑpːɑ] (‘old man, grandfather’) is a meaningful word in Finnish and ‘sasa’ [sɑ⌈sɑ] (‘bamboo grass’) in Japanese. However, in the experiments, I asked the informants to produce the test words without any meanings and they were successful in doing so.

were written only in *hiragana* so that the informants could concentrate exclusively on their sound. They did not follow the tonal patterns in the meaningful words. The informants of both languages were instructed to read at the natural speed of their own language.

3.2.3 Experimental methods

The recordings were made in the recording room of the Department of Phonetics at the University of Helsinki, using a DAT tape recorder and an AKG C420 microphone. The microphone was securely fixed so that the distance between the mouth and the microphone remained unchanged. The utterances were digitised as sound files using the speech analysis programme Praat. Spectrograms were used to measure the segmental and word durations.

The number of word tokens was 720 (8 syllable structures x 3 different consonantal patterns x 6 informants x 5 times) and that of segmental tokens was 2,880 (720 x 4 segments). Long segments for vowels and consonants had no internal segment boundary and were measured as one segment.

3.2.4 Segmentation

Segmentation was based on the spectrogram. The word-initial plosives occurred at the word boundary and the preceding phoneme was /ɑ/. I had to decide whether the beginning of plosive /p/ was a pause or the plosive closure part. When it was a pause, I could observe some noise on the spectrogram, which showed breathing. I regarded VOT as part of the plosives /p, pp/.[52] When it occurred intervocalically, /p, pp/ was preceded by and followed by /ɑ/. The same method as in the intervocalic plosive was thus basically applied to the word-initial plosive. The sounds /m, mm/ had a clear difference in formant movements on the spectrogram which made it easy to segment. /s/ has very high frequencies between approx. 8 kHz and 12 kHz which facilitates the segmentation. It must be noted that the beginning of increasing intensity and the end of decreasing intensity for a segmental sound do not always parallel the segmental boundary on the spectrogram, and that there is a time lag, the intensity increasing first prior to the spectrogram. The spectrogram was therefore the primary base from which to measure the durations.

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[52] My definition of VOT is based on Henton et al. (1992) and Cho & Ladefoged (1999).

3.3 Method of analysis

The overall mean values were obtained from the mean values, and each mean value from the mean value for three speakers and five repetitions in each language (see Appendices 3-5). Because there were 24 word structures (8 SS x 3 Cs), I did not consider all individual differences between the informants in both Finnish and Japanese in order to illustrate major differences and to achieve significant results. I used the mean values of the informants for both languages in all statistical analyses. In this chapter the 'range (*R*)' was ascertained from the difference between the minimum and maximum values within each category; for example, durational differences or durational ratios within the same segment, syllable structure, etc. 'Difference (D)' implies a simple difference between two values. In ANOVA, I considered only the differences among syllable structures, and between the two languages, since there are more than two factors to be compared.

3.4 Results and analysis

3.4.1 Segmental durational comparison

3.4.1.1 The vowels

Firstly, all the data on short /ɑ/ and long /ɑɑ/ was pooled together and calculated to obtain their mean values. Secondly, I compared the segmental durational difference between short /ɑ/ and long /ɑɑ/ according to each syllable structure.

The overall mean durations of short /ɑ/ and long /ɑɑ/ were listed in Table 3.4, which was translated into Figure 3.1. Table 3.4 shows the overall mean durations (ms) of /ɑ/ and /ɑɑ/ and durational differences (ms) between Finnish and Japanese. The ratios between /ɑ/ and /ɑɑ/, presented in Table 3.5, were calculated when /ɑ/ was 1.0 (100%) in each language separately. The short vowel /ɑ/ and a long vowel /ɑɑ/ are represented in the tables and figures as 'a' or 'aa'.

In both short (79.6 ms) and long (199.3 ms) Japanese vowel durations were longer than their Finnish counterparts (79.3 ms and 180.5 ms respectively). The ratios between /ɑ/ and /ɑɑ/ were 1:2.3 for Finnish and 1:2.5 for Japanese. The difference in the ratios between short and long vowels was longer (20%) in Japanese than in Finnish. The difference values were 0.3 ms for /ɑ/ and 18.8 ms for /ɑɑ/ between the two languages.

This may indicate that the intrinsic duration of Finnish /ɑ/ is very close to the Japanese counterpart, but that of Finnish /ɑɑ/ is shorter than that of its Japanese counterpart.

Table 3.4 Overall mean durational comparison and ratio comparison of /ɑ/ and /ɑɑ/ in Japanese and Finnish.

	Durational comparison (ms)		
	Japanese	Finnish	Difference (J. – F.)
a	79.6	79.3	0.3 (J. > F.)
aa	199.3	180.5	18.8 (J. > F.)

The short vowel /ɑ/ and a long vowel /ɑɑ/ are represented in the table as ‘a’ or ‘aa’.

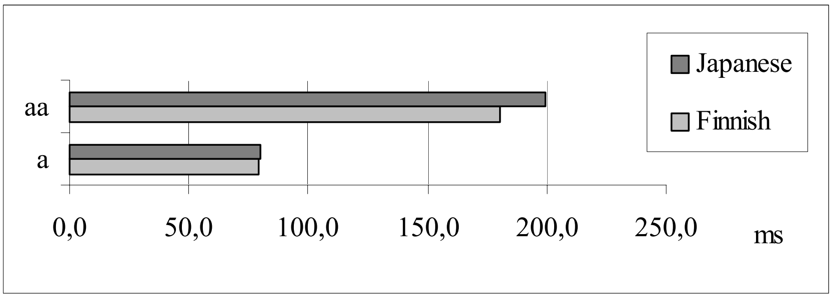


Figure 3.1 The durational comparisons between /ɑ/ and /ɑɑ/ in Japanese and Finnish.

Table 3.5 Ratio comparisons between /ɑ/ and /ɑɑ/ in Finnish and Japanese.

	Finnish	Japanese	Difference (J. – F.)
a:aa	1:2.3	1:2.5	-0.2 (F. < J.)

The following discussion regards the contextual, phonotactical aspects of quantity variation in more details.

The mean durations of interconsonantal (/m, p, s/) /ɑ/ occurring in the first syllable (= ‘a1’) and /ɑ/ in the second syllable (= ‘a2’) preceded by and followed by /m, p, s/ in Finnish and Japanese depending on different syllable structures (word structures) are shown in Table 3.6 and Table 3.7 respectively. D stands for the difference between Finnish and Japanese values of ‘a1’. *SD* stands for standard deviation. The numerical values were translated into Figure 3.2. Figure 3.2 shows the amount of the ranges (*R*) depending on the position within the word.

Table 3.6 The mean durational comparisons of ‘a1’.

Syllable structure	Word structure	F. ‘a1’ (ms)	J. ‘a1’ (ms)	D ‘a1’ (ms) (F. − J.)
CVCV	mama	88.8	81.1	7.7
CVCVV	mamaa	91.0	90.0	1.1
CVCCV	mamma	97.2	75.4	21.8
CVCCVV	mammaa	109.3	121.8	-12.5
CVCV	papa	83.0	63.4	19.6
CVCVV	papaa	78.9	66.3	12.6
CVCCV	pappa	81.7	80.7	1.1
CVCCVV	pappaa	75.4	87.5	-12.1
CVCV	sasa	91.0	70.7	20.3
CVCVV	sasaa	84.6	78.7	5.9
CVCCV	sassa	92.6	100.5	-7.9
CVCCVV	sassaa	90.8	101.5	-10.6
—	**Mean**	**88.7**	**84.8**	**3.9**
—	***R***	**33.9**	**58.4**	**34.3**
—	***SD***	**9.0**	**16.7**	**12.9**

The term ‘a1’ = /ɑ/ occurring in the first syllable and in different syllable structures.

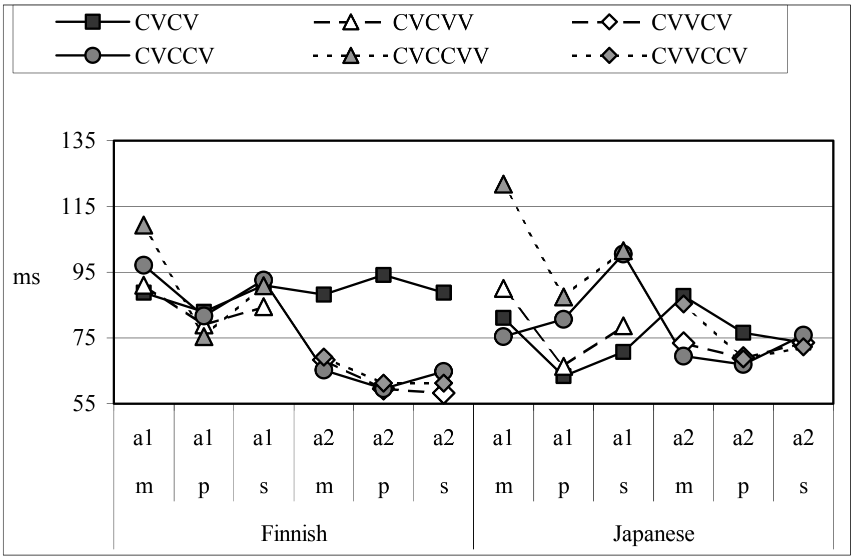
Table 3.7 The mean durational comparisons of ‘a2’.

(ms)

Syllable structure	Word structure	F. ‘a2’ (ms)	J. ‘a2’ (ms)	D ‘a2’ (ms (F. – J.)
CVCV	mama	88.2	87.7	0.5
CVVCV	maama	68.3	73.5	-5.2
CVCCV	mamma	65.3	69.5	-4.3
CVVCCV	maamma	69.2	85.3	-16.1
CVCV	papa	94.2	76.6	17.6
CVVCV	paapa	59.5	68.9	-9.3
CVCCV	pappa	59.6	66.9	-7.3
CVVCCV	paappa	61.2	68.6	-7.3
CVCV	sasa	88.7	73.6	15.1
CVVCV	saasa	58.2	73.6	-15.4
CVCCV	sassa	64.8	75.8	-11.0
CVVCCV	saassa	61.2	72.4	-11.2
—	**Mean**	**69.9**	**74.4**	**-4.5**
—	***R***	**36.0**	**20.8**	**33.7**
—	***SD***	**12.9**	**6.4**	**10.8**

The term ‘a2’ = /ɑ/ occurring in the second syllable and in different syllable structures.

The overall mean duration of ‘a1’ was longer (D = 3.9 ms) in Finnish (88.7ms) than in Japanese (84.8 ms), but that of ‘a2’ was longer (D = 4.5 ms) in Japanese (74.4 ms) than in Finnish (69.9 ms): (J. ‘a1’ < F. ‘a1’, F. ‘a2’ < J. ‘a2’). According to Lehtonen’s data (1970:64, 71) using bisyllabic nonsense words for Finnish, /ɑ/ was 79 ms of the pVppVV in the first syllable (= ‘a1’) and 48 ms in the second syllable (= ‘a2’) of pVVpV. Lehtonen used only one type of consonant (/p, pp/) and two kinds of syllable structure. In my study, I used three kinds of consonant and four types of syllable structure for each ‘a1’ and ‘a2’. All data was pooled and the overall mean durations obtained. My results showed that the Finnish ‘a1’ was quite close to Lehtonen’s ‘a1’ but not in ‘a2’. However, comparing ‘a1’ and ‘a2’ in my pV(V)p(p)V(V) to Lehtonen’s, the durational difference between the ‘a1’ and ‘a2’ in my data is relatively closer to each other, except for pVpV. The duration of the Finnish ‘a1’ and ‘a2’ in CVCV is nearly stable regardless of the consonantal difference and syllable structure. The overall mean



'a1' = /ɑ/ in the first syllable; 'a2' = /ɑ/ in the second syllable. The four left lines show the 'a1' and 'a2' for Finnish and the right for Japanese, each movement of which represents the durational difference in 'a1' and 'a2' depending on its position in different syllable structures. Within each language, the three left represent the durational difference of 'a1' and the right of 'a2', depending on consonantal environment.

Figure 3.2 The durational comparisons between Japanese and Finnish /ɑ/ depending on syllable structure.

durations of 'a1' in Japanese 'mammaa' was the longest (121.8 ms) of all the short vowels /ɑ/. The Japanese 'a1' seems to be more affected by consonantal differences in the first syllable position than in the second syllable position.

The range (*R*), i.e., the difference between the maximum and minimum value between the shortest 'a1' and longest 'a1' was 33.9 ms in Finnish and 58.4 ms in Japanese. Japanese had a higher *R* in 'a1'. The *SD* in the first and second syllable for Finnish was the reverse of that in Japanese: (F. 'a1'< J. 'a1', F. 'a2' > J. 'a2').

The absolute durations of the short vowel /ɑ/ in the first syllable were longer but *SD* was smaller in Finnish (*SD* 9.0 ms) than in Japanese (*SD* 16.7 ms), while those in the second syllable were shorter but *SD* was higher in Finnish (12.9 ms) than in Japanese (6.4 ms). One exception for Finnish was /ɑ/ in CVCV, in which the durations of /ɑ/ were very stable in any environment. These results indicate that Finnish is affected by the environmental consonants and syllable structures more than Japanese. Japanese short vowels had more variation in the first syllable than in the second, although the absolute durations and the *SD* were approx. 10 ms.

The mean durations of /ɑɑ/ occurring in the first syllable (= 'aa1') and /ɑɑ/ in the second syllable (= 'aa2') in Finnish and Japanese depending on surrounding consonants /m, p, s, mm, pp, ss/ are shown in Table 3.8 and Table 3.9 respectively. The values were translated into Figure 3.3. The overall mean durations of both 'aa1' and 'aa2' were longer in Japanese ('aa1' = 211 ms, 'aa2' = 187.6 ms) than in Finnish ('aa1' = 186.3 ms, 'aa2' = 174.8 ms). According to Lehtonen's data (1970:64, 71), /ɑɑ/ was 180 ms in the first syllable of pVVpV and 142 ms in the second syllable pVppVV. My result for the 'aa1' value was closer to his data, but that for 'aa2' was longer than his. As we saw in the short vowel /ɑ/, this durational difference may be because of the consonantal and structural differences.

The *R* between the two languages was markedly higher in Japanese 'aa2' (24.7 ms) than in Finnish 'aa2' (12.8 ms). The overall difference between 'aa1' and 'aa2' was higher in Japanese (23.4 ms) than in the Finnish 'aa2' (11.5 ms). The variation of 'aa1' within each language was great in Japanese (58.1 ms) than Finnish (44.8 ms), but 'aa2' was the reverse: Finnish 38.7 ms > Japanese 23.9 ms. We can also observe from Figure 3.3 that the durational pattern in the Finnish 'aa1' and 'aa2' are quite stable within each syllable position regardless of the type of consonant, but that of the Japanese counterparts are more affected by not only the consonantal differences but also by the structural differences. This indicates that with regard to /ɑɑ/, the degree of durational compensation may be higher in Japanese than in Finnish because the consonantal duration varies dependent on their types as we shall see in the later sections.

There was a tendency for /CVVCCVV/ structures to have relatively higher values in the variation than the other word structures between Japanese and Finnish. The *SD* for Japanese /ɑɑ/ was higher than in Finnish in both 'aa1' and 'aa2'.

Difference (D) variations

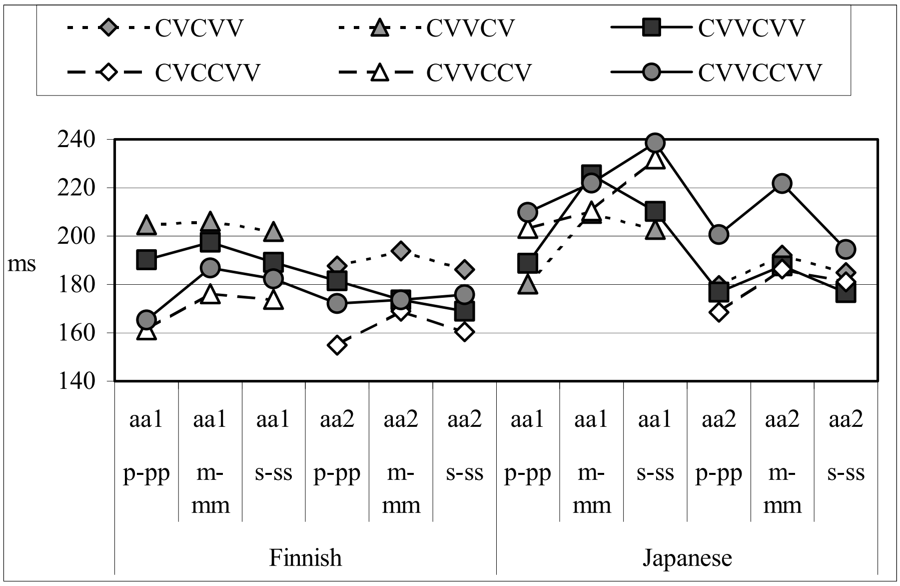
Below I compare the durational differences of D values depending on the syllable structures and consonants.

The difference in the durations of /ɑ/ varied depending on word structure and the preceding and following consonants. The durational difference (D) values are shown in Tables 3.10 and 3.11 respectively. These tables were translated into Figures 3.4. The values in Tables 3.10 and 3.11 were obtained from the durational difference (D) within each syllable structure and each syllable position. In both 'a1' and 'a2', the *R* values of the differences within the language tended to be higher in Finnish than in Japanese. The

Japanese /ɑ/ in ‘mamma’ had the greatest difference range of all (56.86 ms). On the other hand, the minimum difference range was in Japanese ‘saassa’ (2.73 ms). As a result, the *R* values were more stable in Finnish but mostly larger than in Japanese in both ‘a1’ and ‘a2’.

The difference in the durations of /ɑɑ/ varied depending on word structure and the preceding and following consonants as shown in Tables 3.12 and 3.13 respectively. These tables were translated into Figure 3.5. Concerning the varied durations of /ɑɑ/, Finnish had higher values in both ‘aa1’ and ‘aa2’. Finnish ‘aa1’ (74.18 ms) was slightly higher than that of Japanese (3.22 ms). Finnish ‘aa2’ (70.1 ms) was much higher than that of Japanese (19.78 ms), indicating that individual variation was greater in Finnish than Japanese for /ɑɑ/, regardless of whether it occurred in the first syllable or the second. It varied particularly according to its position between Finnish and Japanese.

To summarise, in all cases the variations between ‘a1’ and ‘a2’ and ‘aa1’ and ‘aa2’ largely depended on word structure and on the preceding and following consonants.



‘aa1’ = /ɑɑ/ in the first syllable and ‘aa2’ = /ɑɑ/ in the second syllable. The left four lines show the ‘aa1’ and ‘aa2’ for Finnish and the right for Japanese, each movement of which represents the durational difference of ‘aa1’ and ‘aa2’ depending on its position in different syllable structures. Within each language, the three on the left represent the durational difference of ‘aa1’ and the right ‘aa2’, depending on consonantal environment.

Figure 3.3 The durational comparisons between Japanese and Finnish /ɑɑ/ depending on syllable structure.

Table 3.8 The mean durational comparisons of 'aa1'.

Syllable structure	Word structure	F. 'aa1' (ms)	J. 'aa1' (ms)	D 'aa1' (ms) (F. − J.)
CVVCV	maama	206.1	209.4	-3.3
CVVCVV	maamaa	197.5	225.3	-27.8
CVVCCV	maamma	176.1	210.4	-34.3
CVVCCVV	maammaa	186.8	221.9	-35.1
CVVCV	paapa	204.7	180.3	24.4
CVVCVV	paapaa	190.1	188.7	1.5
CVVCCV	paappa	161.3	203.2	-41.9
CVVCCVV	paappaa	165.2	209.7	-44.4
CVVCV	saasa	202.0	202.7	-0.7
CVVCVV	saasaa	189.2	210.3	-21.0
CVVCCV	saassa	173.8	231.9	-58.1
CVVCCVV	saassaa	182.4	238.4	-56.1
—	**Mean**	**186.3**	**211.0**	**-24.7**
—	***R***	**44.8**	**58.1**	**82.5**
—	***SD***	**15.0**	**16.7**	**25.5**

Table 3.9 The mean durational comparisons of 'aa2'.

Syllable Structure	Word structure	F. 'aa2' (ms)	J. 'aa2' (ms)	D 'aa2' (ms) (F – J)
CVCVV	mamaa	193.7	192.2	1.6
CVVCVV	maamaa	173.5	187.7	-14.2
CVCCVV	mammaa	168.9	186.3	-17.4
CVVCCVV	maammaa	173.6	221.8	-48.2
CVCVV	papaa	187.7	179.5	8.2
CVVCVV	paapaa	181.4	176.8	4.6
CVCCVV	pappaa	155.0	168.6	-13.6
CVVCCVV	paappaa	172.2	200.6	-28.4
CVCVV	sasaa	186.1	185.0	1.1
CVVCVV	saasaa	169.0	176.7	-7.7
CVCCVV	sassaa	160.5	181.1	-20.6
CVVCCVV	saassaa	175.7	194.5	-18.8
—	**Mean**	**174.8**	**187.6**	**-12.8**
—	***R***	**38.7**	**53.2**	**56.4**
—	***SD***	**11.2**	**13.9**	**15.9**

Table 3.10 The durational comparisons of D in 'a1'.

Syllable structure	Word structure	F. (ms)	J. (ms)	D. (ms) (F. – J.)
CVCV	mama	20.72	30.59	-9.86
CVCVV	mamaa	21.23	14.15	7.07
CVCCV	mamma	19.44	59.91	-40.47
CVCCVV	mammaa	19.90	3.05	16.85
CVCV	papa	18.23	11.82	6.42
CVCVV	papaa	16.89	7.96	8.93
CVCCV	pappa	33.87	10.90	22.97
CVCCVV	pappaa	27.30	7.96	19.34
CVCV	sasa	25.07	5.75	19.32
CVCVV	sasaa	19.94	8.97	10.97
CVCCV	sassa	14.24	30.68	-16.45
CVCCVV	sassaa	16.50	28.82	-12.32
–	**Mean**	**21.11**	**18.38**	**2.73**
–	***R***	**19.7**	**56.8**	**63.5**
–	***SD***	**5.4**	**16.4**	**18.9**

Table 3.11 The durational comparisons of D in 'a2'.

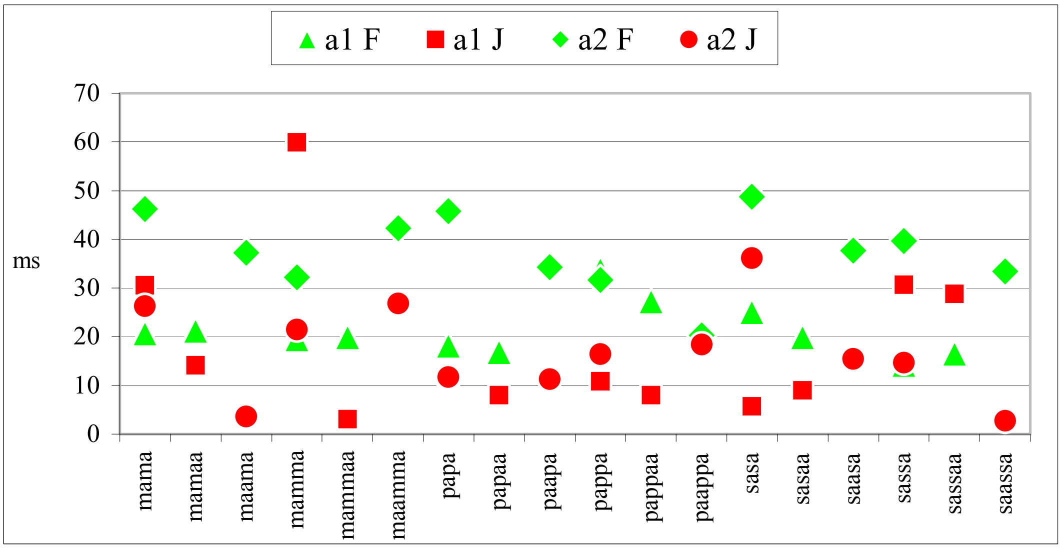
Syllable structure	Word structure	F. (ms)	J. (ms)	D. (ms) (F. – J.)
CVCV	mama	46.2	26.3	19.9
CVVCV	maama	37.2	3.6	33.6
CVCCV	mamma	32.2	21.5	10.7
CVVCCV	maamma	42.3	26.9	15.5
CVCV	papa	45.8	11.7	34.1
CVVCV	paapa	34.3	11.3	23.0
CVCCV	pappa	31.6	16.4	15.2
CVVCCV	paappa	20.2	18.4	1.8
CVCV	sasa	48.7	36.1	12.6
CVVCV	saasa	37.6	15.5	22.2
CVCCV	sassa	39.6	14.6	25.0
CVVCCV	saassa	33.5	2.7	30.7
—	**Mean**	**37.4**	**17.1**	**20.4**
—	***R***	**28.5**	**33.4**	**32.3**
—	***SD***	**7.9**	**9.6**	**9.8**

Table 3.12 The durational comparisons of D in 'aa1'.

Syllable structure	Word structure	F. (ms)	J. (ms)	D (ms) (F. – J.)
CVVCV	maama	84.0	54.4	29.6
CVVCVV	maamaa	88.2	96.8	-8.7
CVVCCV	maamma	17.0	39.4	-22.4
CVVCCVV	maammaa	18.0	25.9	-7.9
CVVCV	paapa	31.6	45.9	-14.3
CVVCVV	paapaa	42.1	57.4	-15.3
CVVCCV	paappa	27.9	45.8	-17.9
CVVCCVV	paappaa	45.0	32.0	13.0
CVVCV	saasa	59.1	52.9	6.1
CVVCVV	saasaa	55.3	70.7	-15.4
CVVCCV	saassa	14.0	47.6	-33.6
CVVCCVV	saassaa	19.0	52.4	-33.4
—	**Mean**	**41.8**	**51.8**	**-10.0**
—	***R***	**74.2**	**70.9**	**63.2**
—	***SD***	**25.6**	**18.4**	**18.5**

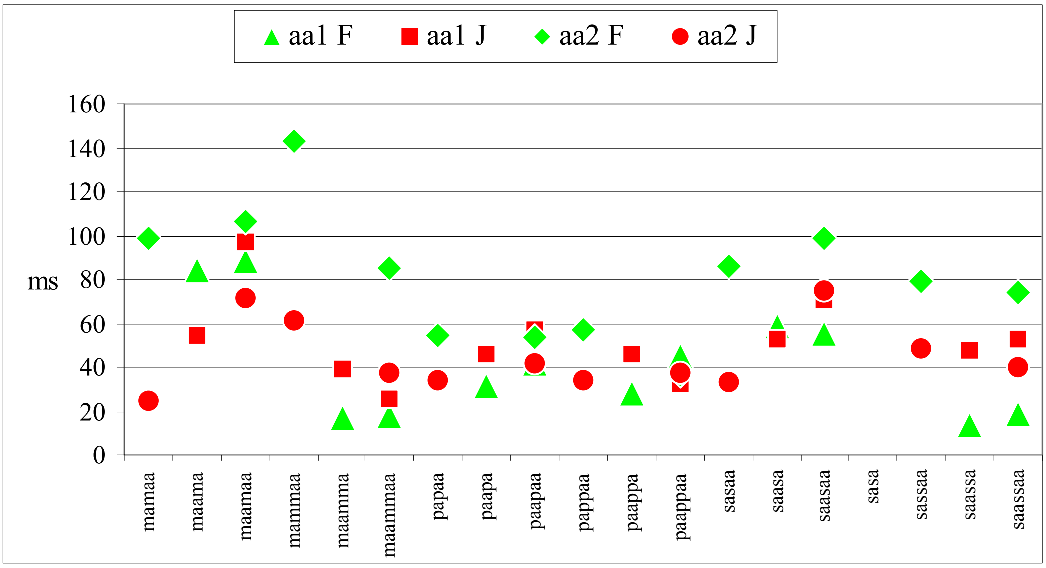
Table 3.13 The durational comparisons of D in 'aa2'.

Syllable structure	Word structure	F. (ms)	J. (ms)	D. (ms) (F. – J.)
CVCVV	mamaa	99.0	24.7	74.3
CVVCVV	maamaa	106.5	71.4	35.1
CVCCVV	mammaa	142.8	60.9	81.9
CVVCCVV	maammaa	85.3	37.4	47.9
CVCVV	papaa	54.6	34.2	20.4
CVVCVV	paapaa	53.6	41.6	12.1
CVCCVV	pappaa	57.3	34.2	23.1
CVVCCVV	paappaa	36.4	37.2	-0.8
CVCVV	sasaa	85.7	33.4	52.4
CVVCVV	saasaa	98.5	75.0	23.5
CVCCVV	sassaa	78.9	48.6	30.3
CVVCCVV	saassaa	74.4	40.4	34.1
—	**Mean**	**81.1**	**44.9**	**36.2**
—	***R***	**106.5**	**46.7**	**82.7**
—	***SD***	**28.9**	**16.0**	**24.3**



F = Finnish, J = Japanese.

Figure 3.4 The durational comparisons of between ‘a1’ and ‘a2’, depending on word structure.



F = Finnish, J = Japanese.

Figure 3.5 *R* durational comparisons between ‘aa1’ and ‘aa2’, depending on word structure.

3.4.1.2 The consonants

Firstly, all the data on /m, p, s/ and /mm, pp, ss/ were pooled together from word-medial positions and calculated to obtain the mean values. Secondly, I compared the durational difference of the short consonants /m, p, s/ and their long counterparts /mm, pp, ss/ depending on each word structure.

The overall mean duration of the consonants /m, p, s/ and /mm, pp, ss/, and their variations in Japanese and Finnish are listed in Table 3.14, the short and long consonants having already been compared in Figure 3.6. In Table 3.15, the mean ratios show the ratio differences between short and long consonants. The first word takes the ratio one as a basis for calculation.

The mean durational values of all word-medial consonants were higher in Japanese than in Finnish. The ratios between word-medial /p, m, s/ and their long counterparts /pp, mm, ss/ were 1:1.99 (F.) < 1:2.33 (J.), 1:1.99 (F.) < 1:2.14 (J.), and 1:2.03 (F.) > 1:1.95 (J.). respectively, indicating that Finnish /ss/ was longer than Japanese /ss/ but Japanese /pp, ss/ were longer than their Finnish counterparts.

The ratio differences of all short/long consonants between these two languages were varied depending on consonant but were negligible in short consonants. The greatest differences between the two languages were /mm/ (24.1 ms: F. < J.) and /pp/ (18.1 ms: F. < J.), their ratio differences being 34% and 15% respectively. However, the ratio difference of /mm/ was higher in Finnish (8%) than the Japanese counterparts.

Table 3.14 The overall mean durational comparisons of word-medial short and long consonants between Japanese and Finnish.

	Durational Comparisons		
Word-medial	Finnish (ms)	Japanese (ms)	Difference (F. – J.) (ms)
m	69.1	69.2	-0.2 (F. < J.)
mm	137.3	161.4	-24.1 (F. < J.)
p	94.4	96.4	-2.0 (F. < J.)
pp	188.3	206.4	-18.1 (F. < J.)
s	82.8	88.5	-5.7 (F. < J.)
ss	168.2	172.4	-4.2 (F. < J.)

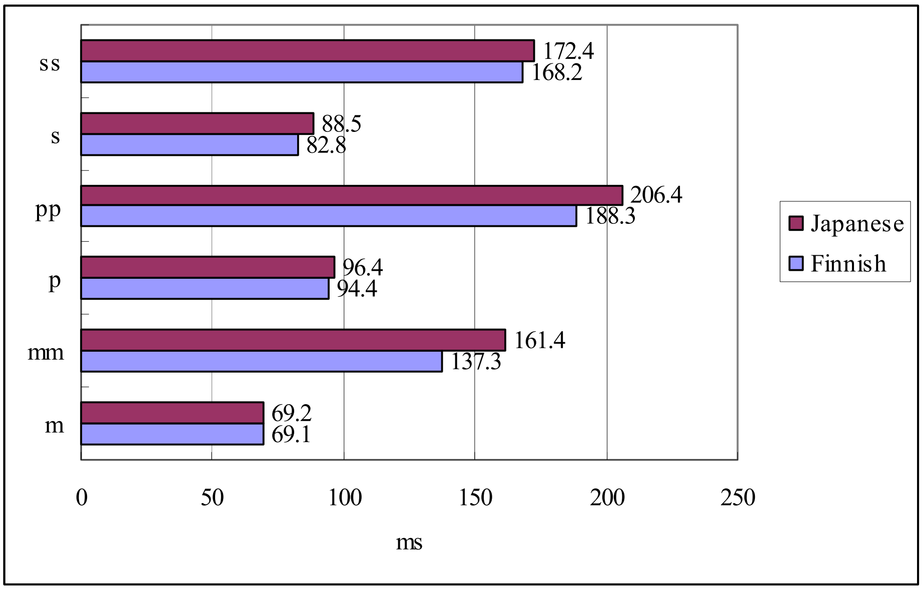


Figure 3.6 The overall mean durational comparisons of the word-medial consonants /m, p, s/ and /mm, pp, ss/ in Japanese and Finnish.

Table 3.15 The overall mean ratio comparison of word-medial short and long consonants.

	Durational ratio comparisons		
	Finnish	Japanese	Difference (F. – J.)
m:mm	1:1.99	1:2.14	0.34 (J. > F.)
p:pp	1:1.99	1:2.33	0.15 (J. > F.)
s:ss	1:2.03	1:1.95	-0.08 (J. < F.)

The next analysis was to compare segmental durations and variations of each short/long consonants, whether or not it varied depending on word structure. Table 3.16 shows the mean durations of /p/ and /pp/ and their differences in Japanese and Finnish. Word-initial /p/ occurs in every word structure but word-medial /p/ and /pp/ occur in only four syllable structures. Word-initial /p/ contains the closure part which falls between the word-boundary and the preceding vowel. The abbreviation ‘p1’ means word-initial /p/, ‘p2’ word-medial /p/, and /pp/ word-medial /pp/. The segmental durations in Table 3.16 were translated into Figure 3.7.

The overall comparative ratios between ‘p2’ and pp were 1:2.23 in Finnish and 1:2.3 in Japanese. The Japanese closure part in these comparative ratios was slightly longer (7%) than the Finnish counterpart. Table 3.16 shows that there was a tendency for the closure part of Japanese word-initial /p/ to be longer than Finnish. In particular, in ‘paappa’, this was much longer than that of its Finnish counterpart. The closure part of the Japanese word-initial /p/ in ‘paappa’ was relatively longer than all other counterparts in both Finnish and Japanese. In addition, the mean durations of the closure part of the word-medial Japanese /p/ and /pp/ were longer than their Finnish counterparts except for that of the Finnish word-medial /p/ in ‘papa’.

The variation of the closure part between the word-initial /p/ and word-medial /pp/ became larger with the following syllable structures: ‘pappa’ < ‘pappaa’ < ‘paappa’, except for ‘paappaa’. It is also noticeable that, as Figure 3.7 shows, there was only a slight difference between the closure part of Finnish word-medial /pp/ and the closure part of Japanese word-medial /p/ in ‘paappa’. Neither was there any significant difference between the Japanese word-initial /p/ (145.4 ms) in ‘paappa’ and the Finnish word-medial /pp/ (149.8 ms) in ‘paappa’.

A plosive comprises a closure part and VOT (= voice onset time). VOT varied depending on language. Table 3.17 shows the mean duration of VOT in /p/ and /pp/ and the durational differences between Japanese and Finnish. The mean durations of VOT in Table 3.17 were translated into Figure 3.8.

The overall mean values between the Finnish VOT (12.7 ms) of word-initial /p/ were nearly the same as the Japanese counterpart (13.0 ms). The overall mean values between the Finnish VOT of word-initial /pp/ (12.4 ms) were also approximately the same as their Japanese counterpart (12.3 ms). However, the overall mean values between the Finnish VOT of word-medial /p/ (15.5 ms) were longer than their Japanese counterpart (11.9 ms). This was true in three structures: ‘paapa’, ‘papaa’, and ‘paapaa’ as against their Japanese counterparts, while the VOT in the other syllable structures looked nearly alike between the languages.

The durations of /p/ and /pp/ were obtained by adding the closure part and VOT. Table 3.18 shows the mean duration in /p/ and /pp/ and the durational differences between Japanese and Finnish. The mean durations in /p/ and /pp/ were translated into Figure 3.9.

The mean durations of the Finnish word-initial /p/ and word-medial /pp/ are shorter than their Japanese counterparts when their closure part and VOT are added, while the length contrast between short /p/ and long /pp/ is very clear in both languages, the value of Finnish long /pp/ (163 ms) in ‘paappa’ is very close to the Japanese word-initial /p/

(157.7 ms). This was mainly because the closure part of the Japanese word-initial /p/ in 'pappaa' was relatively longer than the others, rather than because of the differences in VOT between the languages.

Concerning /m/ and /mm/, Table 3.19 shows their mean duration and their difference values (ms) for Japanese and Finnish. The mean durations of /m/ and /mm/ were translated into Figure 3.10. The overall duration of the Japanese 'm1' was slightly longer than the Finnish counterpart, but the Japanese 'm2' (69.2 ms) was the same as Finnish 'm2' (69.1 ms). However. Finnish mm (137.3 ms) was much shorter than the Japanese mm (161.4 ms). The word-initial /m/ ('m1') was much longer (85.6 ms for F an 90.4 ms for J.) than word-medial /m/ ('m2') (69.1 ms for F. 69.2 ms for J.) in both Japanese and Finnish. The differences were more than 15 ms in both languages. The ratios between word-medial /m/ and the corresponding /mm/ were 1:99 for Finnish and 1:2.33 for Japanese, indicating that the relative duration of Japanese /mm/ is much longer than that of Finnish.

In all of the variations of 'm1', 'm2' and mm Finnish ('m1' = 10.5 ms, 'm2' = 19.2 ms, mm = 28.7 ms) had lower values than Japanese ('m1' = 24.0 ms, 'm2' = 25.8 ms, mm = 54.7 ms).

With regard to the relationship between segmental durations and word structure, the values of Finnish /mm/ and Japanese /mm/ were quite close to the values of Japanese 'm1' in 'mamma', and Finnish /mm/ was also very close to Finnish 'm1' and Japanese 'm1' in 'maamma' compared to the other word structures, as Figure 3.10 shows. The durations of J. /mm/ in 'mammaa', 'maamma', and 'maammaa', except for 'mamma' were consistently higher than their Finnish counterparts. The durational ratios of the Finnish long /mm/ compared to its single /m/ are much shorter than the other cases, /pp/ and /ss/, and the same can be said when comparing the Japanese ratios between short and long segments that were tested here. It should be noted that the 'maammaa' structure word does not exist in Japanese, but the Japanese informants could clearly differentiate /mm/ from /m/ in duration.

Table 3.16 The mean durational comparisons of the closure part of ‘p1’, ‘p2’ and ‘pp’.

	Closure part of p and pp								
	‘p1’ (ms)			‘p2’ (ms)			‘pp’ (ms)		
	F.	J.	D (F. – J.)	F.	J.	D (F. – J.)	F.	J.	D (F. – J.)
papa	94.2	88.2	6	72.9	59.4	13.5	–	–	–
paapa	100.7	111.9	-11.2	64.6	75.1	-10.5	–	–	–
papaa	95.5	98.8	-3.3	91	91.4	-0.4	–	–	–
paapaa	105.5	110.8	-5.3	87.1	111.8	-24.7	–	–	–
pappa	103.7	102.1	1.7	–	–	–	180	180.5	-0.5
pappaa	101.9	114.2	-12.2	–	–	–	199.8	213.6	-13.7
paappa	109.5	145.4	-35.9	–	–	–	149.8	175.9	-26.1
paappaa	114.4	134.3	-19.9	–	–	–	173.8	206.6	-32.7
Mean	**103.2**	**113.2**	**-10**	**78.9**	**84.4**	**-5.5**	**175.9**	**194.2**	**-18.3**
R	**20.2**	**57.2**	**41.9**	**26.4**	**52.4**	**38.2**	**50**	**37.7**	**32.2**
SD	**6.75**	**18.69**	**13.28**	**12.3**	**22.44**	**16.13**	**20.6**	**18.73**	**14.21**

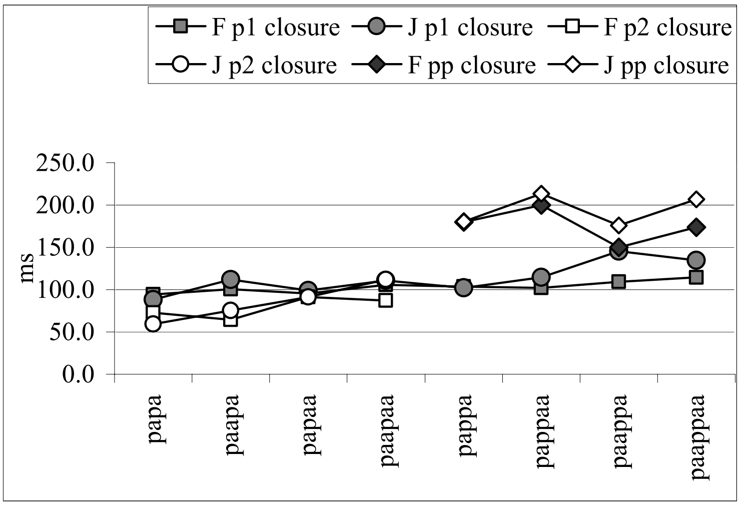


Figure 3.7 The mean durational comparisons of the closure part of ‘p1’, ‘p2’ and ‘pp’.

Table 3.17 The mean durational comparisons of VOT in 'p1', 'p2' and 'pp'.

	VOT								
	'p1' (ms)			'p2' (ms)			'pp' (ms)		
	F.	J.	D (F. – J.)	F.	J.	D (F. – J.)	F.	J.	D (F. – J.)
papa	12.6	14.0	-1.4	14.0	12.3	1.7	–	–	–
paapa	12.6	12.1	0.5	16.8	11.8	5.1	–	–	–
papaa	12.7	13.4	-0.7	15.0	11.0	4.0	–	–	–
paapaa	14.4	12.9	1.5	16.1	12.4	3.7	–	–	–
pappa	12.3	12.5	-0.2	–	–	–	11.7	12.1	-0.5
pappaa	11.8	14.6	-2.8	–	–	–	12.0	11.9	0.1
paappa	12.6	12.3	0.3	–	–	–	13.5	13.7	-0.2
paappaa	12.7	12.4	0.3	–	–	–	12.6	11.4	1.2
Mean	**12.7**	**13.0**	**-0.3**	**15.5**	**11.9**	**3.6**	**12.4**	**12.3**	**0.2**
R	**2.6**	**2.5**	**4.3**	**2.8**	**1.4**	**3.4**	**1.8**	**2.3**	**1.7**
SD	**0.7**	**0.9**	**1.3**	**1.2**	**0.6**	**1.4**	**0.8**	**1.0**	**0.7**

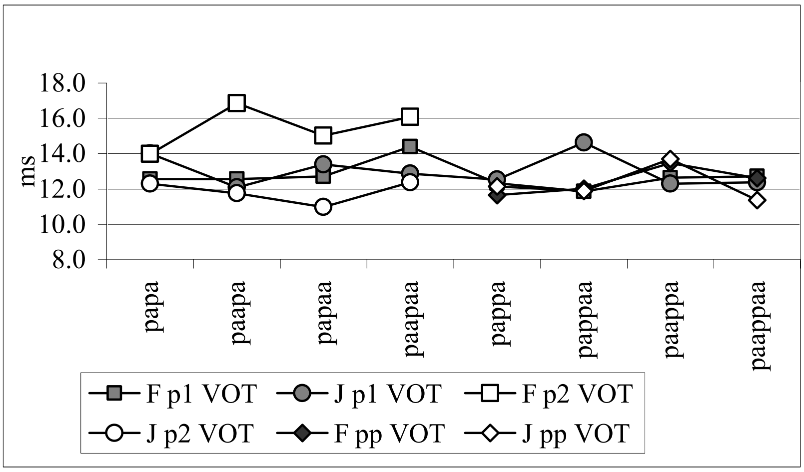


Figure 3.8 The mean durational comparisons of VOT in 'p1', 'p2' and 'pp'.

Table 3.18 The mean durational comparisons of the closure part + VOT in ‘p1’, ‘p2’ and ‘pp’.

	Closure + VOT								
	‘p1’ (ms)			‘p2’ (ms)			‘pp’ (ms)		
	F.	J.	D (F. – J.)	F.	J.	D (F. – J.)	F.	J.	D (F. – J.)
papa	106.8	102.2	4.6	86.9	71.7	15.2	–	–	–
paapa	113.2	124.0	-10.7	81.4	87.5	-6.0	–	–	–
papaa	108.2	112.1	-4.0	106.0	102.3	3.7	–	–	–
paapaa	119.9	123.7	-3.7	103.2	124.2	-21.0	–	–	–
pappa	116.1	114.6	1.5	–	–	–	191.6	192.7	-1.0
pappaa	113.8	128.8	-15.0	–	–	–	211.9	225.5	-13.6
paappa	122.2	157.7	-35.5	–	–	–	163.3	189.6	-26.4
paappaa	127.1	146.7	-19.6	–	–	–	186.5	218.0	-31.5
Mean	**115.9**	**126.2**	**-10.3**	**94.4**	**96.4**	**-2.0**	**188.3**	**206.4**	**-18.1**
R	**20.3**	**55.5**	**40.1**	**24.6**	**52.5**	**36.2**	**48.6**	**35.9**	**25.4**
SD	**6.9**	**18.3**	**13.0**	**12.1**	**22.3**	**15.3**	**20.0**	**18.0**	**13.7**

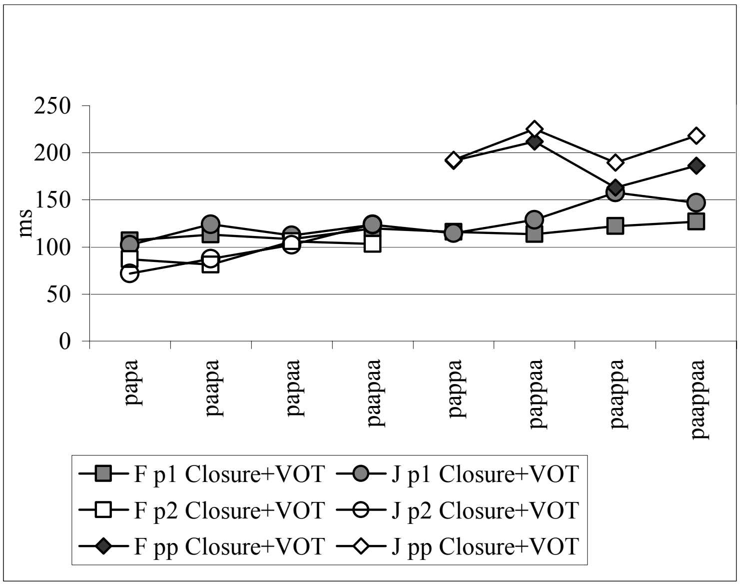


Figure 3.9 The mean durational comparisons of the closure part + VOT in ‘p1’, ‘p2’ and ‘pp’.

Table 3.19 The mean durational comparisons of 'm1', 'm2' and 'mm'.

	'm1' (ms)			'm2' (ms)			mm (ms)		
	F.	J.	D (F. – J.)	F.	J.	D (F. – J.)	F.	J.	D (F. – J.)
mama	84.0	79.9	3.9	60.2	58.1	2.1	—	—	—
mamaa	84.9	75.8	9.1	69.9	66.4	3.6	—	—	—
maama	86.2	88.2	-2	66.8	68.5	-1.7	—	—	—
maamaa	83	90.8	-7.8	79.4	84	-4.6	—	—	—
mamma	81.8	99.8	-18	—	—	—	130	122	7.1
mammaa	81	93.3	-12.3	—	—	—	155	177	-22
maamma	92.3	96.2	-3.9	—	—	—	126	171	-45
maammaa	91.6	98.8	-7.2	—	—	—	139	175	-36
Mean	**85.6**	**90.4**	**-4.8**	**69.1**	**69.2**	**-0.2**	**137.3**	**161.4**	**-24.1**
R	**10.5**	**24.0**	**27.2**	**19.2**	**25.8**	**6.6**	**28.7**	**54.7**	**52.2**
SD	**4.3**	**8.7**	**8.6**	**8.0**	**10.8**	**3.7**	**12.8**	**26.1**	**22.8**

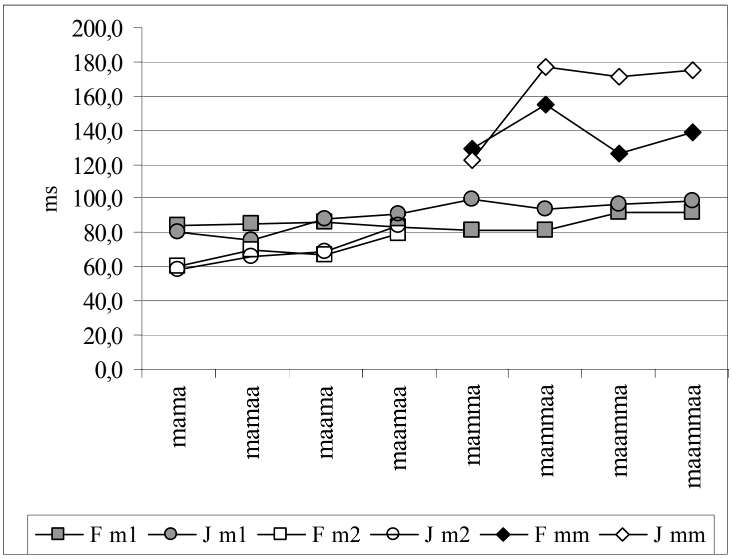


Figure 3.10 The mean durational comparisons of 'm1', 'm2' and 'mm'.

Table 3.20 shows the different range comparison of /m/ and /mm/ in Japanese and Finnish. The durational comparisons in Table 3.20 were translated into Figure 3.11. The difference ranges of /m/ were quite stable in both languages, and those of Japanese /mm/ were also stable. However, the difference ranges of Finnish /mm/ varied, largely depending on word structure. It was longest in ‘mammaa’ and shortest in ‘maammaa’. Concerning /s/ and /ss/, Table 3.21 shows the overall mean duration of /s/ and /ss/ and the durational differences (ms) between Japanese and Finnish. The mean durations of /s/ and /ss/ were translated into Figure 3.12. The overall durations of the Japanese ‘s1’, ‘s2’ and ss were slightly longer than the Finnish counterparts. The word-initial /s/ (‘s1’) was much longer (100.1 ms for F, 104.9 ms for J.) than word-medial /s/ (‘s2’) (82.8 ms for F and 88.5 ms for J.) in both Japanese and Finnish. The differences were more than 12 ms in both languages. The ratios between word-medial /s/ and the corresponding /ss/ were 1:2.03 for Finnish and 1:1.948 for Japanese, indicating that the relative mean duration of Finnish word-medial /ss/ is slightly longer than that of Japanese. The differentiations between /s/ and /ss/ show similar patterns according to word structure in both languages.

With regard to the relationship between segmental duration and word structure, the values of F ‘s1’ and J. ’s1’ were quite close to the values of F /ss/ and J. /ss/ in ‘saassa’, compared to the other word structures, as Figure 3.12 shows. The word structure ‘saassaa’ does not exist in Japanese, but the Japanese informants could clearly differentiate /ss/ from /s/ in duration, as in the case of ‘maammaa’.

Table 3.22 shows the variation value comparison of word-initial and -medial /s/ and word-medial /ss/ in Japanese and Finnish. The *R* durations of /s/ and /ss/ were translated into Figure 3.13.

The difference ranges of both /s/ and /ss/ varied, largely depending on word structure in each language. In particular, Finnish /ss/ had very high values in the difference range, compared to the other word structures. This suggests a greater variation between Finnish speakers in terms of producing /ss/ than Japanese speakers.

Table 3.20 Range (*R*) durational comparisons of ‘m1’, ‘m2’ and ‘mm’.

	‘m1’ (ms)			‘m2’ (ms)			mm (ms)		
	F.	J.	D (F. – J.)	F.	J.	D (F. – J.)	F.	J.	D (F. – J.)
mama	15.9	9.8	6.1	10.6	6.5	4.1	—	—	—
mamaa	9.1	13.6	-4.5	17.8	9.5	8.3	—	—	—
maama	14.0	10.7	3.3	11.0	9.4	1.6	—	—	—
maamaa	14.8	11.9	2.9	13.3	24.1	-10.9	—	—	—
mamma	9.9	17.7	-7.8	—	—	—	81.9	54.7	27.2
mammaa	15.9	27.8	-11.9	—	—	—	92.1	54.6	37.5
maamma	15.8	13.7	2.1	—	—	—	74.7	62.8	11.9
maammaa	17.3	7.9	9.4	—	—	—	42.2	54.7	-12.5
Mean	**14.1**	**14.1**	**-0.1**	**13.2**	**12.4**	**0.8**	**72.7**	**56.7**	**16.0**
R	**8.2**	**19.9**	**-21.3**	**7.2**	**17.6**	**19.1**	**49.9**	**8.2**	**50.0**
SD	**3.0**	**6.3**	**7.3**	**3.3**	**7.9**	**8.3**	**21.6**	**4.1**	**21.7**

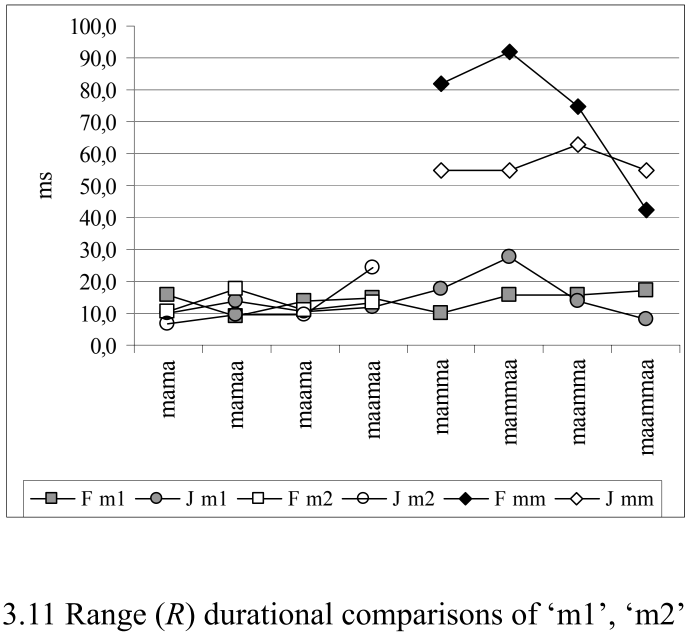


Figure 3.11 Range (*R*) durational comparisons of ‘m1’, ‘m2’ and ‘mm’.

Table 3.21 The mean durational comparisons of ‘s1’, ‘s2’ and ‘ss’.

	‘s1’ (ms)			‘s2’ (ms)			ss (ms)		
	F.	J.	D (F. – J.)	F.	J.	D (F. – J.)	F.	J.	D (F. – J.)
sasa	97.5	87.1	10.4	73.8	71.3	2.6	—	—	—
sasaa	89.8	94.5	-4.7	93.5	96.4	-3.0	—	—	—
saasa	98.8	109.5	-10.8	70.5	82.3	-11.8	—	—	—
saasaa	101.4	110.6	-9.1	93.3	104.0	-10.7	—	—	—
sassa	95.3	99	-3.7	—	—	—	159.9	153.4	6.4
sassaa	94.3	93.8	0.5	—	—	—	191.2	200.7	-9.5
saassa	113.6	124	-10.4	—	—	—	152.5	155.5	-3
saassaa	110.5	120.6	-10	—	—	—	169.4	180.0	-10.6
Mean	**100.1**	**104.9**	**-4.7**	**82.8**	**88.5**	**-5.7**	**168.2**	**172.4**	**-4.2**
R	**23.8**	**36.9**	**21.2**	**23**	**32.7**	**14.4**	**38.7**	**47.3**	**17.0**
SD	**8.1**	**13.4**	**7.3**	**12.3**	**14.6**	**6.8**	**16.8**	**22.4**	**7.8**

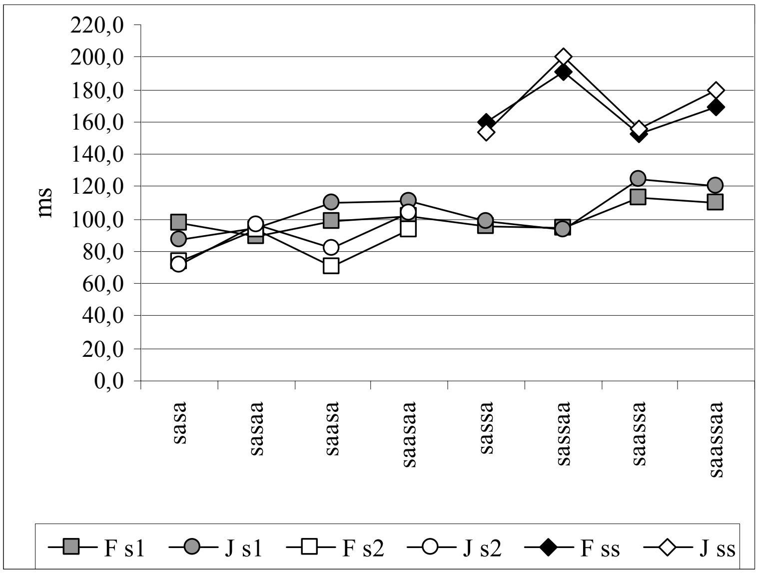


Figure 3.12 The mean durational comparisons of ‘s1’, ‘s2’ and ‘ss’.

Table 3.22 Range (*R*) durational comparisons of 's1', 's2' and 'ss'.

	's1' (ms)			's2' (ms)			ss (ms)		
	F.	J.	D (F. – J.)	F.	J.	D (F. – J.)	F.	J.	D (F. – J.)
sasa	30.9	29.6	1.3	45.4	17.8	27.5	—	—	—
sasaa	26.2	32.7	-6.6	34.3	14.9	19.5	—	—	—
saasa	33.9	17.1	16.8	30.7	15.0	15.7	—	—	—
saasaa	27.7	28.2	-0.6	32.5	20.6	11.9	—	—	—
sassa	35.0	18.8	16.3	—	—	—	61.9	28.2	33.7
sassaa	22.0	32.3	-10.3	—	—	—	64.8	50.2	14.6
saassa	20.1	3.6	16.5	—	—	—	60.9	40.7	20.1
saassaa	22.8	12.4	10.4	—	—	—	51.0	6.9	44.1
Mean	**27.3**	**21.9**	**5.5**	**35.7**	**17.1**	**18.6**	**59.6**	**31.5**	**28.1**
R	**14.9**	**29.1**	**27.1**	**14.7**	**5.8**	**15.6**	**13.8**	**43.2**	**29.5**
SD	**5.6**	**10.6**	**11.0**	**6.6**	**2.7**	**6.7**	**6.0**	**18.7**	**13.3**

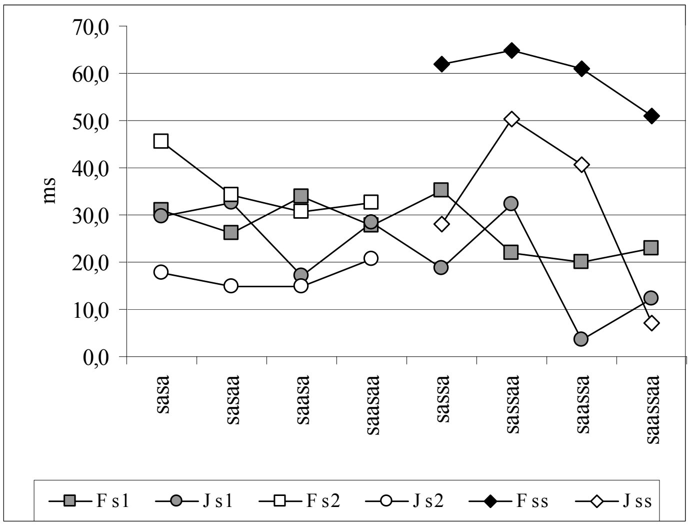


Figure 3.13 Range (*R*) durational comparisons of 's1', 's2' and 'ss'.

3.4.1.3 Significance of the measurement results

A two-factor analysis of variance of the segmental durations between Finnish and Japanese, which included the tests inquiring into the differences between the syllable structures (SS) and languages for vowels and consonants (see Appendix 6), was conducted. The factors were different syllable structures and different languages. The mean absolute values for other differences were used for vowels and consonants (see Tables 3.8, 3.9, 3,12, 3,13, 3,18, 3.19, 3.21). The results are listed in Table 3.23. The number of data (*N*) differs from segment to segment because of their positions within a word. The 'a1', 'a2', 'aa1', and 'aa2' structures are surrounded by three kinds of consonant: /m, mm, p, pp, s, ss/ under four different syllable structures respectively. Therefore, the number of *N* became 12 (3 x 4 = 12). The two languages were compared and the total number of data compared for ANOVA became 24 (12 x 2 = 24). On the other hand, the word-initial consonants: 'm1', 'p1', and 's1' occur in all eight word structures (8 x 2 languages = 16), but the word-medial consonants: 'm2', 'p2', 's2', 'mm', 'pp' and 'ss' in four structures (4 x 2 languages = 8). Each variable is the overall mean value of 15 mean values since three speakers repeated the test word five times in both Finnish and Japanese respectively.

Significant differences were found in the following cases:

In the syllable structures,

V 'a1' ($p = 0.03$*, F: 3.38)
C 'm2' ($p = 0.01$*, F: 25.40),
'ss1' ($p = 0.004$**, F: 8.14),
's2' ($p = 0.03$*, F: 14.86),
'ss' ($p = 0.01$*, F: 24.76).

In the language difference,

V 'aa1' ($p = 0.006$**, F: 11.31),
'aa2' ($p = 0.02$*, F: 1.51).

The vowels thus showed greater significance more than the consonants.

Table 3.23 The results of ANOVA in different syllable structures and languages.

			Conditions		Languages	
			p	*F*	*p*	*F*
V/C		*N*	SS	SS	F/J	F/J
V	'a1'	24	0.03*	3.38	0.32	1.10
	'a2'	24	0.07	2.58	0.18	2.09
	'aa1'	24	0.83	0.56	0.006**	11.31
	'aa2'	24	0.25	1.51	0.02*	7.74
C	'm1'	16	0.30	1.51	0.16	2.46
	'm2'	8	0.01*	25.40	0.94	0.01
	'mm'	8	0.26	2.25	0.13	4.45
	'p1'	16	0.06	3.49	0.06	5.01
	'p2'	8	0.12	4.48	0.81	0.07
	'pp'	8	0.08	6.72	0.08	7.03
	's1'	16	0.004**	8.14	0.07	4.29
	's2'	8	0.03*	14.86	0.19	2.85
	'ss'	8	0.01*	24.76	0.36	1.14

*: p<0.05, **: p<0.01. V = vowels, C = consonants.

3.4.2 Durational ratio distribution

3.4.2.1 'ma(a)m(m)a(a)'

Each mean duration and comparative ratio of each structured word 'ma(a)m(m)a(a)' in Finnish and Japanese is listed in Table 3.24. The mean durations of each structured word 'ma(a)m(m)a(a)' in Finnish and Japanese are translated into Figure 3.14 and comparative ratios of each structured word in Figure 3.15. The comparative ratios from 'mama' to 'maammaa' in Finnish and Japanese, which were obtained from the values in Table 3.24, were listed in Table 3.25. The 'moraic model' shows increasing ratios according to each structure word based on the Japanese mora concept. In each language the word 'mama' is ascribed the ratio one as a basis for calculation.

As the tables and figures show, lexical durational increase was steeper in Japanese and very close to the model based on mora counting, except for ‘maama’. In Finnish lexical durational ratios, the increase was less steep than Japanese, exhibiting a gradual slope. ‘Maama’, ‘mamaa’ and ‘mamma’ are trimoraic words and ‘maamaa’, ‘mammaa’ and ‘maamma’ quandri moraic words in Japanese. When we compare the absolute durations of these Finnish words, the duration of each decreases gradually: ‘maama’ > ‘mamaa’ > ‘mamma’ and ‘maamaa’ > ‘mammaa’ > ‘maamma’. This pattern was not observed in Japanese.

3.4.2.2 ‘pa(a)p(p)a(a)’

The mean durations and comparative ratios between each structured word in ‘pa(a)p(p)a(a)’ in Finnish and Japanese are listed in Table 3.26. The mean durations of each structured word in ‘pa(a)p(p)a(a)’ in Finnish and Japanese are translated into Figure 3.16, and the comparative ratios (increasing ratios) of each structured word in ‘pa(a)p(p)a(a)’ in Finnish and Japanese are listed in Table 3.27. These values were represented in Figure 3.17. The closure part of word-initial /p/ is included as the duration of word-initial /p/ in all tables and figures.

These tables and figures show that lexical durational increase is steeper in Japanese and very close to the model created by mora counting. The lexical durational ratio increase in Finnish is less steep than Japanese, but has a gradual slope. These increasing patterns were very distinct compared to ‘ma(a)m(m)a(a)’. ‘paappa’. ‘pappaa’ and ‘pappa’ are trimoraic words and ‘paappa’, ‘pappaa’ and ‘paappa’ are quadri moraic words in Japanese. Comparing the durations of these Finnish words, each word decreases gradually: ‘paapa’ > ‘papaa’ > ‘pappa’ and ‘paapaa’ > ‘pappaa’ > ‘paappa’.

3.4.2.3 ‘sa(a)s(s)a(a)’

Each mean duration and comparative ratio of each structured word ‘sa(a)s(s)a(a)’ in Finnish and Japanese are listed in Table 3.28. The overall mean durations of each structured word ‘sa(a)s(s)a(a)’ in Finnish and Japanese are translated into Figure 3.18. Comparative ratios (increasing ratios) of each structured word in ‘sa(a)s(s)a(a)’ in Finnish and Japanese are listed in Table 3.29, these values being represented in Figure 3.19.

We can observe similar patterns to ‘pa(a)p(p)a(a)’ in these tables and figures. Lexical durational increases are steeper in Japanese and very close to the model based on mora counting. In Finnish, lexical durational increases are less steep than in Japanese, but show a gradual increase. ‘saasa’, ‘sasaa’ and ‘sassa’ are trimoraic words and ‘saasaa’, ‘sassaa’ and ‘saassa’ are quadri moraic words in Japanese. When we compare the absolute durations of these Finnish words, the duration of each decreases gradually: ‘saasa’ > ‘sasaa’ > ‘sassa’ and ‘saassaa’ > ‘sassaa’ > ‘saassa’. These overall patterns were observed in all word structures.

Table 3.24 The overall mean duration comparisons of each structured word in ‘ma(a)m(m)a(a)’ in Finnish and Japanese.

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Word structure	Finnish (ms)	Japanese (ms)	D (ms) (F. – J.)
mama	321.0	306.9	14.1 (F. > J.)
mamaa	439.6	437.5	2.1 (F. > J.)
maama	427.4	367.2	60.4 (F. > J.)
mamma	373.7	426.4	-52.7 (F. < J.)
maamaa	533.5	587.8	-54.3 (F. < J.)
mammaa	514.0	578.5	-64.5 (F. < J.)
maamma	463.8	563.2	-99.4 (F. < J.)
maammaa	590.7	717.2	-126.5 (F. < J.)

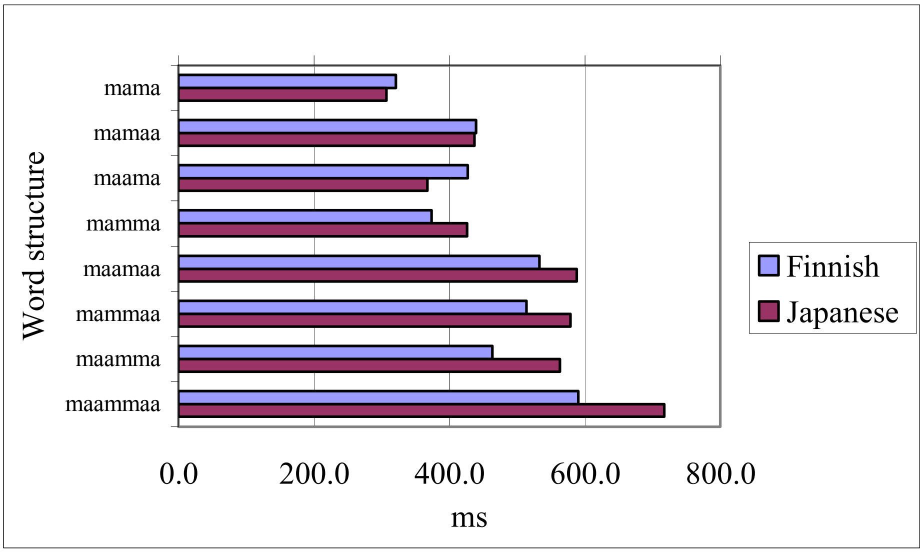


Figure 3.14 The durational comparisons of each structured word in ‘ma(a)m(m)a(a)’ in Finnish and Japanese.

Table 3.25 Comparative ratios of each structured word in 'ma(a)m(m)a(a)' in Finnish and Japanese.

Word	Finnish	Japanese	Moraic Model
mama	1.0	1.0	1.0
mamaa	1.4	1.4	1.5
maama	1.3	1.2	1.5
mamma	1.2	1.4	1.5
maamaa	1.7	1.9	2.0
mammaa	1.6	1.9	2.0
maamma	1.4	1.8	2.0
maammaa	1.8	2.3	2.5

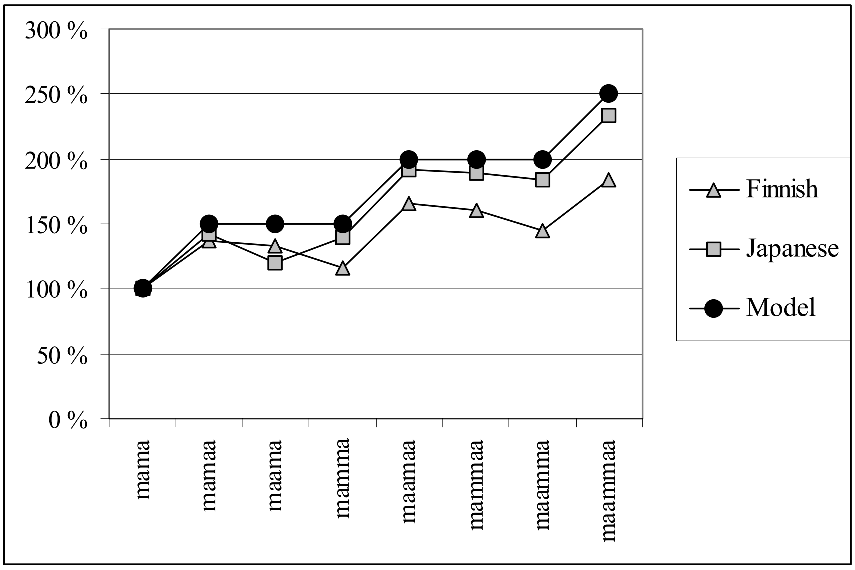


Figure 3.15 The increasing ratio of each structured word in 'ma(a)m(m)a(a)' in Finnish and Japanese.

Table 3.26 The overall mean durational comparisons of each structured word in 'pa(a)p(p)a(a)' in Finnish and Japanese.

	Finnish (ms)	Japanese (ms)	D (ms) (F. – J.)
papa	370.9	313.9	57.0 (F. > J.)
papaa	480.8	460.3	20.5 (F. > J.)
paapa	458.9	460.6	-1.7 (F. < J.)
pappa	449.0	454.8	-5.8 (F. < J.)
paapaa	594.6	613.3	-18.7 (F. < J.)
pappaa	556.0	610.4	-54.4 (F. < J.)
paappa	507.9	619.1	-111.2 (F. < J.)
paappaa	651.0	774.9	-123.9 (F. < J.)

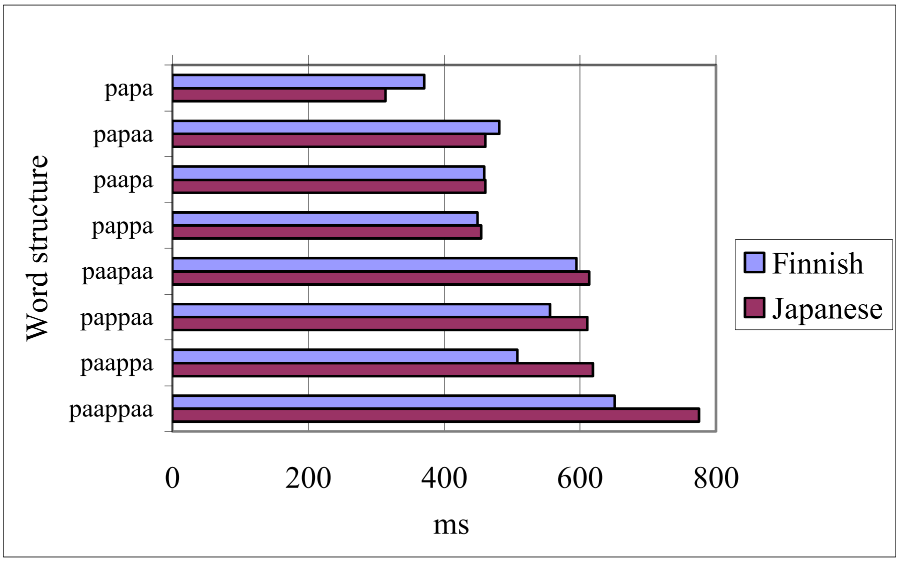


Figure 3.16 The durational comparisons of each structured word in 'pa(a)p(p)a(a)' in Finnish and Japanese.

Table 3.27 The comparative ratios of each structured word ‘pa(a)p(p)a(a)’ in Finnish and Japanese.

	Finnish	Japanese	Moraic Model
papa	1.0	1.0	1.0
papaa	1.3	1.5	1.5
paapa	1.2	1.5	1.5
pappa	1.2	1.4	1.5
paapaa	1.6	2.0	2.0
pappaa	1.5	1.9	2.0
paappa	1.4	2.0	2.0
paappaa	1.8	2.5	2.5

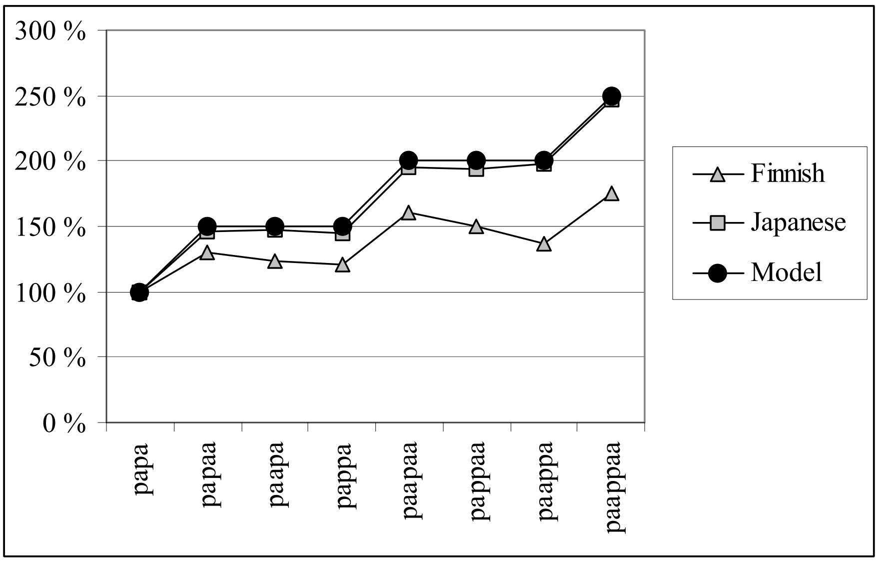


Figure 3.17 The increasing ratio of each structured word in ‘pa(a)p(p)a(a)’ in Finnish and Japanese.

Table 3.28 The overall mean durations and comparative ratios of each structured word 'sa(a)s(s)a(a)' in Finnish and Japanese.

	Finnish (ms)	Japanese (ms)	D
sasa	351.10	302.76	48.34
sasaa	453.87	454.55	-0.68
saasa	429.44	468.07	-38.63
saasaa	412.55	428.77	-16.22
sassa	552.97	601.55	-48.58
sassaa	536.87	577.02	-40.15
saassa	501.05	583.76	-82.71
saassaa	638.01	733.47	-95.46

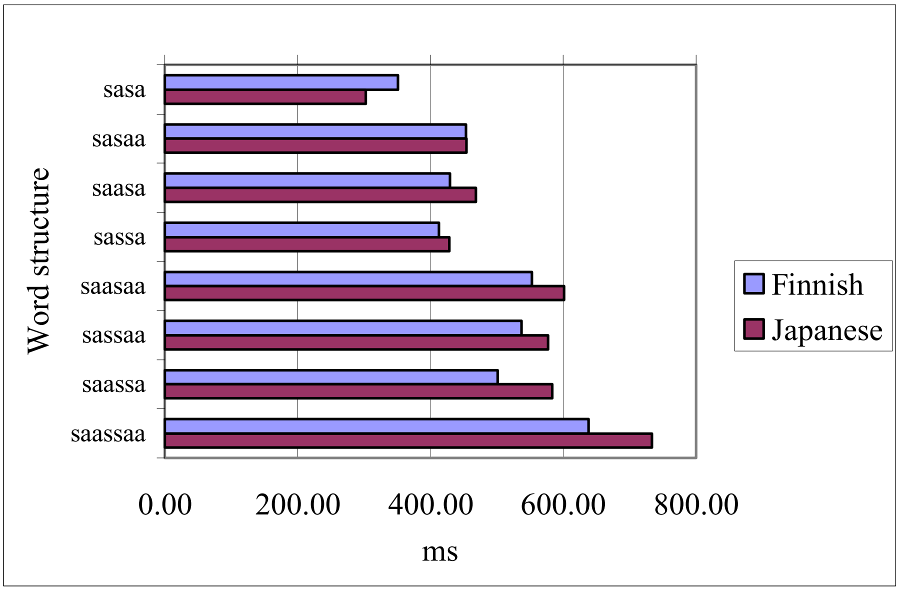


Figure 3.18 The durational comparisons of each structured word in 'sa(a)s(s)a(a)' in Finnish and Japanese.

Table 3.29 Comparative ratios of each structured word 'sa(a)s(s)a(a)' in Finnish and Japanese.

	Comparative ratio (%)	Comparative ratio (%)	Moraic Model
sasa	100%	100%	1.0
sasaa	129%	150%	1.5
saasa	122%	155%	1.5
saasaa	118%	142%	1.5
sassa	157%	199%	2.0
sassaa	153%	191%	2.0
saassa	143%	193%	2.0
saassaa	182%	242%	2.5

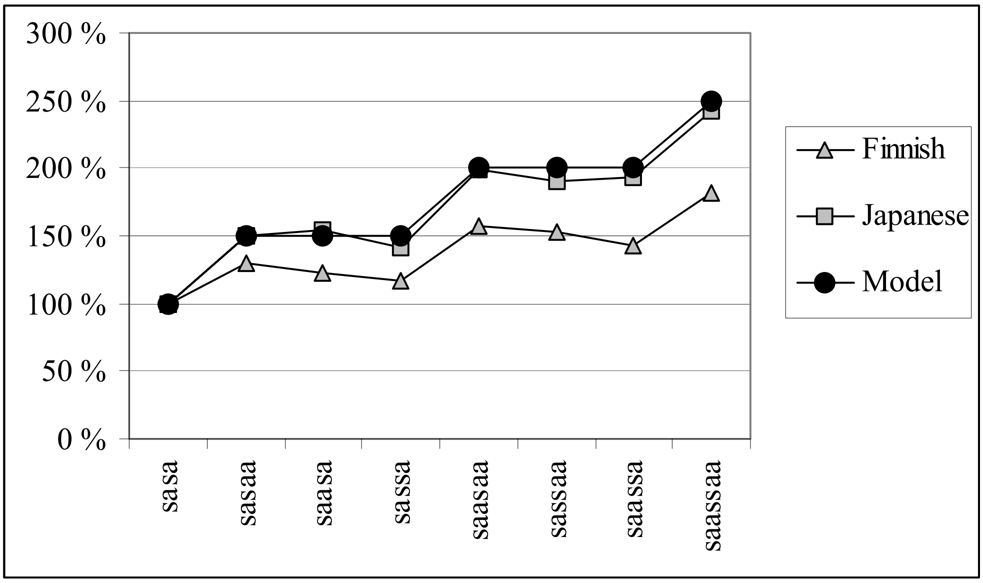


Figure 3.19 The increasing ratio of each structured word in 'sa(a)s(s)a(a)' in Finnish and Japanese.

3.4.3 Durational ratios of segments within the word

Tables 3.30 – 37 shows each durational ratio of segments within a word when the word length was 100%. These are translated into Figures 3.20 – 27, showing the durational distribution within a word according to each word structure. contrasting Finnish with Japanese. In the figures there are four segments of short/ long and short/long consonants, regardless of the number of phonemes (from four to seven) and the combination of vowels and consonants.

From these figures, some noticeable features can be pointed out:

(1) /CVCV/ (Table 3.30, Fig. 3.20)
Word-initial consonants are longer than the word-medial ones, particularly in 'mama' in both languages.

(2) /CVCVV/ (Table 3.31, Fig. 3.21)
Word-initial /m/ is longer than word-medial /m/ in both languages. The first /CV/ occupies nearly 40% of the whole word.

(3) /CVVCV/ (Table 3.32, Fig. 3.22)
The first syllable occupies over 65% of the whole word.

(4) /CVCCV/ (Table 3.33, Fig. 3.23)
Word-initial consonants are markedly longer than the word-medial ones in all cases in both languages. Vowels, however, are shorter both in the first and second syllable. The first CV occupies over 45% of the whole word.

(5) /CVVCVV/ (Table 3.34, Fig. 3.24)
The first syllable CVV has approximately the same proportion as the second /CVV/.

(6) /CVCCVV/ (Table 3.35, Fig. 3.25)
The segment distribution patterns look very similar between the languages.

(7) /CVVCCV/ (Table 3.36, Fig. 3.26)
The proportional ratios of word-initial consonants as short consonants were not necessarily half the ratio of the long counterparts in either languages. The first syllable, /CVV/, occupies nearly 55 – 60% of the whole word. Finnish word-medical /mm/ in /maamma/ was very short as the long segment compared to its word-initial /m/.

(8) /CVVCCVV/ (Table 3.37, Fig. 3.27)
The first syllable /CVV/ occupies over 45% of the whole word.

It was not possible to compare syllabic durations because there was no internal boundary in the long segment to divide into separate syllables when they occurred. If it had been possible to compare, however, we could have observed a tendency for the first /CV/ or /CVV/ to have relatively longer durations than the second syllables. This was probably because the word-initial consonant was relatively longer than the word-medial consonant. While there may be intrinsic articulatory differences between consonants, the syllable duration did not necessarily change according to their natures, the vowel duration changing according to its position within a word. All these might suggest that durational compensation works within a word in both languages. In conclusion, significant differences in temporal distributions of segments of words between Japanese and Finnish were not found.

Table 3.30 /CVCV/ structure words – 'mama', 'papa', 'sasa'.

Word structure	Language	C1	V1	C2	V2	Total
mama	Finnish	26.2%	27.7%	18.9%	27.2%	100.0%
	Japanese	26.2%	26.3%	19.0%	28.5%	100.0%
papa	Finnish	29.0%	22.6%	23.4%	25.1%	100.0%
	Japanese	32.6%	20.2%	22.8%	24.4%	100.0%
sasa	Finnish	28.0%	26.3%	20.7%	25.0%	100.0%
	Japanese	29.0%	23.4%	23.5%	24.2%	100.0%

Each distributional ratio of segments within a word when the whole word length is 100%.

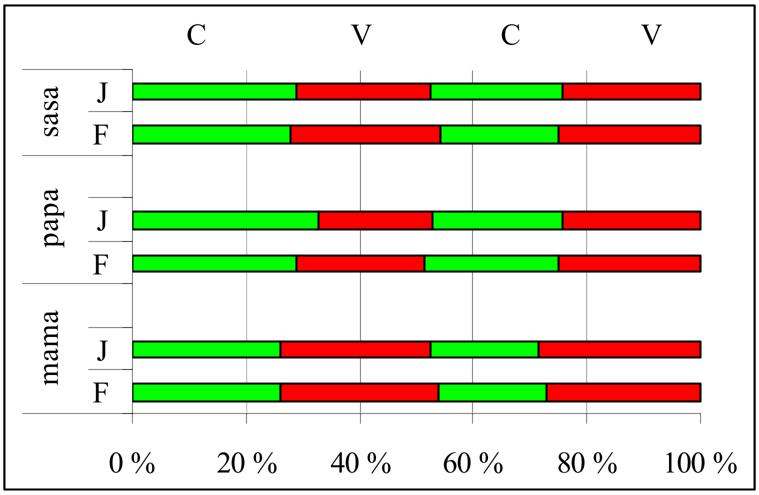


Figure 3.20 Segmental durational ratio distributions in /CVCV/ structure.

Table 3.31 /CVCVV/ structure words – 'mamaa', 'papaa', 'sasaa'.

Word structure	Language	C1	V1	C2	VV2	Total
mamaa	Finnish	19.6%	20.9%	16.0%	43.5%	100.0%
	Japanese	17.8%	21.1%	16.1%	45.0%	100.0%
papaa	Finnish	22.5%	16.5%	22.0%	39.0%	100.0%
	Japanese	24.4%	14.4%	22.2%	39.0%	100.0%
sasaa	Finnish	19.9%	18.8%	20.6%	40.7%	100.0%
	Japanese	20.7%	17.3%	21.2%	40.7%	100.0%

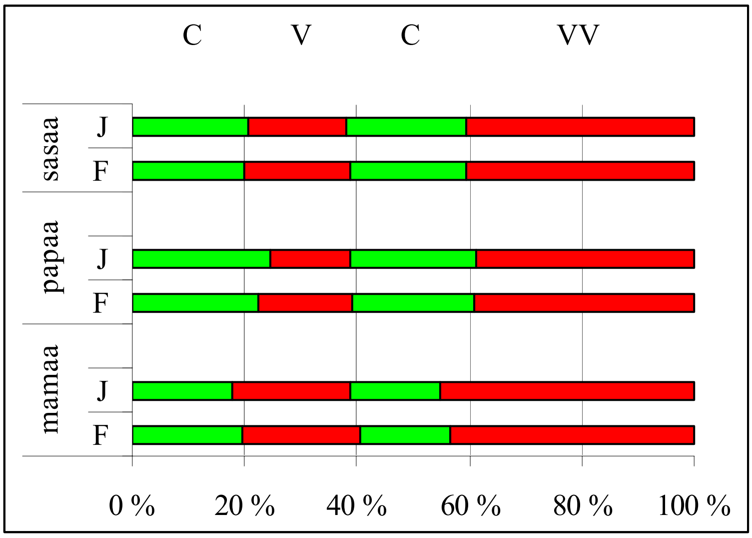


Figure 3.21 Segmental durational ratio distributions in /CVCVV/ structure.

Table 3.32 /CVVCV/ structure words – 'maama', 'paapa', 'saasa'.

Word structure	Language	C1	VV1	C2	V2	Total
maama	Finnish	20.4%	47.9%	15.9%	15.8%	100.0%
	Japanese	20.2%	47.7%	15.2%	16.9%	100.0%
paapa	Finnish	24.6%	44.8%	17.9%	12.7%	100.0%
	Japanese	26.9%	39.0%	19.0%	15.0%	100.0%
saasa	Finnish	23.1%	47.3%	16.3%	13.3%	100.0%
	Japanese	23.5%	43.2%	17.6%	15.7%	100.0%

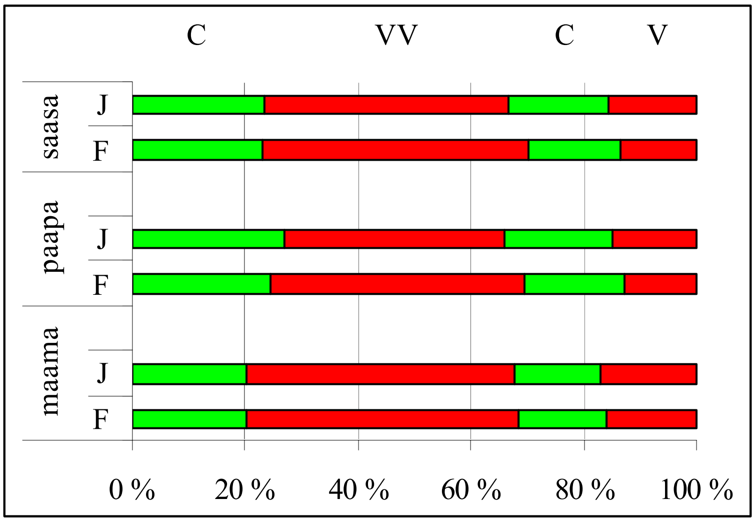


Figure 3.22 Segmental durational ratio distributions in /CVVCV/ structure.

Table 3.33 /CVCCV/ structure words – ‘mamma’, ‘pappa’, ‘sassa’.

Word structure	Language	C1	V1	CC	V2	Total
mamma	Finnish	22.2%	26.3%	34.2%	17.3%	100.0%
	Japanese	27.6%	20.0%	33.2%	19.1%	100.0%
pappa	Finnish	25.8%	18.4%	42.7%	13.1%	100.0%
	Japanese	25.2%	17.7%	42.3%	14.7%	100.0%
sassa	Finnish	23.3%	22.7%	38.5%	15.5%	100.0%
	Japanese	23.1%	23.5%	35.7%	17.7%	100.0%

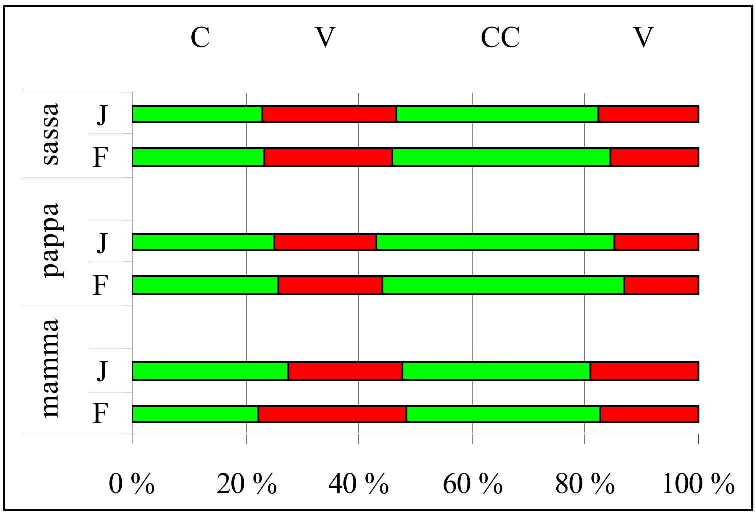


Figure 3.23 Segmental durational ratio distributions in /CVCCV/ structure.

Table 3.34 /CVVCVV/ structure words – 'maamaa', 'paapaa', 'saasaa'.

Word structure	Language	C1	VV1	C2	VV2	Total
maamaa	Finnish	15.8%	36.9%	15.2%	32.1%	100.0%
	Japanese	15.7%	38.1%	14.3%	31.9%	100.0%
paapaa	Finnish	20.1%	32.0%	17.4%	30.5%	100.0%
	Japanese	20.3%	30.7%	20.2%	28.9%	100.0%
saasaa	Finnish	18.4%	34.5%	16.9%	30.2%	100.0%
	Japanese	18.7%	34.4%	17.5%	29.3%	100.0%

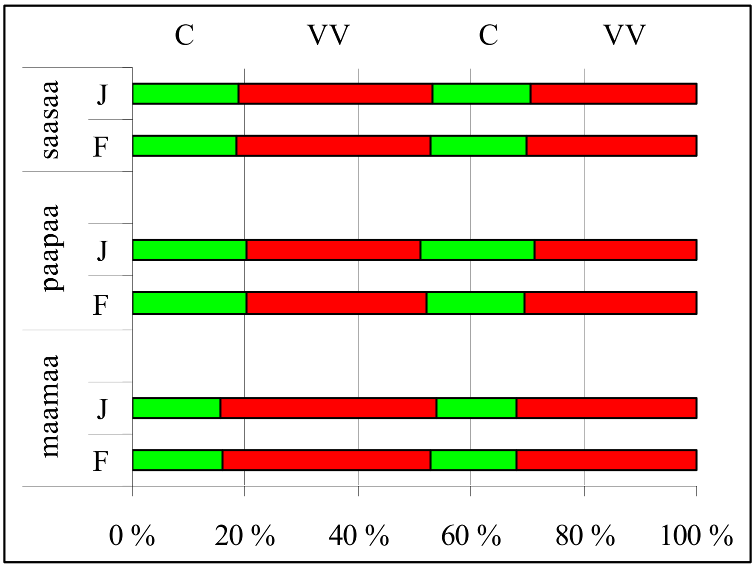


Figure 3.24 Segmental durational ratio distributions in /CVVCVV/ structure.

Table 3.35 /CVCCVV/ structure words – 'mammaa', 'pappaa', 'sassaa'.

Word structure	Language	C1	V1	CC	VV2	Total
mammaa	Finnish	15.9%	21.8%	29.7%	32.6%	100.0%
	Japanese	16.2%	21.2%	30.5%	32.1%	100.0%
pappaa	Finnish	20.4%	13.8%	38.1%	27.8%	100.0%
	Japanese	21.0%	14.4%	37.0%	27.6%	100.0%
sassaa	Finnish	17.7%	17.2%	35.5%	29.6%	100.0%
	Japanese	16.3%	17.7%	34.7%	31.3%	100.0%

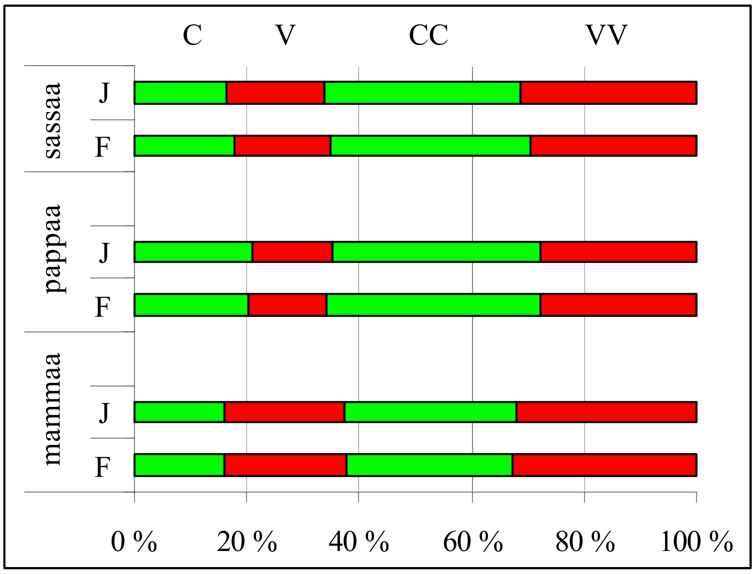


Figure 3.25 Segmental durational ratio distributions in /CVCCVV/ structure.

Table 3.36 /CVVCCV/ structure words – 'maamma', 'paappa', 'saassa'.

Word structure	Language	C1	VV1	CC	V2	Total
maamma	Finnish	20.0%	38.2%	26.9%	15.0%	100.0%
	Japanese	17.1%	37.5%	30.2%	15.2%	100.0%
paappa	Finnish	24.0%	31.9%	32.1%	12.0%	100.0%
	Japanese	25.5%	32.8%	30.6%	11.1%	100.0%
saassa	Finnish	22.8%	34.9%	30.2%	12.1%	100.0%
	Japanese	21.3%	39.7%	26.6%	12.4%	100.0%

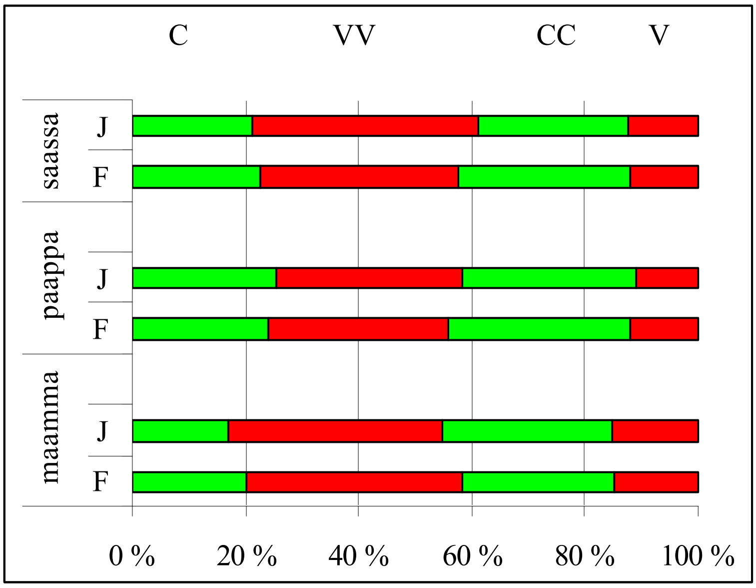


Figure 3.26 Segmental durational ratio distributions in /CVVCCV/ structure.

Table 3.37 /CVVCCVV/ structure words – 'maammaa', 'paappaa', 'saassaa'.

Word structure	Language	C1	VV1	CC	VV2	Total
maammaa	Finnish	15.6%	31.9%	23.4%	29.1%	100.0%
	Japanese	13.8%	31.0%	24.3%	30.9%	100.0%
paappaa	Finnish	19.4%	25.4%	28.7%	26.5%	100.0%
	Japanese	19.0%	27.1%	28.1%	25.8%	100.0%
saassaa	Finnish	17.4%	28.8%	26.5%	27.3%	100.0%
	Japanese	15.7%	33.7%	23.0%	27.6%	100.0%

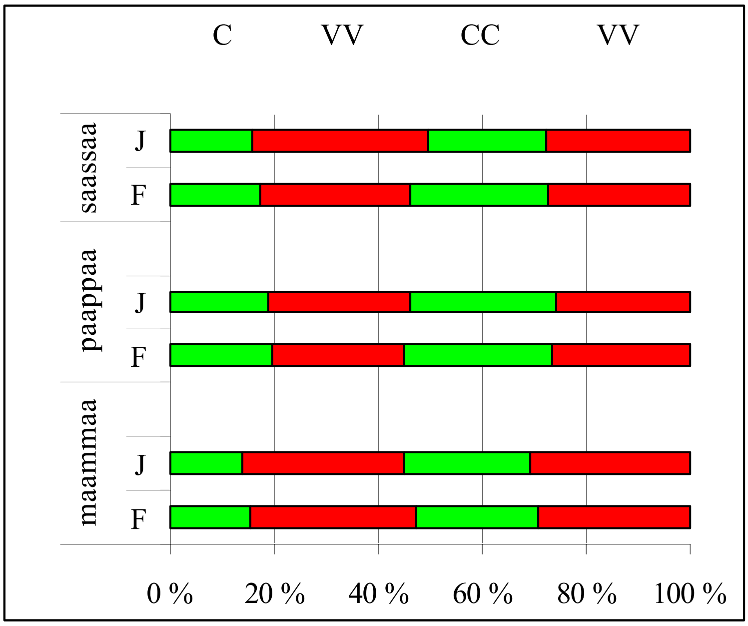


Figure 3.27 Segmental durational ratio distributions in /CVVCCVV/ structure.

3.5 Summary and discussion

3.5.1 Summary

In this chapter, 24 nonsense word types (720 words) were analysed to study lexical quantity in production between Japanese and Finnish. I summarise the results below. In terms of vowels at the segmental level, the findings were as follows.

(1) Finnish mean durations of /ɑ/ and /ɑɑ/ were shorter but their mean durational ratios between /ɑ/ and /ɑɑ/ were greater than their Japanese counterparts.

(2) The overall mean durations of /ɑɑ/ in both the first and second syllables were longer in Japanese than Finnish.

(3) The overall variations between the languages were markedly greater in Japanese 'aa2' than Finnish 'aa2'. The overall variations between 'aa1' and 'aa2' were greater in Japanese than Finnish 'aa2'. The variations of 'aa1' within each language were greater in Japanese than Finnish, but 'aa2' produced the reverse result. There was a tendency for /CVVCCVV/ structured words to have relatively high variation values compared to the other word structures between Japanese and Finnish.

(4) In terms of the variations which depended on consonants and on the language, Japanese had greater variations than Finnish. The Japanese /ɑ/ in the first syllable had a very high value in particular. In all cases the variations between 'a1' and 'a2' and between 'aa1' and 'aa2' largely depended on word structure, and the preceding and following consonants. Both Finnish and Japanese /ɑ/s were more affected by the first syllable position than the second, but /ɑɑ/s were not greatly affected by the position.

The findings for consonants at the segmental level were as follows.

(1) The overall mean durational values of all consonants, /m, p, s, mm,

pp, ss/, were higher in Japanese than in Finnish. The Finnish ratio difference between /s/ and /ss/ was higher than that of Japanese counterparts, but the ratio differences between /m/ and /mm/ and /p/ and /pp/ were higher than their Finnish counterparts. However, these ratios differed, largely depending on whether the short segment occurred either in word-initial or word-medial position in comparison with the long segment.

(2) The variations in all consonants between these two languages were very small.

(3) The overall mean values between the Finnish VOT of word-initial /p/ were nearly the same as its Japanese counterpart.

The comparative ratios of the closure part between word-medial /p/ and /pp/ were greater in Japanese than in Finnish.

(4) The Finnish variations of the closure part of /p/ were shorter than the Japanese counterparts, but the durational difference of /pp/ was longer in Finnish than in Japanese.

(5) The variations in /m/ were rather stable in both languages. While the variations in Japanese /mm/ also were stable, those of Finnish /mm/ largely depended on word structure.

(6) The variations of both /s/ and /ss/ largely depended on word structure in both languages. Finnish /ss/ in particular had very high values in the variation, compared to the other word structure. This suggests that there is a greater variation among Finnish speakers in terms of producing /ss/ than Japanese speakers.

The overall result was that all consonantal segmental durations were shorter in Finnish and *SD* were smaller in Finnish than in Japanese except for VOT in /pp/ for Finnish. Therefore, the general evaluations at the segmental level is that the absolute durations and durational ratios were shorter in Finnish than in Japanese, and the ranges were relatively smaller in Finnish than in Japanese. In analysis of variance, the vowels showed greater significance more than the consonants.

The findings for word durations were as follows:

(1) The durational increase was very close to the mora-counting model in all word structure in Japanese than in Finnish.

(2) Japanese and Finnish showed the same patterns of stepwise increase with the number of segment in all ‘ma(a)m(m)a(a)’, ‘pa(a)p(p)a(a)’ and ‘sa(a)s(s)a(a)’ structure words, except for the Japanese maama. The number of phonemes increased from four to seven. Japanese was seemingly not affected by the combinations of phonemes but their number, i.e., word structure or the number of mora, while Finnish was seemingly affected by the combinations of phonemes, and/or? phonotactic influence, rather than by the number of phonemes.

When /CVCV/ words were the base from which to count each word durational ratio, Japanese and Finnish word durations increased consistently and showed the same patterns within bimoraic and trimoraic words in all three structure words. While Japanese had a strong tendency to have linearity towards mora timing from the second morae toward five morae, Finnish showed regular patterns according to syllable structure and the phonemic combination.

In terms of durational ratios of segments within each structure word:

(1) There was a tendency for the first syllable to be slightly longer than the second syllable and,
(2) There were no significant differences in durational ratios of segments within each structure word between Japanese and Finnish.

These results indicate that compensation works within both the syllable and the word for both languages, because each phonemic (intrinsic) duration was not the same.

3.5.2 Discussion

We may conclude that Japanese segmental ratios between singletons and geminates in both vowels and consonants were larger than those of Finnish when all segments were pooled. However, there were very wide variations in their positions in different structures. The ratios between singletons and geminates were smaller in both Japanese and Finnish than those in the literature referred to in this study. The long segments were rather close to the doubling of a short segment (1:2) but not as much as three times longer (1:3, see e.g., Han 1962a). Comparing moraic ratios based upon the Japanese mora-counting concept, the Finnish durational ratio of each mora was smaller than that of Japanese.

It was not possible to compare the durational ratio between /CVC/ and /CV/ in /CVCCV/, /CVVC/ and /CV/ in /CVVCCV/, /CVC/ and /CVV/ in /CVCCVV/, or /CVVC/ and /CVV/ in /CVVCCVV/, because there was no acoustic boundary in /C.C/ in these structures.

The most striking result was that the increasing lexical ratios were parallel to the word structures, whose increasing ratio was relatively stable according to the number of syllables in both languages, although these patterns were slightly different from each other. There was a clear linearity in the stepwise increase corresponding to the number of phonemes/morae in both duration and ratio in Japanese, except for ‘ma(a)m(m)a(a)’, particularly ‘maama’. This is probably because the intrinsic duration of /m, mm/ is much shorter than the other consonants, /p, pp, s, ss/. This indicates that /mV/ is not isochronic with the other combinations, /sV, pV/, when /m, mm/ are combined with the vowel. On the other hand, Finnish showed similar patterns corresponding to the combinations of vowels and consonants in all three cases. Nevertheless, the Japanese moraic durational patterns were more isochronic according to the word structure (and the number of morae or syllables) than Finnish, indicating that in Japanese compensation works within the word so that mora-timing can be maintained (up to five morae) more than in Finnish. This may indicate that the underlying isochronic timing principle is based more on the mora in Japanese (Campbell and Sagisaka 1991, Kaiki and Sagisaka 1993, Sagisaka and Toukura 1984 and many others) than in Finnish. However, applying the syllable concept to Japanese cannot be neglected.

In the bisyllabic nonsense structure /CV(V)C(C)V(V)/, one phoneme was added starting with four and rising to seven, using /m, p, s, ɑ/. The position of these phonemes was imposed as one mora constituent within the word structure. The result showed that the vowel, short or long, occurring in the first syllable was longer than that in the second. This result agrees with that of Sagisaka et al. (1984) but not with Homma (1985).

Comparing the variation between vowels and consonants, the *R* of the short vowels was shorter in Finnish (33.9 ms) than in Japanese (58.4 ms) in ‘a1’ but not in ‘a2’ (F. = 36.0 ms, J. = 20.8 ms). The standard deviation showed the same result:

‘a1’ F. = 9.0 ms < J. = 16.7 ms
‘a2’ F. = 12.9 ms > J. = 6.4 ms.

However, the *R* of the long vowels was shorter in Finnish (44.8 ms in ‘aa1’ 38.7 ms in ‘aa2’) than in Japanese (58.1 ms in ‘aa1’ 53.2 ms in ‘aa2’ in both ‘aa1’ and ‘aa2’). The *SD* also showed the same result:

‘aa1’ F. = 15.0 ms < J. = 16.7 ms
‘aa2’ F. = 11.2 ms < J. = 13.9 ms.

These results indicate that the range is larger only in ‘a1’, but smaller in the other cases, short or long, in Finnish than in Japanese, as was the standard deviation. Observing the *R* of D (difference), Finnish had relatively higher variations. In terms of consonants, the *R* of ‘p1’ and ‘p2’ were smaller in Finnish (20.3 ms in ‘p1’ 24.6 ms in ‘p2’) than in Japanese (55.5 ms in ‘p1’ 52.5 ms in ‘p2’), but not in ‘pp’ (F. = 48.6 ms, J. = 35.9 ms). The *SD* showed the same result:

‘p1’ F. = 6.9 ms < J. = 18.3 ms
‘p2’ F. = 12.1 ms < J. = 22.3 ms
‘pp’ F. = 20.0 ms > J. = 18. ms in.

However, the results were different in consonants:
‘m1’ (*R*: F. = 10.5 ms < J. = 24.0 ms; *SD*: F. = 4.3 ms < J. = 8.7 ms),
‘m2’ (*R*: F. = 19.2 ms < J. = 25.8 ms; *SD*: F. = 8.0 ms < J. = 10.8 ms),
‘mm’ (*R*: F. = 28.7 ms < J. = 54.7 ms; *SD*: F. = 12.8 ms < J. = 26.1 ms),
‘s1’ (*R*: F. = 23.8 ms < J. = 36.9 ms; *SD*: F = 8.1 ms < J. = 13.4 ms),
‘s2’ (*R*: F. = 23.0 ms < J. = 32.7 ms; *SD*: F. = 12.3 ms < J. = 14.6 ms),
‘ss’ (*R*: F. = 38.7 ms < J. = 47.3 ms; *SD*: F. = 16.8 ms < J. = 22.4 ms).

In all cases in C1, C2 and CC, the *R* and *SD* were smaller in Finnish than in Japanese, except for ‘pp’. Therefore, the exceptions to the *R* and *SD* being smaller were in ‘a1’and ‘pp’ (two cases out of 13). This could be partly because the duration of Finnish segments, whether short or long, were shorter than that of Japanese.

These *R* and *SD* results were obtained by calculating the difference between the minimum and maximum duration in each word structure. This indicates that the Japanese vowel and consonantal segments are more influenced by word (syllable) structure than their Finnish counterparts, demonstrating that the Finnish speakers have narrower ranges and less deviation in producing both short and long segments. It also implies that Finns are more bound to each segmental (intrinsic) duration and less flexible in temporal control while Japanese is precisely the reverse. This may be the reason why Japanese shows more linearity than Finnish according to the increasing number of phonemes and each word structure.

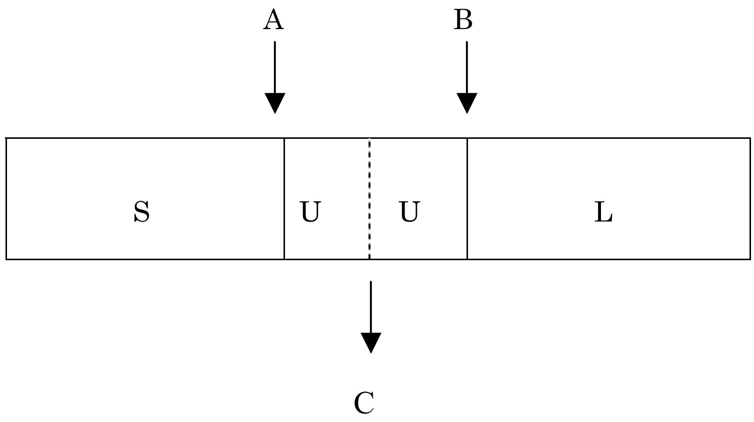
Although word duration varied more in Finnish according to the word structure, segmental durational distributions within the word were very similar in both Japanese and Finnish, which may explain why the Japanese perceive Finnish quantity organization as being similar (and vice-versa). These results and analysis showed the durational differences not only between languages, but also the environments dependent on word structures and phonological combinations of segments.

4 Perception of lexical quantity

4.1 Introduction

The primary purpose of the experiments was to compare perceptual quantity boundaries in Japanese and Finnish. The secondary purpose was to see how some concomitant factors influence the perception of quantity boundary. The following acoustic factors were examined: varying intensity (dB) and the fundamental frequency (F0, Hz) of the vowel, varying syllable structure and word duration (Isei-Jaakkola 2003b). Perceptual identification tests do not often consider syllable structures and varying F0 and intensity level, and the data have been analysed by a binary concept of quantity, short or long (cf. e.g. Fujisaki and Sugitou (1977) for Japanese, Richardson (1998) for Finnish, and Aoyama (2001) for both languages). The boundary range problem has been discussed by Lehtonen (1970) for Finnish and Fujisaki and Sugitou (1977) for Japanese, but no comparative study under the experimental conditions enumerated above has been carried out so far to my knowledge. In the perception test, Fujisaki and Sugitou (1977) found that Japanese speakers perceived a geminate when the duration of the test word was more than 141 ms or 169 ms depending on two factors: (1) whether it occurs in isolation or in a sentence and (2) the duration of the preceding and following vowels. The perceived boundary was greater or less in proportion to the length of the preceding mora, indicating that Japanese can perceive the duration of an isolated phoneme by relative judgement. Their results show that the ratio between single consonants and geminates in perception is approximately 1.4 - 1.7. They used *ama* and *amma* for stimulus words. This ratio will be compared in the later section. Richardson (1998) investigated the perceptual boundaries of /t/ and /tt/, using nonsense words *ata* and *atta*. The subjects were control and dyslexic adults. She used 20 ms increments for the closure part of the plosives to create stimulus to obtain the cross-over point of these test words. Aoyama (2001) states that the perceptual boundary between the two phonemes – /n, nn/ using the *hana – hanna* continuum appeared to be narrower in Finnish than in Japanese in her experiment. I did not include /n, nn/ in this study, but this finding can be compared to that for /m, mm/ in the present study where both /n/ and /m/ are phonetic realisations of the Japanese /N/. Japanese is also characterised as a pitch-accented language and thus F0 plays an important role in relation to quantity, although studies on this issue are rare, particularly in perception. Homma (1981), as the result of the experiments on durational relationship between Japanese stops and vowels, says that pitch accent does not have a significant influence on vowel duration, but she did not conduct experiments on whether gemination has a significant influence on the pitch of the following vowel.

Perceptual boundary range (BR, hereafter) refers to the durational border between the two quantity categories (V^1/V^1V^1, C^1/C^1C^1) and indicates the auditory uncertainty area between short and long segments, as Figure 4.1 illustrates.



S = short, L = long, and U = uncertain. A = maximum short segment,
B = minimum long segment in perception. C = PSE.

Figure 4.1 Illustration of the perceptual boundary area (U = BR) lying between short and long segments.

The following questions arose:

(1) Is there a difference between Japanese and Finnish in terms of perceptual boundary ranges? Is the difference language-specific?
(2) To what degree do such prosodic variants as F0 and dB, different syllable structures, and variable word durations affect perceptual boundaries in Finnish and Japanese within the segment and word?

The primary issue in this study was to investigate the perceptual boundary ranges and so a trichotomy, i.e., three response choices (short, long or uncertain), was used, as distinct from a dichotomy (short or long), i.e., the binary concept. In the experiments different syllable structures, prosodic variants, and variable word durations were conditioned to create synthetic stimuli. Additionally, I also observed and compared the minimum long quantity ('B' in Fig. 4.1) and maximum short quantity ('A' in Fig. 4.1) in perception between each language, and PSE. The questions in this study are thus concerned with the linguistic-specific issue, and so I did not compare individual differences among the subjects in either Finnish or Japanese.

4.2 Experimental procedure

For the perception tests, I used synthetic bisyllabic nonsense words in isolation. Stimuli were produced using an Infovox speech synthesizer simulating a male voice.

4.2.1 Experimental design 1 – syllable structures

As seen in Chapter 3, among the real bisyllabic words Finnish can have at most eight different kinds of syllable structure with combinations of phonologically short and long vowels and short and long consonants – /CVCV, CVCVV, CVVCV, CVVCVV, CVCCV, CVCCVV, CVVCCV, CVVCCVV/. The same word structures as used in chapter 3 (see Table 3.3) were utilised to investigate the perceptual boundaries of vowels and consonants for Japanese and Finnish speakers. These structures include from two to five morae according to Japanese mora-counting (see Table 3.2). Since the combination /CVVCCVV/ does not exist in Japanese, this structure meant some sort of test challenge for the Japanese listeners.

As I mentioned in chapter 3, neither of these two languages share meaningful words which all have these combinations with exactly the same short/long vowels and consonants in the eight different syllable structures above. This led me to use nonsense words for both languages for perception tests. I also avoided using real words since it might lose a certain amount of prosodic information while reducing the duration of a long segment to a short segment or adding duration from a short segment to a long segment.

In designing these syllable structures, I made four kinds of combination to test vowels and four to test consonants as in Table 4.1.

4.2.2 Experimental design 2 – word length

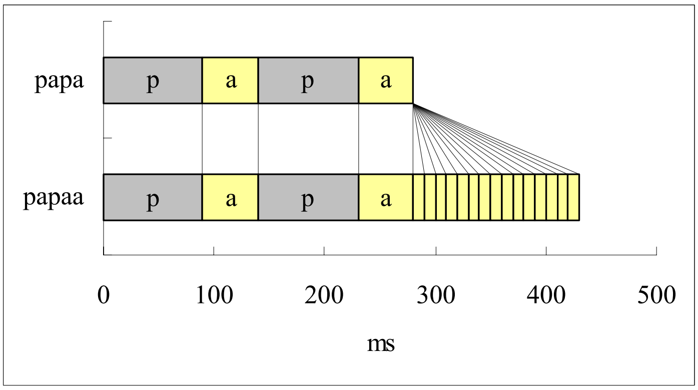
Stimuli employing a male voice were produced using an Infovox speech synthesizer (cf. Vainio 1993). The V was always /ɑ/ and the alternative Cs were /p, m, s/ in synthetic words like ‘papa’, ‘mama’, ‘sasa’, etc. as shown in Table 4.1. The reason for choosing these phonemes was the same as in the Chapter 3 – making the combination of short/long segments. Only the underlined part in Table 4.1 – either word-medial and word-final vowels or word-medial consonants – was tested for identification tests. The word-medial vowel is the vowel in the first syllable and the word-final vowel in the second syllable. In making the test words, none of the other respective phoneme durations except the phoneme being tested were changed. The duration of word-initial /m/ was 60 ms that of /p/ 90 ms and that of /s/ 90 ms. The duration of word-initial and word-final vowel was 50 ms when its duration was not changed. In terms of the segment tested, the number of word-medial and word-final vowel stimuli continua (50-200 ms) was 16 and the number of corresponding consonants 12 for word-medial /p – pp/ (90-200 ms), 11 for /m – mm/ (60-160 ms) and 13 for /s – ss/ (80-200 ms) with a 10 ms incremental increase for all four phonemes. Figure 4.2 illustrates and exemplifies how the vowel stimuli in ‘papaa’ with a 10 ms incremental increase were created from ‘papa’ and had a continuum representing 16 stimuli. Only one segment in every word (the underlined part in Table 4.1) had these incremental increases. Hence, the other segments within each word remained unchanged. When deciding on the phonemic durations and word durations, I used the data from the previous production test and Lehtonen’s data (1970:64, 71), which was obtained using a carrier sentence. In general, experiments show that each short or long segmental duration varies largely depending on the syllable structures and the environments, whether occurring in the first or second syllable, or word-initially or medially. It also depends on whether it is uttered in isolation or in a conversation. It is thus difficult to determine what durations should be used to combine proper syllable timing for each of the eight test word structures. Finally, I relied on my auditive impression so that each word sounded natural: 50 ms for /ɑ/, 60 ms for /m/, 90 ms for /p/, 90 ms for word-initial /s/ and 80 ms for word-medial /s/ for the beginning of each stimulus.[53]

[53] Some studies use the recorded speech of geminates, cutting into gradual durational decrease to create stimulus words of short segment (e.g., Aoyama 2001). Others use opposite method, adding gradual durational increase to a short segment until it reaches to be geminates (e.g., Gabriella 1999).

Table 4.1 Syllable structure and stimulus words.

Test Segment	No.	Syllable Structure		C = p V = a		C = m V = a		C = s V = a	
Vowel	1	CVCV	–	papa	–	mama	–	sasa	–
		CVVCV		paapa		maama		saasa	
Vowel	2	CVCV	–	papa	–	mama	–	sasa	–
		CVCVV		papaa		mamaa		sasaa	
Vowel	3	CVVCV	–	paapa	–	maama	–	saasa	–
		VVCVV		paapaa		maamaa		saasaa	
Vowel	4	CVCVV	–	papaa	–	mamaa	–	sasaa	–
		VVCVV		paapaa		maamaa		saasaa	
Consonant	1	CVCV	–	papa	–	mama	–	sasa	–
		CVCCV		pappa		mamma		sassa	
Consonant	2	CVVCV	–	paapa	–	maama	–	saasa	–
		VVCCV		paappa		maamma		saassa	
Cconsonant	3	CVCVV	–	papaa	–	mamaa	–	sasaa	–
		VCCVV		pappaa		mammaa		sassaa	
Consonant	4	CVVCVV	–	paapaa	–	maamaa	–	saasaa	–
		CVVCCVV		paappaa		maammaa		saassaa	

‘a’ = /ɑ/. ‘No.’ refers to tables and graphs in this work.



This example shows that /ɑ/ in the second syllable of ‘papaa’ had a continuum representing 16 stimuli.

Figure 4.2 Illustration of how the stimulus word ‘papaa’ with a 10 ms incremental increase was made from ‘papa’.

The durations of word-initial consonants were unchanged. The word-medial C(C) was created simply made by lengthening the C continuum. V(V) was varied by the same process as C(C). The shortest word stimulus was thus 220 ms and the longest 690 ms. Table 4.2 explains how word duration was stretched from the shortest to the longest, depending on syllable structure.

Table 4.2 The whole duration of each stimulus word.

		SS	C = m (ms)	C = p (ms)	C = s (ms)
V	1	CVCV-CVCVV	220 – 370	280 – 430	270 – 420
	2	CVCV-CVVCV	220 – 370	280 – 430	270 – 420
	3	CVCVV-CVVCVV	370 – 520	430 – 580	420 – 570
	4	CVVCV-CVVCVV	370 – 520	430 – 580	420 – 570
		SS	m – mm	p – pp	s – ss
C	1	CVCV-CVCCV	220 – 320	280 – 580	270 – 390
	2	CVCVV-CVCCVV	370 – 470	430 – 540	420 – 540
	3	CVVCV-CVVCCV	370 – 470	430 – 540	420 – 540
	4	CVVCVV-CVVCCVV	520 – 620	580 – 690	570 – 690

SS = syllable structure, V = vowel, C = consonant. /m, p, s/=consonants used in the stimulus word.

4.2.3 Experimental design 3 – prosodic variants

Furthermore, prosodic conditions were added to those above. There were five patterns in the prosodic conditions as in Table 4.3, the label ‘Level’ for prosodic conditions representing unchanged parameters in the stimulus word. ‘HL’ (high-low) represents the pitch in the first syllable being higher than that in the second syllable but intensity remaining unchanged in the word. ‘LH’ (low-high) represents lower pitch in the first syllable than in the second but unchanged intensity. ‘SW’ (strong-weak) represents greater intensity in the first syllable than in the second but unchanged pitch. ‘WS’ (weak-strong) represents lower intensity in the first syllable than in the second but unchanged pitch. Only the vowel in the first and second syllables had unchanged F0 – 100 Hz and changed F0 – 95 Hz/120 Hz, 120 Hz/95 Hz,[54] and unchanged intensity –

[54] It was a male voice. I judged these F0 values to be sufficient for the test.

26 dB and changed intensity – 26/29 dB, 29/26 dB. Before the experiments the following details were confirmed: (1) 25 Hz[55] (4.0441 semitone differences)[56] was enough to differentiate higher or lower pitch between syllables, and (2) 3 dB[57] was also sufficient to differentiate the syllable with higher or lower intensity. Hence, there were five kinds of prosodic conditions yielding complex stimuli in eight different syllable structures and all variants add up to 120 test sets (8 SS (= syllable structures) x 5 PC (= prosodic conditions) x 3 Cs (= kinds of consonants)) for vowel and consonant distinctions. The 120 test sets imply 120 conditions in the perception test.

Table 4.3 Prosodic conditions to create nonsense word stimuli.

		1st Syllable	2nd Syllable
Conditions	Prosodic Parameters	(C)V(V)C	(C)V(V)
Level	Pitch	100Hz	100Hz
	Amplitude	26dB	26dB
HL	Pitch	120Hz	95Hz
	Amplitude	26dB	26dB
LH	Pitch	95Hz	120Hz
	Amplitude	26dB	26dB
SW	Pitch	100Hz	100Hz
	Amplitude	29dB	26dB
WS	Pitch	100Hz	100Hz
	Amplitude	26dB	29dB

[55] I used HL, LH Japanese words. HL had a higher F0 than LH – 25 Hz was enough to differentiate the meaning between HL and LH words in my informal experiment. The difference between L and H in LH was lower than that of HL.

[56] The calculation 39.86*LOG (F0n) was made according to *Clinical speech and voice measurement laboratory exercises instructor's manual*, by Robert F. Orlikoff, R. J. Baken (1993:71). The semitone (ST) difference between the F0 levels of syllables was considered as a significant auditory measure.

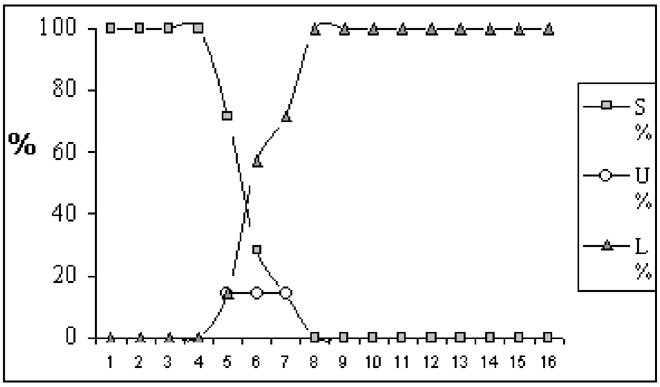
[57] My estimation was not based on acoustic calibration (e.g. Johnson 1977:50-54), but only on my own ear. Three dB differences can make the least but clear difference of sonority to distinguish between lower and louder voice.

4.2.4 Subjects

Seven Japanese subjects who are Tokyo dialect speakers and seven Finnish subjects from Helsinki and its environs participated in the discrimination tests. They had no or little knowledge of the other language. Their mother tongues were either Finnish or Japanese.

They were asked to choose one of three choices, including the word ‘uncertain’. When a subject could not decide and circle the word containing either short or long segment (e.g., ‘mama’ or ‘mamaa’), s/he had to circle the word ‘uncertain’. The subjects were guided to do so, but they were not aware of what was being tested. They listened to the test word only once in a quiet room. There were approximately two seconds between each stimulus word so that they had enough time to respond. The response words were written in the appropriate writing system. The response number became 29,120 ((V (16)+C (11+12+13=36) continua) x 8 SS x 5 PC x *n*14). The total test time listening to the test words was nearly three hours altogether. The informants had a break between test series. The responses were then categorized into three groups – short, uncertain and long. When short or long portion was not 100% as seen in Figure 4.3, then it was counted as U = ‘uncertain’, S = ‘short’ implied that the segment had short quantity and L = ‘long’ implied long quantity. The boundary range values were thus acquired from the uncertainty area, which lies between 100% for short and 100% for long. The ‘uncertain’ area means the perceptual durational range in which a listener cannot decide whether a segment is either short or long.

The number of word responses was 1,680 (*n*: 14 x 120 test sets). I built up the database with the words containing S, U, L values in duration (ms) and ratio (%) within the segment and word for the analysis and to obtain mean values between the languages, vowels and consonants, syllable structure and prosodic conditions (see Appendices 7-10). During analysis it was found that all responses in 16 words were short and thus were eliminated from the analysis, so that the number of word responses to analyse was in fact 1,664. This figure indicates the amount of the raw data in the calculations.

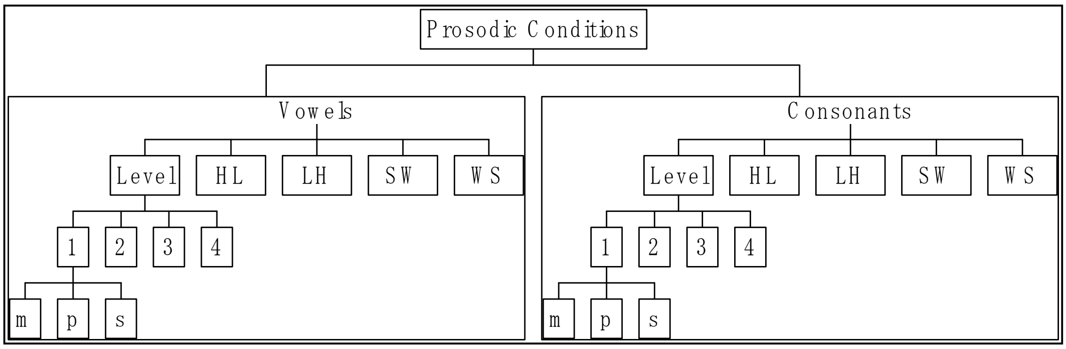


This figure exemplifies the stimuli of CVCV-CVVCV to test /ɑ/ and /ɑɑ/ for a Finnish subject. The white circle shows the ratio of the 'uncertain' category. The number on the horizontal scale at the bottom shows the numbers 1-16 of the stimulus continuum in 10 ms increments. S = short, L = long, and U = uncertain. U = BR ((less than 100% from the responses)

Figure 4.3 Illustration of categorisation to show boundary range.

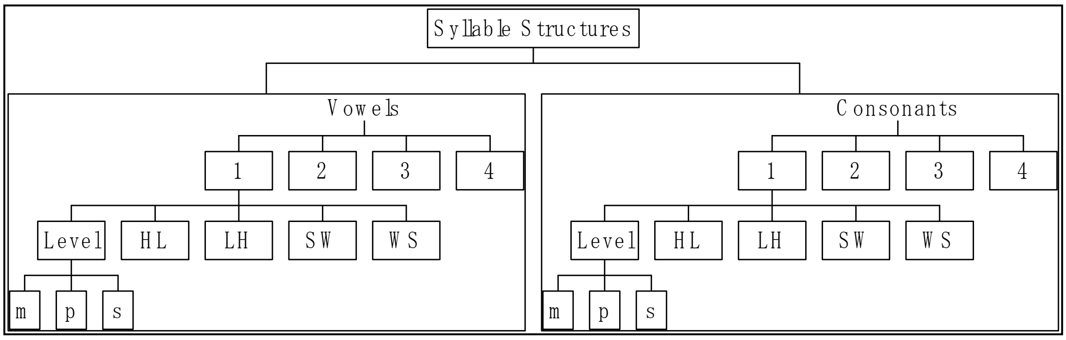
4.3 Methods of analysis

The experimental designs are illustrated as flow charts (Figures 4.4 and 4.5). In Figure 4.4, '1', '2', '3' and '4' imply four kinds of syllable structure, which have five kinds of branching prosodic conditions respectively, and each prosodic condition has three branches of three different kinds of consonant. Only one vowel, /ɑ-ɑɑ/, was tested, surrounded by /m, mm, p, pp, s, ss/. The consonants tested are /m-mm, p-pp, s-ss/, surrounded by /ɑ, ɑɑ/. I illustrated only one example of the branching of '1'. The rest, '2', '3', and '4', have the same branching. In Figure 4.5, five different prosodic conditions, 'Level', 'HL', 'LH', 'SW' and 'WS', have four kinds of branching syllable structure '1', '2', '3' and '4', which have three different branching kinds of consonant. The vowels tested are only /ɑɑ/, surrounded by /m, mm, p, pp, s, ss/ and the consonants tested are /m, mm, p, pp, s, ss/, surrounded by /ɑɑ/, as in Figures 4.4 and 4.5. I illustrated only one example of the branching of 'Level', but 'HL', 'LH', 'SW' and 'WS' have the same branching. The syllable structures of '1', '2', '3' and '4' for vowels are different from those in consonants '1', '2', '3' and '4' (cf. Table 4.1). The subjects were tested in the last layered part by adopting the method of limits. PSE was calculated by applying the complete series method. The mean values and overall mean values were calculated based on these charts. Therefore, the (overall) mean values of all



1, 2, 3 and 4 = syllable structures.

Figure 4.4 The flow chart of syllable structures in the analysis.



1, 2, 3 and 4 = syllable structures.

Figure 4.5 The flow chart of prosodic conditions in the analysis.

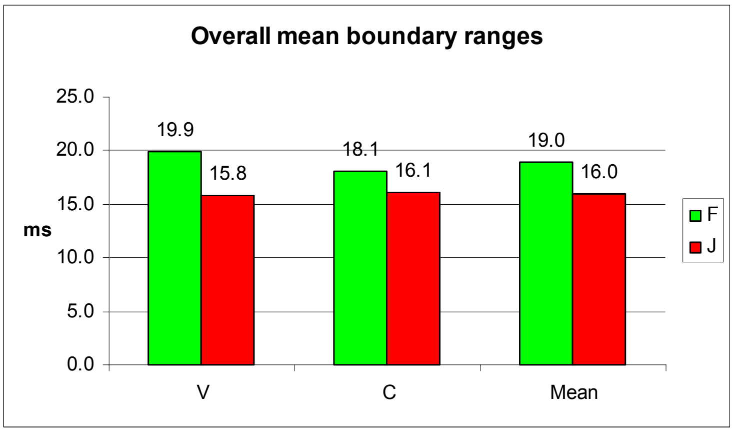
responses were compared between vowels and consonants of each language, based on syllable structures and variable prosodic conditions. There are 120 kinds of condition for the perception tests conducted for this chapter. Because of the very large amount of data, I did not consider all individual differences between the subjects in both Finnish and Japanese. In all statistical analysis, I used the mean values of the subjects for both languages. Therefore, the individual difference among seven informants within each language was calculated as the mean value. Neither did I conduct t-tests for all 120 conditions, because the number of conditionswere too great for test purposes (see Section 4.1) to illustrate major differences and to achieve significant results. In analysis of variance, I considered only the differences between syllable structures and prosodic differences, and between the two languages, since there are more than two variants to be compared and it is not possible to use ANOVA for all condition analysis at a time. The term *n* is used for the number of subjects and *N* for the number of data used. ‘Range’ (*R*) was ascertained from the difference value between the minimum and maximum mean value, but ‘difference’ (D) between only two mean values. The point of subjective equality (PSE), which is the crossover point of the two lines (S, L) in Figure 4.3, is obtained from the minimum long segment (B in Fig. 4.1) minus half the value of the perceptual boundaries (PB) or maximum short segment (A in Fig. 4.1) plus half the value of the PB, as in the following formula.

$$\text{PSE} = \text{B} - \frac{PB}{2} \quad \text{or} \quad \text{A} + \frac{PB}{2}$$

4.4 Results and analysis of BR

4.4.1 Overall mean BR

The overall mean values of the perceptual boundary range, i.e., the uncertainty area, in all responses were 19 ms for Finnish and 16 ms, for Japanese, as shown in Figure 4.6, when all perceptual boundary ranges for vowels and consonants were pooled. The overall mean durational values of the boundary range for the vowels were longer in Finnish (19.9 ms) than in Japanese (15.8 ms). The same values for the consonants were also longer in Finnish (18.1 ms) than in Japanese (16.1 ms). These values show that the overall perceptual boundary ranges are longer in Finnish than in Japanese. In other words, the Japanese subjects made their decision in a shorter time (*Me* 10 ms, *SD* 7.95 ms, *R* 40 ms) than their Finnish counterparts (*Me* 20 ms, *SD* 10.07 ms, *R* 50 ms) in differentiating between short and long.



V=vowels, C=consonants. The number of response words was 1,664 (*N*). *n*=14.

Figure 4.6 Overall mean perceptual boundary range durations of vowels and consonants, and the mean values for Finnish and Japanese.

4.4.2 Distribution of BR

Response time counts in Finnish and Japanese are listed in Table 4.4 in each perceptual boundary range between 10 ms and 60 ms. The corresponding histogram is illustrated in Figure 4.7. The number of vowel and consonantal perceptual boundary ranges were scattered, mainly from 10 ms to 40 ms, with a gradual decrease in both languages. Finnish had a wider distribution in degree of boundary range (10 – 60ms) than Japanese (10 – 50 ms).

4.4.3 Perceptual boundary ranges in different word structures

The overall mean durations (ms) of the perceptual boundary range (BR) for vowels and consonants according to the syllable structures are analysed. (See also Appendix 7)

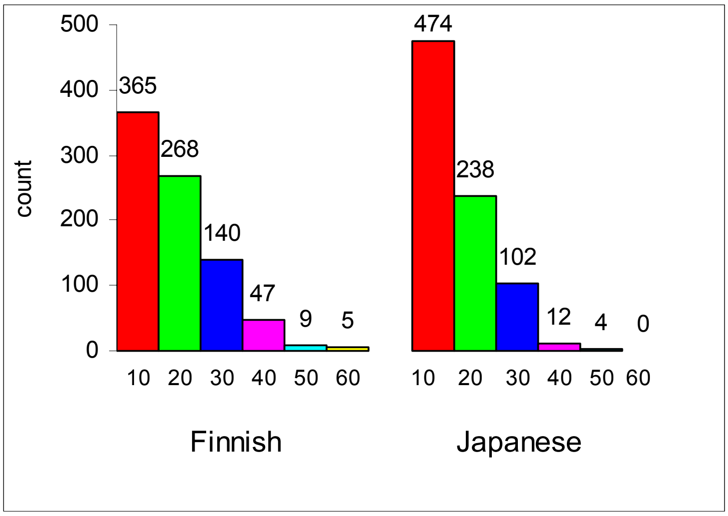
4.4.3.1 BR, *R* and *SD* durations – vowels

The overall mean values of the BR, *R* and *SD* for vowels in four syllable structures between Finnish and Japanese are listed in Table 4.5. The mean values under diffent prosodic conditions are listed within each overall mean value. Table 4.6 lists the mean value of the BR (ms), *R* (ms) and *SD* (ms) for vowels in four syllable structures under different consonants (C: m, mm, p, pp, s, ss) in Finnish and Japanese. The values of BR were translated into Figure 4.8.

It is clear that the variations in the Finnish BR for vowels were greater than those in Japanese under any consonantal influence. The variations for Japanese were grouped in the same durational areas. The Finnish BR of vowels were particularly higher in the /CVVCV/ – /CVVCVV/ structure. Those under /m – mm/ were dispersed, depending on the structure. The *R* and *SD* of Finnish vowels were much longer and higher than their Japanese counterparts.

Table 4.4 Response time count in the perceptual boundary range (BR) for vowels and consonants.

	Finnish		Japanese	
Boundary Range (ms)	Count	Ratio	Count	Ratio
10	365	43.8%	474	57.1%
20	268	32.1%	238	28.7%
30	140	16.8%	102	12.3%
40	47	5.6%	12	1.4%
50	9	1.1%	4	0.5%
60	5	0.6%	0	0.0%
Total	**834**	**100.0%**	**830**	**100.0%**



The number on the horizontal scale at the bottom shows each boundary range (ms). Count totalled 1,664: Finnish = 834, Japanese = 830. Number of subjects: *n* = 14.

Figure 4.7 Response time count in the perceptual boundary range (BR) for Finnish and Japanese subjects.

4.4.3.2 BR, *R* and *SD* durations – consonants

The overall mean values of the BR, *R* and *SD* for consonants in four syllable structures are listed between Finnish and Japanese in Table 4.7. The mean values under diffent prosodic conditions are listed within each overall mean value. The mean of the BR (ms), *R* (ms) and *SD* (ms) for consonants in four syllable structures in Finnish and Japanese are listed in Table 4.8, according to consonant (C: m – mm, p – pp, s – ss). Table 4.8 is translated into Figure 4.10. Compared to the vowel BR, those of the consonants were grouped in the same durational areas in both Japanese and Finnish regardless of structure. The Japanese BR in /p – pp/ were shorter than those of Finnish, but the Japanese *R* and *SD* were longer and higher than their Finnish counterparts.

Table 4.5 The mean durational comparisons of the BR, *R* and *SD* for vowels within prosodic conditions in Finnish and Japanese under four syllable structures.

(ms)

SS	PC	F. (ms)	J. (ms)	SS	PC	F. (ms)	J. (ms)
CVCV-CVCVV	Level	21.0	15.7	CVCVV-CVVCVV	Level	15.7	17.6
	HL	21.0	16.2		HL	17.6	15.2
	LH	18.1	14.8		LH	18.6	16.7
	SW	19.0	14.8		SW	20.0	15.7
	WS	20.0	13.8		WS	18.1	17.6
	Mean	**19.8**	**15.0**		**Mean**	**18.0**	**16.6**
	R	**7.1**	**2.9**		***R***	**5.7**	**4.8**
	SD	**1.2**	**0.9**		***SD***	**1.6**	**1.1**
CVCV-CVVCV	**Level**	**17.6**	**14.3**	CVVCV-CVVCVV	Level	24.8	16.5
	HL	16.2	16.2		HL	27.6	15.8
	LH	14.8	16.2		LH	21.0	14.7
	SW	16.7	14.8		SW	24.3	19.5
	WS	17.6	14.3		WS	29.0	15.7
	Mean	**16.6**	**15.1**		**Mean**	**25.3**	**16.5**
	R	**4.3**	**5.2**		***R***	**11.9**	**5.4**
	SD	**1.2**	**1.0**		***SD***	**3.1**	**1.8**

SS = syllable structure, PC = prosodic conditions, F. = Finnish, J. = Japanese.

Table 4.6 The mean durational comparisons of the BR, *R* and *SD* for vowels in four syllable structures under different consonants in Finnish and Japanese.

	/m/		/p/		/s/	
Syllable Structure	Finnish	Japanese	Finnish	Japanese	Finnish	Japanese
CVCV-CVCVV	20.9	15.4	18.9	14.6	19.7	15.1
CVCV-CVVCV	16.3	15.1	16.3	15.7	17.1	14.6
CVCVV-CVVCVV	16.6	18.6	16.9	13.7	20.6	17.4
CVVCV-CVVCVV	24.6	17.4	25.1	16.4	26.3	15.6
Mean	**19.6**	**16.6**	**19.3**	**15.1**	**20.9**	**15.7**
R	**8.3**	**3.5**	**8.8**	**2.7**	**9.2**	**2.8**
SD	**3.9**	**1.6**	**4.1**	**1.2**	**3.9**	**1.2**

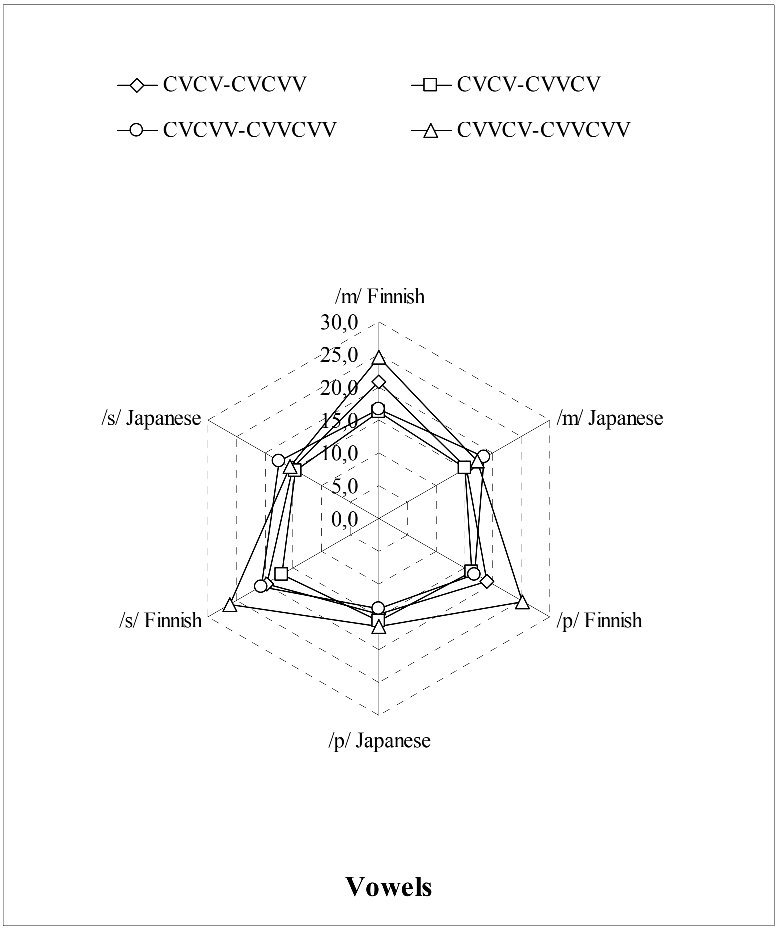
Table 4.7 The mean durational comparisons of the BR, *R* and *SD* durations for consonants within prosodic variants in Finnish and Japanese under four syllable structures.

SS	PC	F. (ms)	J. (ms)	SS	PC	F. (ms)	J. (ms)
CVCV-CVCCV	Level	21.4	13.8	CVVCV-CVVCCV	Level	18.9	16.2
	HL	15.2	15.0		HL	15.8	18.1
	LH	18.1	16.2		LH	18.1	17.1
	SW	19.5	13.3		SW	17.1	15.7
	WS	17.6	14.3		WS	19.0	18.1
	Mean	**18.4**	**14.5**		**Mean**	**17.8**	**17.0**
	R	**8.6**	**4.8**		***R***	**6.3**	**4.8**
	SD	**2.3**	**1.1**		***SD***	**1.4**	**1.1**
CVCVV-CVCCVV	Level	17.1	15.7	CVVCVV-CVVCCVV	Level	19.5	15.7
	HL	17.0	17.1		HL	18.0	15.7
	LH	17.6	17.0		LH	19.0	16.7
	SW	16.2	16.5		SW	16.7	17.1
	WS	20.0	14.5		WS	18.6	18.1
	Mean	**17.6**	**16.2**		**Mean**	**18.4**	**16.7**
	R	**19.0**	**16.2**		***R***	**8.1**	**5.7**
	SD	**1.4**	**1.1**		***SD***	**1.1**	**1.0**

SS = syllable structure, PC = prosodic conditions, F. = Finnish, J. = Japanese.

Table 4.8 The mean durational comparisons of the BR, *R* and *SD* for consonants in four syllable structures in Finnish and Japanese.

	/m – mm/		/p – pp/		/s – ss/	
Syllable Structure	F. (ms)	J. (ms)	F. (ms)	J. (ms)	F. (ms)	J. (ms)
CVCV-CVCCV	18.2	14.9	18.0	12.4	18.9	16.3
CVCVV-CVCCVV	16.8	15.4	17.7	15.4	18.3	17.8
CVVCV-CVVCCV	15.8	17.1	19.1	16.3	18.6	17.7
CVVCVV-CVVCCVV	20.0	17.7	19.4	15.4	15.7	16.9
Mean	**17.7**	**16.3**	**18.6**	**14.9**	**17.9**	**17.2**
R	**4.2**	**2.8**	**1.7**	**3.9**	**3.2**	**1.5**
SD	**1.8**	**1.4**	**0.8**	**1.7**	**1.4**	**0.7**



/m, p, s/ are the consonants associated with the vowels.

Figure 4.8 Durational comparisons of the BR (ms) for vowels related to consonants in four syllable structures for Japanese and Finnish.

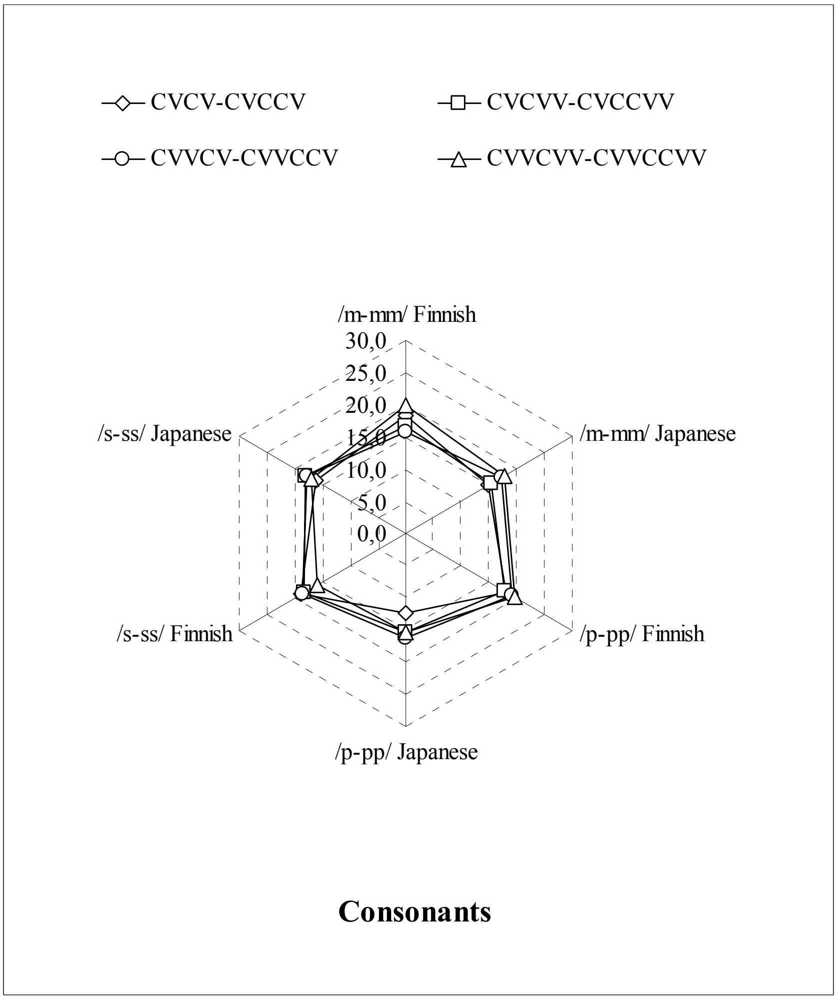
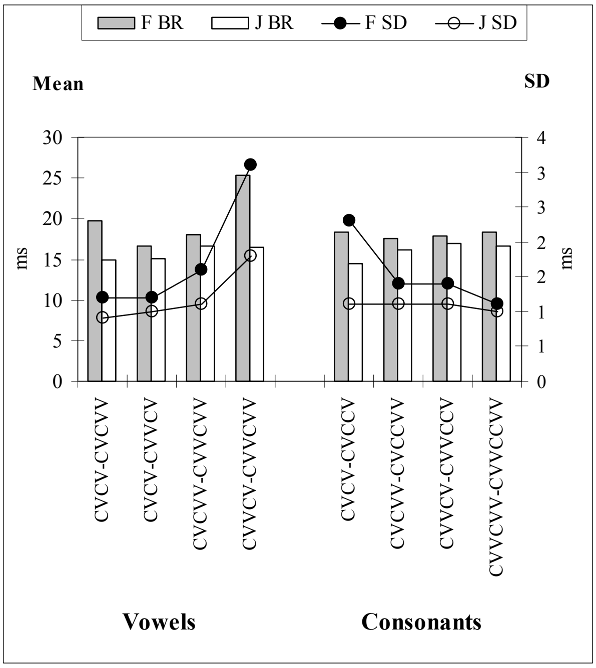


Figure 4.9 The durational comparisons of the BR (ms) of consonants in four syllable structures for Japanese and Finnish.



The left axis (bars) shows the overall mean values of BR and the right (circles on lines) the standard deviation (*SD*).

Figure 4.10 The overall mean durations of the BR and *SD* within each syllable structure for vowels and consonants between Finnish and Japanese.

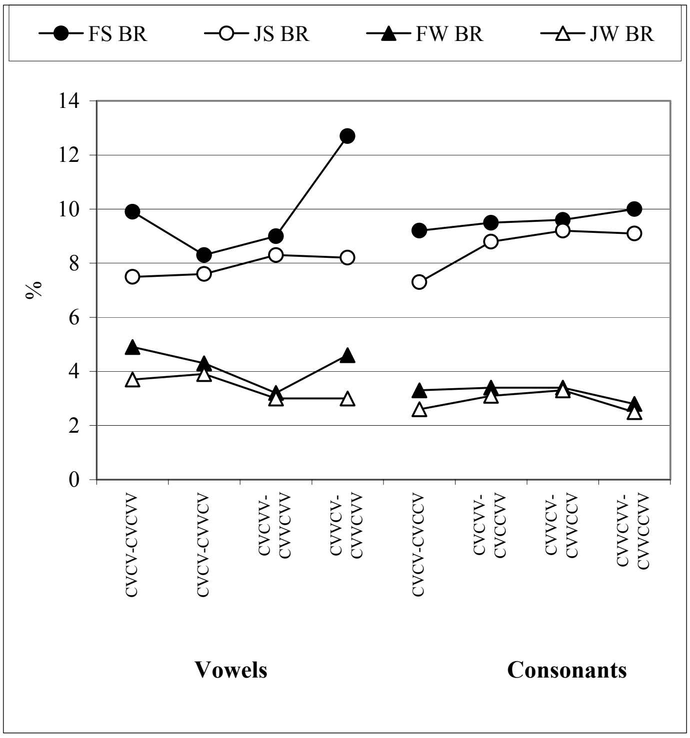
The relationships between the overall BR and *SD* values for vowels and consonants in the four syllable structures are illustrated in Figure 4.10, based on Tables 4.5 and 4.7. The Finnish vowel in the structure /CVVCV/-/CVVCVV/ had the longest mean value and *SD* of all among the vowels and consonants. For BR, *R* and *SD* under the various syllable structures, it was found that the Japanese subjects differentiated both vowels and consonants within a shorter boundary range. The *R* and *SD* were also lower for Japanese than their Finnish counterparts in all four structures, except for R in the /CVCV/-/CVVCV/ structure (J. 5.2 ms > F. 4.3 ms). In terms of the BR, the Finnish vowel in /CVVCV/-/CVVCVV/ structure was the highest among the all the structures. The Japanese vowels mostly had stable values in any syllable structure. The Japanese vowels mostly had stable values in any syllable structure. The BR value patterns of consonants in both Finnish and Japanese look alike in any structure, although the Japanese consonants in /CVCV/-/CVCCV/ had slightly lower values than the rest. In terms of *R*, the consonants in the /CVCVV/-/CVCCVV/ structure had considerably high values for all four structures (19 ms for Finnish and 16.2 ms for Japanese: F > J).

The patterns of *R* in the remaining structures were relatively parallel to those of BR for vowels and consonants in both Finnish and Japanese. In terms of *SD*, the patterns were similar for vowels and consonants in both Finnish and Japanese. The overall standard deviation (*SD*) for vowels was longer in Finnish (1.2 ms ~ 3.1 ms) than in Japanese (0.9 ms ~ 1.8 ms): F > J. There was a tendency for the *SD* to become longer for vowels the longer the word durations were, while the reverse applied to consonants.

4.4.3.3 BR, *R* and *SD* ratios within the segment and word

The durational ratios of the perceptual boundary ranges (Mean = BR) for vowels and consonants within the segment and word between Finnish and Japanese are listed in Table 4.9 according to the four syllable structures. Based on Table 4.9, the overall BR for vowels and consonants within the segment and word between Finnish and Japanese are illustrated in Figure 4.11. In Figure 4.11, the two upper lines show the BR ratios within the segment. The two lower lines show the BR durational ratios within the word. In terms of BR within within the segment, the overall mean ratios between the languages were higher in Finnish (10.0%) than in Japanese (7.9%) for vowels. Those of the consonants (9.6% for F., 8.6% for J.) were lower than the vowels. The overall mean ratios between the languages within the word were thus higher in Finnish (4.2% for V, 3.2% for C) than in Japanese (3.4% for V, 2.9% for C) for both vowels and consonants.In terms of *R*, the overall mean ratios between the languages were higher in Finnish (7.3%) than in Japanese (6.0%) for vowels within the segment. Those of the consonants (6.0% for F., 4.8% for J.) were lower than the vowels. The overall ratios between the languages within the word were higher in Finnish (3.0% for V, 2.7% for C) than in Japanese (2.4% for V, 2.2% for C) for both vowels and consonants. In terms of *SD*, the overall mean ratios between the languages were higher in Finnish (0.5%) than in Japanese (0.2%) for vowels within the segment. Those of the consonants (0.2% for F., 0.0% for J.) were lower than the vowels. The overall ratios between the languages within the word were higher in Finnish (0.2% for V, 0.2% for C) than in Japanese (0.1% for V, 0.1% for C) for both vowels and consonants. There was a clear difference in the patterns in the perceptual boundary ranges, particularly for the vowels, according to the word structure within the segment between Finnish and Japanese, whereas these patterns became similar within the word. The Japanese also perceived consonant differentiations within a shorter BR, narrower *R* and lower *SD* than their Finnish counterparts in all four structures within the segment and word. It is noted that the

Finnish *SD* was noticeably high for the vowels. We can observe that the Finnish BR of vowels within the segment were explicitly affected by the word structural differences, compared to those of the Japanese. On the other hand, the boundary range ratios of consonants were quite stable in any syllable structure, compared to those of vowels in both languages. The Japanese vowels and consonants were not affected very much by the word-structural differences.



F. = Finnish, J. = Japanese, S = segment, W = word.

Figure 4.11 The overall mean ratios of the perceptual boundary ranges (BR) for vowels and consonants within the segment and word in Finnish and Japanese.

Table 4.9 The mean durational ratios of the BR, *R* and *SD* within the segment and word for vowels and consonants according to the syllable structure.

			Segment		Word	
V/C	Syllable structure		Finnish	Japanese	Finnish	Japanese
V	CVCV – CVCVV	Mean	9.9%	7.5%	4.9%	3.7%
		R	1.4%	1.2%	1.7%	0.7%
		SD	0.6%	0.5%	0.28%	0.25%
	CVCV – CVVCV	Mean	8.3%	7.6%	4.3%	3.9%
		R	1.4%	1.0%	1.1%	1.4%
		SD	0.6%	0.5%	0.29%	0.26%
	CVCVV – CVVCVV	**Mean**	9.0%	8.3%	3.2%	3.0%
		R	2.1%	1.2%	1.0%	0.8%
		SD	0.8%	0.5%	0.28%	0.19%
	CVVCV – CVVCVV	**Mean**	12.7%	8.2%	4.6%	3.0%
		R	4.0%	2.4%	2.2%	1.0%
		SD	1.6%	0.9%	0.61%	0.33%
	Overall	**Mean**	10.0%	7.9%	4.2%	3.4%
		R	7.3%	6.0%	3.0%	2.4%
		SD	0.5%	0.2%	0.2%	0.1%
C	CVCV – CVCCV	**Mean**	9.2%	7.3%	3.3%	2.6%
		R	3.1%	1.4%	1.6%	0.8%
		SD	1.1%	0.6%	0.61%	0.33%
	CVCVV – CVCCVV	**Mean**	9.5%	8.8%	3.4%	3.1%
		R	2.1%	1.4%	3.7%	3.1%
		SD	0.8%	0.6%	0.61%	0.33%
	CVVCV – CVVCCV	**Mean**	9.6%	9.2%	3.4%	3.3%
		R	1.9%	1.3%	1.2%	0.9%
		SD	0.8%	0.6%	0.43%	0.20%
	CVVCVV – CVVCCVV	**Mean**	10.0%	9.1%	2.8%	2.5%
		R	1.5%	1.4%	1.2%	0.9%
		SD	0.6%	0.6%	0.17%	0.16%
	Overall	**Mean**	9.6%	8.6%	3.2%	2.9%
		R	6.0%	4.8%	2.7%	2.2%
		SD	0.2%	0.0%	0.2%	0.1%

4.4.4 Perceptual boundary ranges in various prosodic variants

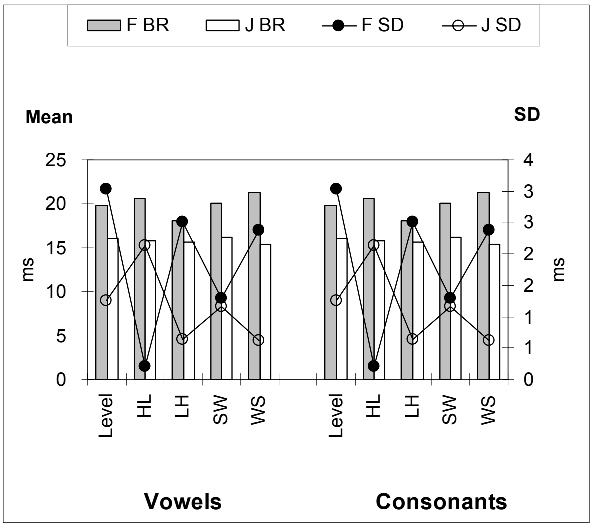
The overall mean durations of boundary range durations (mean = BR), variations (*R*), and standard deviations (*SD*) for vowels and consonants according to five prosodic variants, Level, HL, LH, SW, and WS, are listed in Table 4.10. The BR and *SD* were translated into Figure 4.12. The overall mean values of the BR of vowels in five prosodic differences for Japanese and Finnish according to the surrounding consonant (C: m, mm, p, pp, s, ss) are listed in Table 4.11, which was translated into Figure 4.13. The overall mean values of the BR of consonants in five prosodic differences for Japanese and Finnish according to the consonant (C: m-mm, p-pp, s-ss) are also listed in Table 4.12, which was translated into Figure 4.14.

Overall mean BR, *R* and *SD* durations for the vowels were shorter and smaller in Japanese than in Finnish. The overall mean vowel (BR) durations were 19.94 ms for Finnish and 15.82 ms for Japanese: F > J. The overall mean range (*R*) durations were 9.14 ms for Finnish and 2.96 ms for Japanese, so that it was much longer in Finnish than in Japanese: F > J. The overall mean *SD* durations were 4.04 ms for Finnish and 1.36 ms for Japanese: F > J.

Overall mean BR, *R* and *SD* durations for the consonants were shorter and smaller in Japanese than in Finnish. The overall mean consonantal (BR) durations were 18.02 ms for Finnish and 16.14 ms for Japanese: F > J. The overall mean range (*R*) durations were 2.84 ms for Finnish and 2.01 ms for Japanese: F > J. The overall *R* in particular was shorter than the vowel *R* in Finnish. The overall mean *SD* durations were 1.22 ms for Finnish and 1.34 ms for Japanese: F < J. This indicates that the Japanese differentiated long segments from short in less time, and that the ranges between prosodic conditions were smaller in Japanese, but that the Japanese perception was more stable in the vowel but not in the consonant differentiation than the Finnish.

Table 4.10 The overall mean durational comparisons of the BR durations (mean), *R* and *SD* for vowels and consonants in five PC. PC = prosodic conditions.

	Vowels			Consonants		
PC	Syllable Structure	F. (ms)	J. (ms)	Syllable structure	F. (ms)	J. (ms)
Level	Mean	19.8	16	Mean	19.2	15.4
	R	9.1	3.3	*R*	4.3	2.4
	SD	4	1.4	*SD*	1.8	1.1
HL	Mean	20.6	15.9	Mean	16.5	16.5
	R	11.4	1	*R*	2.8	3.1
	SD	5.1	0.5	*SD*	1.2	1.4
LH	Mean	18.1	15.6	Mean	18.2	16.8
	R	6.2	2	*R*	1.4	0.9
	SD	2.6	1	*SD*	0.6	0.4
SW	Mean	20	16.2	Mean	17.4	15.7
	R	7.6	4.7	*R*	3.3	3.8
	SD	3.2	2.2	*SD*	1.5	1.7
WS	Mean	21.2	15.4	Mean	18.8	16.3
	R	11.4	3.8	*R*	2.4	3.8
	SD	5.3	1.7	*SD*	1.0	2.1

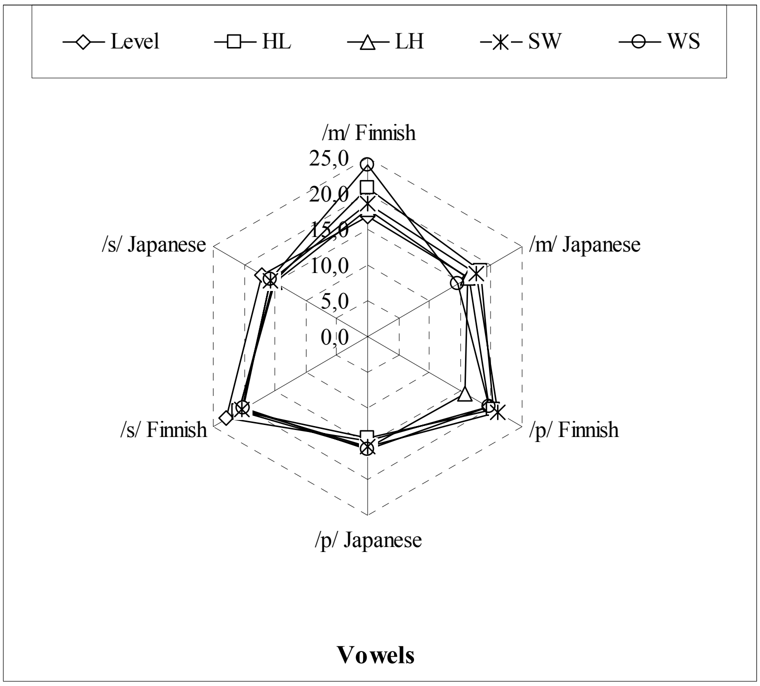


The left axis (bars) shows the overall mean values (ms) and the right (circles on lines) the standard deviation (ms).

Figure 4.12 The overall mean durations of the BR and *SD* for vowels and consonants between Finnish and Japanese according to each prosodic variant.

Table 4.11 The mean durational comparisons of the BR of vowels in five prosodic differences.

PC	/m/		/p/		/s/	
	F. (ms)	J. (ms)	F. (ms)	J. (ms)	F. (ms)	J. (ms)
Level	16.8	16.4	19.6	14.6	22.9	17.1
HL	20.7	18.2	20.4	14.1	20.7	15.2
LH	17.9	16.3	15.7	15.5	20.7	15.0
SW	18.6	17.5	21.1	15.4	20.4	15.7
WS	23.9	14.6	19.6	15.7	20.0	15.7



/m, p, s/ means that the vowel is surrounded by the consonants /m, mm, p, pp, s, ss/.

Figure 4.13 The mean durational comparisons of the BR (ms) of vowels in five prosodic differences according to consonant.

Table 4.12 The mean durational comparisons of the BR of consonants in five prosodic differences for Japanese and Finnish.

	/m-mm/		/p-pp/		/s-ss/	
	F. (ms)	J. (ms)	F. (ms)	J. (ms)	F. (ms)	J. (ms)
Level	21.1	15.0	17.4	15.0	19.3	16.1
HL	16.0	15.7	17.1	14.6	16.4	18.9
LH	16.4	18.6	20.4	14.3	17.9	17.4
SW	16.0	16.1	18.2	14.6	17.9	16.4
WS	18.9	16.1	19.6	15.7	17.9	16.9

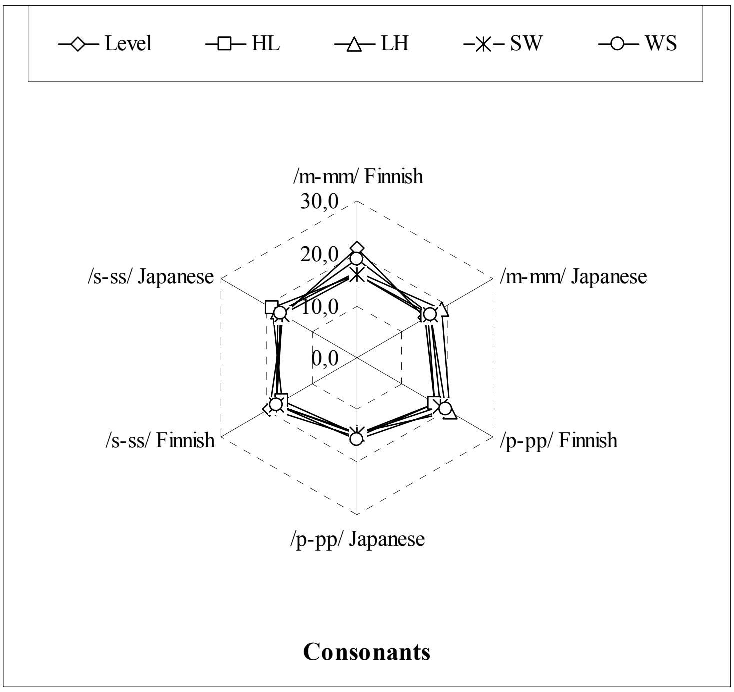


Figure 4.14 The mean durational comparisons of the BR (ms) of consonants in five prosodic differences for Japanese and Finnish.

The durational perceptual boundary areas in five prosodic conditions for the vowels and consonants in order from the shortest to longest are listed below.

Vowels

Finnish:	LH	<	Level	<	SW	<	HL	<	WS
Japanese:	WS	<	LH	<	HL	<	Level	<	SW

Consonants

Finnish:	HL	<	SW	<	LH	<	WS	<	Level
Japanese:	Level	<	SW	<	WS	<	HL	<	LH

I did not find any general tendency for vowels or consonants of Japanese and Finnish.

4.4.4.1 BR and *R* durations – vowels

The BR differences of the perceptual boundary area in four syllable structures for the vowels within the prosodic variants in order from the shortest to longest are as follows.

Level:

Finnish:	CVCVV-CVVCVV	<	CVCV-CVVCV	<	CVCV-CVCVV	<	CVVCV-CVVCVV
Japanese:	CVCV-CVVCV	<	CVCV-CVCVV	<	CVVCV-CVVCVV	<	CVCVV-CVVCVV

HL:

Finnish:	CVCV-CVVCV	<	CVCVV-CVVCVV	<	CVCV-CVCVV	<	CVVCV-CVVCVV
Japanese:	CVCVV-CVVCVV	<	CVVCV-CVVCVV	<	CVCV-CVCVV	=	CVCV-CVVCV

LH:

Finnish:	CVCV-CVVCV	<	CVCV-CVCVV	<	CVCVV-CVVCVV	<	CVVCV-CVVCVV
Japanese:	CVVCV-CVVCVV	<	CVCV-CVCVV	<	CVCV-CVVCV	<	CVCVV-CVVCVV

SW:

Finnish:	CVCV-CVVCV	<	CVCV-CVCVV	<	CVCVV-CVVCVV	<	CVVCV-CVVCVV
Japanese:	CVCV-CVVCV	<	CVCV-CVCVV	<	CVCVV-CVVCVV	<	CVVCV-CVVCVV

WS:

Finnish:	CVCV-CVVCV	<	CVCVV-CVVCVV	<	CVCV-CVCVV	<	CVVCV-CVVCVV
Japanese:	CVCV-CVCVV	<	CVCV-CVVCV	<	CVCVV-CVVCVV	<	CVVCV-CVVCVV

Finnish had the shortest BR in the /CVCV/-/CVVCV/ of the four structures, excluding that in 'Level'. Japanese did not have stable BR according to the structures.

4.4.4.2 BR and *R* durations – consonants

The BR durational differences for the consonants by four syllable structures within the prosodic variants in order from the shortest to longest are as follows.

Level:

Finnish: CVCVV-CVCCVV < CVVCV-CVVCCV < CVVCVV-CVVCCVV < CVCV-CVCCV
Japanese: CVCV-CVCCV < CVCVV-CVCCVV < CVVCVV-CVVCCVV = CVVCV-CVVCCV

HL:

Finnish: CVCV-CVCCV < CVVCV-CVVCCV < CVCVV-CVCCVV < CVVCVV-CVVCCVV
Japanese: CVCV-CVCCV < CVCVV-CVCCVV < CVVCV-CVVCCV < CVVCVV-CVVCCVV

LH:

Finnish: CVCVV-CVCCVV < CVCV-CVCCV = CVVCV-CVVCCV < CVVCVV-CVVCCVV
Japanese: CVCV-CVCCV < CVVCVV-CVVCCVV < CVCVV-CVCCVV < CVVCV-CVVCCV

SW:

Finnish: CVCVV-CVCCVV < CVVCVV-CVVCCVV < CVVCV-CVVCCV < CVCV-CVCCV
Japanese: CVCV-CVCCV < CVVCV-CVVCCV < CVCVV-CVCCVV < CVVCVV-CVVCCVV

WS:

Finnish: CVCV-CVCCV < CVVCVV-CVVCCVV < CVVCV-CVVCCV < CVCVV-CVCCVV
Japanese: CVCV-CVCCV < CVCVV-CVCCVV < CVVCV-CVVCCV = CVVCVV-CVVCCVV

Japanese had the shortest BR in /CVCV/-/CVCCV/ in all structures, but there was no particular pattern in Finnish.

4.4.4.3 BR, *R* and *SD* ratios within the segment and word

Tables 4.13 (BR), 4.14 (*R*), and 4.15 (*SD*) list the overall durational ratios of the perceptual boundary ranges (BR), ranges (*R*) and *SD* within the segment and word for vowels and consonants in Finnish and Japanese according to the prosodic conditions. The BR ratios within the segment and word (see Table 4.13) have been translated into

Figure 4.15. We must remember that since the word durations varied according to their structures, the durational ratios within the word are much smaller than the ratios within the segment.

Mean perceptual boundary ranges (BR)

In Figure 4.15, the two upper lines show the BR ratios within the segment and the two lower lines within the word. In terms of the vowels, Japanese had relatively stable patterns (*R*: 0.4%), regardless of the prosodic conditions, within the segment and word. In Finnish, the LH had least effect of all the conditions, but the WS the most (*R*: 1.6%). In terms of the consonants, Japanese had more stable patterns (*R*: 0.8%) than Finnish (*R*: 1.5%) within the segment. Within the word, the variations among the conditions were mostly stable in both Finnish and Japanese, but the Finnish Level and WS were slightly higher than the others. In Finnish, the LH had least effect, but the WS the most (*R*: 1.6%). One noticeable point was that Japanese LH was slightly higher than that in Finnish within the segment and word.

Range (*R*)

The range ratios were quite similar within the segment and word for both languages, except for the Finnish vowel within the segment. Japanese produced relatively higher *R* ratios in intensity than Finnish within both the segment and word.

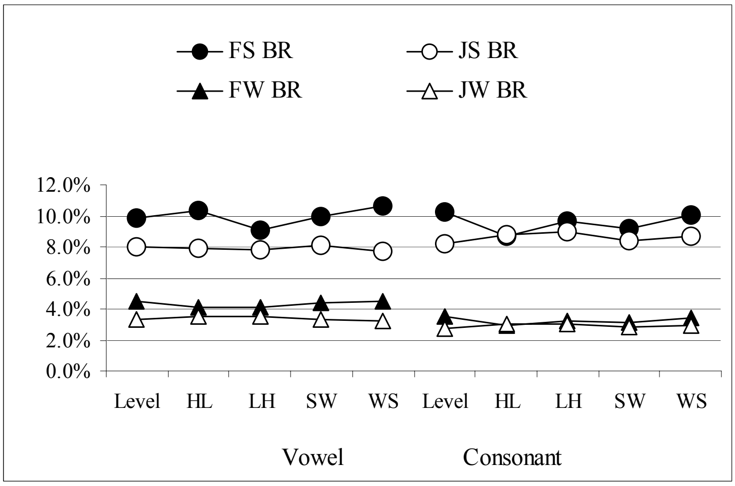
Standard deviation (*SD*)

In terms of the prosodically conditional ranges, there was a significant difference in Finnish vowel differentiations (*SD* = 0.46%), while that of Japanese was much lower (*SD* = 0.21%). The consonantal differentiations between the two languages had a smaller variation in Japanese (*SD* = 0.02%) than in Finnish (*SD* = 0.22%). Observing the ratios only within the word, the differences between the boundary range ratios did not show very great differences, but the variations did have clear differences between the languages.

Comparing the structural differences to prosodically conditional differences, the word structural differences had more effect than the prosodically conditional differences in differentiation between short and long segments. The overall mean consonantal *SD* was smaller than those of the vowels in both languages.

Table 4.13 The overall durational ratios of the BR within the segment and word for vowels and consonants.

	PC	Within Segment		Within Word	
		Finnish	Japanese	Finnish	Japanese
Vowels	Level	9.9%	8.0%	4.5%	3.3%
	HL	10.3%	7.9%	4.1%	3.5%
	LH	9.0%	7.8%	4.1%	3.5%
	SW	10.0%	8.1%	4.4%	3.4%
	WS	10.6%	7.7%	4.5%	3.2%
Consonant	Level	10.2%	8.2%	3.5%	2.8%
	HL	8.7%	8.8%	2.9%	3.0%
	LH	9.6%	9.0%	3.3%	3.0%
	SW	9.2%	8.4%	3.1%	2.8%
	WS	10.0%	8.7%	3.4%	2.9%



F. = Finnish, J. = Japanese, S = segment, W = word. BR = perceptual boundary range.

Figure 4.15 The overall mean ratios of BR for vowels and consonants within the segment and word in Finnish and Japanese.

Table 4.14 The overall mean ratio comparisons of *R* within the segment and word for vowels and consonants in Finnish and Japanese.

	PC	Segment		Word	
		Finnish	Japanese	Finnish	Japanese
Vowel	Level	4.5%	1.7%	2.0%	1.1%
	HL	5.7%	0.5%	1.8%	1.5%
	LH	3.1%	1.0%	0.9%	1.3%
	SW	3.8%	2.4%	2.1%	1.0%
	WS	5.7%	1.9%	2.1%	0.8%
Consonant	Level	1.4%	1.8%	1.0%	0.8%
	HL	2.2%	2.4%	0.5%	1.2%
	LH	1.3%	1.2%	0.6%	0.8%
	SW	1.0%	2.6%	1.0%	0.8%
	WS	2.1%	2.7%	1.1%	0.9%

Table 4.15 The overall mean ratio comparisons of *SD* within the segment and word for vowels and consonants in Finnish and Japanese.

	PC	Segment	Segment	Word	Word
		Finnish	Japanese	Finnish	Japanese
Vowels	Level	2.0%	0.7%	0.9%	0.6%
	HL	2.5%	0.2%	0.8%	0.8%
	LH	1.6%	1.1%	0.9%	0.4%
	SW	1.6%	1.1%	0.9%	0.4%
	WS	2.7%	0.9%	0.9%	0.4%
Consonant	Level	0.6%	0.8%	0.4%	0.4%
	HL	0.9%	1.0%	0.3%	0.5%
	LH	0.5%	0.6%	0.3%	0.4%
	SW	0.4%	1.2%	0.4%	0.4%
	WS	0.9%	1.4%	0.5%	0.4%

PC = prosodic conditions.

4.4.5 Significance of the results

A two-factor analysis of variance of the perceptual boundaries (PB) was conducted (see Appendix 12). The factors were different syllable structures (SS) and prosodic conditional (PC) differences for vowels and consonants between Finnish and Japanese. The overall mean values for both SS and PC were used in the calculation (see Appendices 7 & 8). The results are listed in Table 4.16. (See Appendix 11 for the basis for the calculations.) In Table 4.16, "conditions" implies analysis of variance for vowels and consonants respectively, among different syllable structures (SS) or different prosodic conditions (PC). "Languages" indicates analysis of variance for Finnish and Japanese, depending on syllable structures (SS) or on prosodic conditions (PC). "Overall" indicates analysis of variance of the overall mean values. There are four syllable structures within SS for vowels and consonants respectively (see Table 4.2), and five kinds of prosodic variant within PC for vowels and consonants respectively (see Table 4.3).

Significant differences were found in the following cases:

In the conditional differences: PC V /s-ss/ $p = 0.04$* (*F*: 7.57)

In the language difference between Finnish and Japanese:

SS	C	/p-pp/	$p = 0.02$* (*F*: 24.64)
PC	V	/p-pp/	$p = 0.02$* (*F*: 15.19)
	V	/s-ss/	$p = 0.00006$*** (*F*: *302.41*)
	C	/p-pp/	$p = 0.005$** (*F*: 30.70)

Thus there were more significant cases between the two languages than among conditional differences. When all the data was pooled ("Overall" in Table 4.16), significant differences were found among syllable structure (SS) differences, but significant differences were found among prosodic differences (PC) between the two languages as follows:

PC	V	$p = 0.0018$*** (*F*: 54.73)
	C	$p = 0.04$* (*F*: 9.38).

Table 4.16 The results of ANOVA between SS and PC, and between Finnish and Japanese.

			Conditions		Languages	
			p	*F*	*p*	*F*
	V/C		SS	SS	F/J	F/J
SS	V	m-mm	0.47	1.09	0.25	2.00
		p-pp	0.29	2.04	0.09	5.99
		s-ss	0.40	1.38	0.07	7.96
		Overall	**0.38**	**1.46**	**0.10**	**5.43**
	C	m-mm	0.37	1.53	0.26	1.90
		p-pp	0.25	2.33	0.02*	24.64
		s-ss	0.43	1.26	0.43	0.82
		Overall	**0.67**	**0.56**	**0.06**	**8.17**
PC	V	m-mm	0.74	0.50	0.14	3.35
		p-pp	0.66	0.64	0.02*	15.19
		s-ss	0.04*	7.57	0.00006**	302.41
		Overall	**0.55**	**0.87**	**0.0018*** **	54.73
	C	m-mm	0.81	0.38	0.38	0.97
		p-pp	0.48	1.05	0.01**	30.70
		s-ss	0.99	0.06	0.49	0.59
		Overall	**0.71**	**0.54**	**0.04***	9.38

*: $p<0.05$, **: $p<0.01$, ***: $p<0.001$, *n*: 14. *N*: 144. SS = syllable structures, PC = prosodic conditions. V = vowels, C = consonants. F = Finnish, J = Japanese.

4.5 Results and analysis of minimum long segments

The minimum long segment was acquired by adding the short (S) and uncertain area (U) and it is identical to the end of the uncertain area. The values were compared only within the segments because the word durations varied depending on syllable structure. (See also Appendix 13.)

4.5.1 Syllable structures

The mean absolute durations and the durational ratios for vowels and consonants within the segment according to syllable structures and those of prosodic conditions within the same syllable structure are listed in Appendices 14 and 15 respectively. The mean durational ratios have been translated into Figures 4.16 and 4.17. The means of the minimum durations (and ratios) of a long segment within the segment were 116.4 ms (58%) for Finnish and 125.6 ms (63%) for Japanese in the vowel. The difference between the minimum and maximum values among 20 values (4 SS x 5 PC) ranged from 96.2 ms to 147.6 ms for Finnish and from 103.8 to 149.0 ms for Japanese. Thus the range was smaller in Japanese (11.8 ms, 6.1%) than in Finnish (18.1 ms, 9.0%) in both duration and ratio. The *SD* difference was higher in Finnish (2.66 ms, 1.3%) than in Japanese (1.95 ms, 0.97%).

The prosodic conditional mean ranges were higher in Finnish (6.3 ms) than in Japanese (4.4 ms), indicating that the Finnish reached the minimum durational point of a long vowel in less time than the Japanese. The minimum durational ratios for long consonants within the segment were 68% (F.) and 71% (J.).

The minimum long consonant durations (and ratios) within the segment were 101.0 ms (68%) for Finnish and 110.2 ms (71%) for Japanese. The difference between the minimum and maximum values among 20 values (4 SS x 5 PC) ranged from 91.4 ms (64.1%) to 115.2 ms (72.8%) for Finnish and from 105.5 ms (66.1%) to 123.8 ms (75.8%) for Japanese. The range was slightly smaller in Japanese in duration (7.1 ms) than in Finnish (8.4 ms) but not in ratio (2.8% for Finnish, 3.9% for Japanese). These ratios showed the reverse results to those in vowels. The *SD* difference was higher in Finnish (1.99 ms, 0.7%) than in Japanese (1.3 ms, 0.4%).

4.5.2 Prosodic variants

The absolute minimum long segment durations and durational ratios within the segment under five prosodic conditions and those of syllable structures within the same condition for vowels and consonants are listed in Appendices 16 and 17. The mean durational ratios have been translated into Figures 4.18 and 4.19.

The overall mean minimum long segment durations (and ratios) for vowels within the segment were 116.5 ms (58%) for Finnish and 125.6 ms (63%) for Japanese. The difference between the minimum and maximum values among 20 values (5 PC x 4 SS) ranged from 96.2 ms (48.0%) to 147.6 ms (74.0%) for Finnish and from 103.8 ms (52.0%) to 149.0 ms (75.0%) for Japanese. The overall mean range (*R*) was slightly smaller in Japanese in duration (31.3 ms) than in Finnish (32.8 ms) as well as in ratio (15.8% for Japanese < 16.6% for Finnish). These ratios showed the reverse results to those for vowels. The overall mean *SD* difference was higher in Finnish (14.3 ms, 7.2%) than in Japanese (13.1 ms, 6.4%).

The durational perceptual boundary areas under five prosodic conditions for the vowels in order from the lowest to highest are:

Finnish: SW < LH < Level = HL = WS

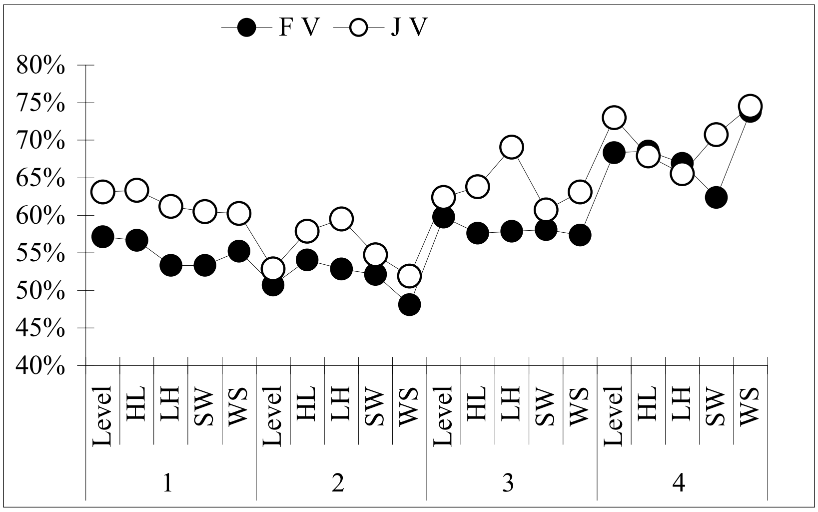
Japanese: SW = WS < Level = HL < LH

The overall mean minimum long consonant durations (and ratios) within the segment were 101.02 ms (67.4%) for Finnish and 110.2 ms (71.2%) for Japanese. The difference between the minimum and maximum values among 20 values (5 PC x 4 SS) ranged from 91.4 ms (64.0%) to 115.2 ms (73.0%) for Finnish and from 96.7 ms (66.0%) to 123.8 ms (76.0%) for Japanese. The overall mean range (*R*) was slightly larger in duration (18.3 ms) in Japanese than in Finnish (17.5 ms) but not in ratio (6.4% for Finnish and 6.2% for Japanese). These ratios showed the reverse results to those for vowels. The overall mean *SD* difference was very slightly higher in Japanese (8.08 ms) than in Finnish (7.8 ms), and the ratios were the same. The durational perceptual boundary areas under five prosodic conditions for the consonants in order from the lowest to highest are:

Finnish: SW < WS < Level = HL = LH

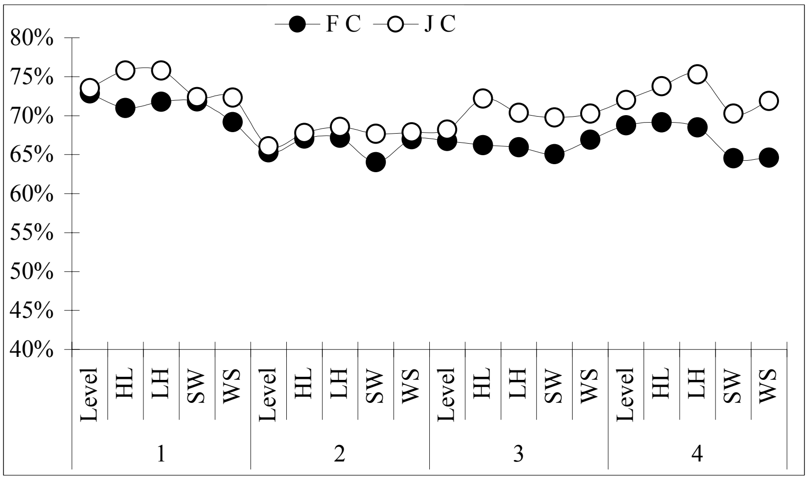
Japanese: Level = SW < WS < HL < LH

The ratios within each prosodic condition show quite similar patterns according to the syllable structures in both Finnish and Japanese. Comparing the structural differences with the prosodic conditional differences, the structural differences had more effect than the conditional differences in differentiating between short and long segments.



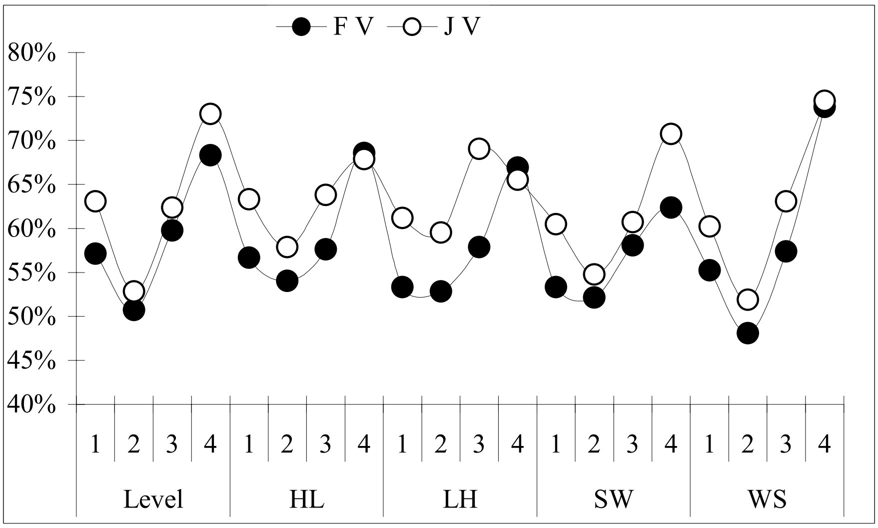
1 – 4 shows the syllable structure: 1 = CVCV-CVCVV, 2 = CVCV-CVVCV,
3 = CVCVV-CVVCVV, 4 = CVVCV-CVVCVV for vowel syllable structures.

Figure 4.16 Minimum durational ratios of long vowels within the segment in four different structures in Finnish and Japanese.



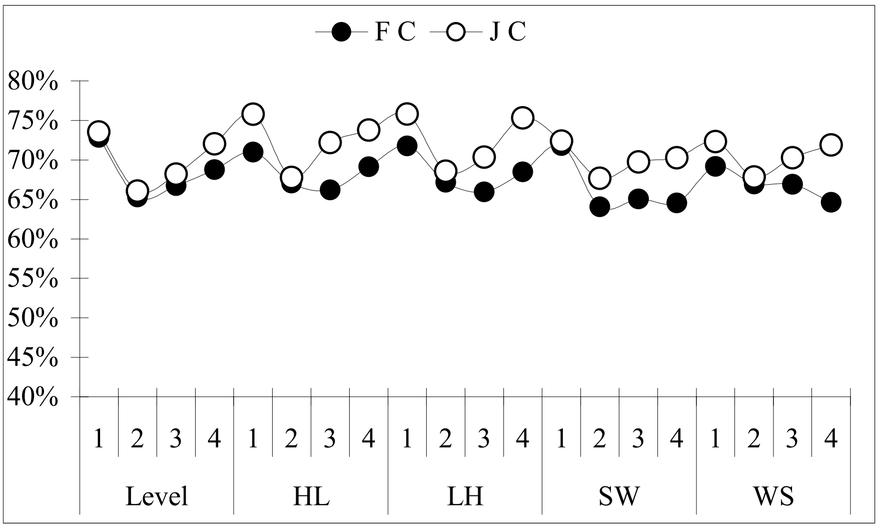
1 = CVCV-CVCCV, 2 = CVCVV-CVCCVV, 3 = CVVCV-CVVCCV,
4 = CVVCVV-CVVCCVV for consonantal syllable structures.

Figure 4.17 Minimum durational ratios of long consonants within the segment in four different structures in Finnish and Japanese.



1 – 4 shows the syllable structure: 1 = CVCV-CVCVV, 2 = CVCV-CVVCV,
3 = CVCVV-CVVCVV, 4 = CVVCV-CVVCVV for vowel syllable structures.

Figure 4.18 Minimum durational ratios of long vowels within the segment in five prosodic conditions in Finnish and Japanese.



1 = CVCV-CVCCV, 2 = CVCVV-CVCCVV, 3 = CVVCV-CVVCCV,
4 = CVVCVV-CVVCCVV for consonantal syllable structures.

Figure 4.19 Minimum durational ratios of long consonants under five prosodic conditions in Finnish and Japanese.

4.6 Results and analysis of maximum short segments

Maximum durations of short segments in perception (see A in Fig. 4.1) can be obtained by deducting perceptual boundary (U) from the minimum long segments (L): S = L - U. The results were compared with minimum long segments in milliseconds (ms) and ratios in Table 4.17. I used the overall mean values in the calculations.

Table 4.17 The durations and ratios of maximum short and minimum long segments in perception.

	Finnish		Japanese	
	Duration (ms)	Ratio	Duration (ms)	Ratio
a:aa	96.5:116.4	1:1.21	109.8:125.6	1:14
m:mm	78.9:96.6	1:1.22	83.4:99.6	1:20
p:pp	86.6:105.2	1:1.21	100.8:115.7	1:15
s:ss	83.5:101.4	1:1.21	98.2:115.3	1:17

The maximum durations of short segments in Japanese were longer than their Finnish counterparts in any quantity differentiation. Finnish ratios were very stable in any quantity differentiation compared to the Japanese counterparts.

PSE values (cf. Section 4.3) are half of the short plus long segmental durations (S + L) in Table 4.17, which are presented in Table 4.18. The values were lower in Finnish than in Japanese in all cases. One reason for this is probably because the Finnish short segments are shorter (in this work) than their Japanese counterparts.

Table 4.18 PSE values.

	Finnish (ms)	Japanese (ms)
a:aa	106.45	117.7
m:mm	87.75	91.5
p:pp	95.9	108.25
s:ss	92.45	106.75

4.7 Summary and discussion

4.7.1 Summary

In this chapter, 24 nonsense word types (1,664 words, 29,120 stimulus responses) were analysed to study durational comparisons in perception between Japanese and Finnish. I summarise the results below. From the above analysis and results, I can draw the following conclusions:

The Japanese perceptual boundary ranges were shorter than their Finnish counterparts in both vowels and consonants in all word structure studies. In other words, the Japanese had a shorter uncertainty time for their "short or long?" decision than their Finnish counterparts in differentiating between short/long vowels and short/long consonants. On the other hand, the standard deviations for Finnish were relatively lower than those of their Japanese counterparts. This agrees with Aoyama's comparisons (2001).

(1) The BR depending on prosodic variants showed rather similar patterns in Finnish and Japanese. However, Finnish had higher variations and *SD* than Japanese in many cases.

(2) Syllable structure affected the perceptual boundary ranges more than the prosodic variants in both languages. The Finnish had greater prosodic variations conditioned by prosody (fundamental frequency and intensity) than Japanese.

(3) Finnish reached the minimum long segment in both vowels and consonants faster than Japanese, ratios which seem to agree with Fujisaki and Sugitou's results (1977) as far as the vowels are concerned, but not for consonants.

(4) Vowel differentiation between short and long took longer than for consonants in both languages.

(5) The Finnish reached the minimum durational point of long vowels and consonants in less time than the Japanese, but the Finnish had wider prosodic conditional variation than the Japanese. The word structural differences were more influential than the prosodic conditional differences in differentiating short segments from long in both languages. The syllable structures are more involved with length

differentiation than the acoustic variations in both Finnish and Japanese.

4.7.2 Discussion

Traditionally perception tests using synthetic stimuli have been done using the dichotomy concept. My method was a challenging to this. My first objective in the perception test was to ascertain the durational ratio between short and long segments, referring to Fujisaki & Sugitou (1977), and the test was thus conducted not at random but in the order of gradual durational increase. This methodology may affect the result in which the perceptual boundary is narrower than in the test at random. In this study I used a trichotomous concept, employing three choices with the possible listener responses ‘short’, ‘uncertain’, and ‘long’.

I conducted the informal perception test using the same test words and same number of informants for two languages, but two choices. The result showed significant differences in the perceptual boundaries. The overall mean perceptual boundary given three choices was longer than for two.

In perception, the overall durational ranges (*R*) between short and long segments were 18.1 ms (F.) and 11.8 ms (J.) for vowels and 8.4 ms (F.) and 7.1 ms (J.) for consonants (all consonants were pooled) within prosodic variants in different syllable structures. The standard deviation (*SD*) was 2.66 ms (F.) and 1.95 ms (J.) for vowels and 1.9 ms (F.) and 1.3 ms (J.) for consonants. This implies that when differentiating a long segment from a short one, both Finnish and Japanese have a perceptual boundary area for their judgement and no sure distinction is possible within the cross-over area.

The stimulus word had a gradual ten millisecond incremental increase. This was because of the limit imposed by the speech synthesiser I used. The perceptual boundary in the perception test using two choices was often 10 ms. This may indicate that the perceptual boundary could be less than 10 ms. Also, the perceptual boundary in the perception test using three choices was sometimes 10 ms. This may suggest that the perceptual boundary for the Finnish and Japanese can be very narrow.

Before this experiment, my preliminary supposition was that the Finnish might be more affected by intensity variants than F0 variants since Finnish has word stress,[58] whereas the Japanese might be more affected by F0 than intensity since Japanese has pitch accent. However, this was not always true as these results revealed. Both

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[58] There are no thorough investigations of the role of auditive cues for word stress.

languages were more affected by F0 than intensity, depend on the structure. Vowels, particularly in Finnish, were more affected by the syllable structural and prosodic variants than consonants. This result can be correlated to that from the production test in Chapter 3. Although the Japanese had wider ranges and standard deviation in production, the result in the perception test was opposite. This may indicate that production and perception are not necessarily correlated (Isei-Jaakkola 2002).

5 Temporal control: /CVNCV/, /CVnCV/, /CVnCCV/

5.1 Introduction

Both Finnish and Japanese have a similar word structure /(C)VnCV/, e.g., *hanki* (F. 'a sort of snow', J. 'half term'), but the symbol /N/ is traditionally used for the phonological moraic nasal and thus also for the coda position in Japanese. Hence, the following notation of the word structures will be /CVNCV/ for Japanese and /CVnCV/ for Finnish. The /N/ in the Japanese /CVNCV/ is a moraic nasal because it is supposed to be approximately one mora in duration. The /CVnCV/ structure in Finnish is counted as bisyllabic, /CVn.CV/, and, according to mora counting, as a three mora structure. The words with the same structure are counted as having three morae in Japanese, /CV|N|CV/. The Japanese speakers perceive the Finnish /CVnCV/ word structure as having three morae. In addition, Finnish has a bisyllabic /$CVnC^1.C^1V$/ word structure, which Japanese does not have. In Finnish, /n/ in /CVnCV/ is in the syllable-final and thus in coda position and /n/ in /$CVnC^1.C^1V$/ is the first consonant in the syllable-final consonant sequence. The Japanese /N/ (as an archiphoneme) is phonetically realised in coda position in the structure /CVNCV/ as various phonemes and allophones as we saw in the above chapter, whereas Finnish /n/ (as an archiphoneme) in coda position has three nasal variants, /n, m, ŋ/. No structure equivalent to the Finnish /CVCCCV/ (e.g., *lantti* 'coin', *lamppu* 'lamp', *pankki* 'bank') occurs in Japanese. It might be possible to describe as /paNQki/ according to Japanese phonology, and the word would be counted as having four morae (as it also has in Finnish). Because the Japanese /CVNCV/ word structure contains qualitatively the same phonemes as both Finnish structures, it is interesting to consider the timing of these structures in both languages and the perception by the Japanese informants when they listen to the Finnish words representing these structures.

5.2 Perception test – dictation and transliteration

Isei (1996) investigated how the Japanese speakers auditively perceived and transliterated the Finnish /CVnC(C)V/ word structure using their mora concept and writing system.

In the present work, Japanese speakers were tested in both transliteration and dictation. The following perception tests were assigned to the Japanese subjects: (A) transliterating Finnish words into Japanese *katakana*, (B) transcribing recorded Finnish words into *katakana* while listening.

5.2.1 Experimental procedure

5.2.1.1 The materials

Two word lists were created for the perception test for Japanese and durational comparisons between Japanese and Finnish (Tables 5.1 and 5.2). Word list 1 had the Finnish /(C)VnCV/ and Japanese /(C)VNCV/ structures having a sequence with the same (phonemic) segments but with a different meaning, and word list 2 had only the Finnish /CVnCCV/ word structure in which /C^1C^1/ were all the voiceless geminate consonants /kk, pp, tt, ss/. In making a common list, I took into consideration phonemes common to both languages presented in Figure 5.1. Hence, there were 29 words for the listening tests.

(C)	V	N/n	C	V
k	ɑ		k	ɑ
s	i		s	i
t	ɯ/u		t	ɯ/u
n	e		n	e
m	o		m	o
j			j	
p			d	
h			p	

Figure 5.1 The phonemes occurring both in Japanese /CVNCV/ and Finnish /CVnCV/ used in the experiment.

Table 5.1 Word list 1: Japanese /(C)VNCV/ and Finnish /(C)VnCV/ words.

		Meaning	
No.	Test word	Japanese	Finnish
1	*pinko*	female name	‘grind’
2	*tanka*	‘Japanese poem’	loanword from Japanese
3	*kanta*	male name	‘opinion’
4	*kanki*	‘joy’	‘rod’, ‘bar’
5	*kansa*	‘inspection’	‘nation’
6	*santa*	male name	‘sand’
7	*sanko*	‘three pieces’	‘pail’
8	*hanki*	‘half period’	‘(a sort of) snow’
9	*panda*	‘panda’, loanword	‘panda’, loanword
10	*sampo*	‘taking a walk’	male name
11	*kampi*	‘dry bark’	‘crank’
12	*tempo*	‘tempo’, (loanword, It.)	‘tempo’, (loanword, It.)
13	*kampa*	‘cold wave’	‘comb’
14	*kompa*	‘party’	‘conundrum’
15	*anki*	‘learning by heart’	female name
16	*inka*	‘catching fire’	female name
17	*inki*	‘gloom’	female name
18	*anna*	‘that kind of’	female name
19	*konna*	‘this kind of’	‘scoundrel’
20	*kannu*	‘Kannu’, loanword	‘pot, can’

Table 5.2 Word list 2: Finnish words in /CVnCCV/ structure.

No.	Test word	Meaning (Finnish)
1	*vamppi*	‘vamp’
2	*kontti*	‘container’
3	*pantti*	‘deposit’
4	*tanssi*	‘dance’
5	*pankki*	‘bank’
6	*lenkki*	‘loop’
7	*penkki*	‘bench’
8	*lamppu*	‘lamp’
9	*pomppu*	‘pomp’

5.2.1.2 Informants

The informants were one Finnish male speaker from Helsinki and one Japanese male from Tokyo dialect speaker.

5.2.1.3 Recording

The recording (Isei, 1996) was made in a quiet room at the Institute of Logopedics and Phoniatrics of Tokyo University. The test words were read in isolation according to the word lists and each word was repeated three times for the listening tests. The informants read the test word as naturally as possible so that there was a pause between word boundaries before and after the test word.

5.2.1.4 Subjects and method

The test words were isolated words in order to avoid confusing the Japanese subjects, since they had no knowledge of Finnish and they would not have known what word was being tested. 49 Japanese subjects, all university students and nearly all Tokyo dialect speakers, participated in two kinds of perception test. First, in the transliteration test from the Finnish alphabet they were told to use the *katakana* form used for foreign words. Second, in the listening test (dictation) the subjects listened to the same word repeated three times, using the language laboratory class headsets. They were given enough time to write down what they heard. The listening test was done on the same day after the transliteration test.

5.2.2 Result

The analysis of dictation and transliteration was based on the mora-counting method, in which one *kana* was counted as one mora. The responses for analysis were 2,842 words (29 words x 49 subjects x 2). All 49 subjects participated in both dictation and transliteration tests. The results in percentages are shown in Figure 5.2.

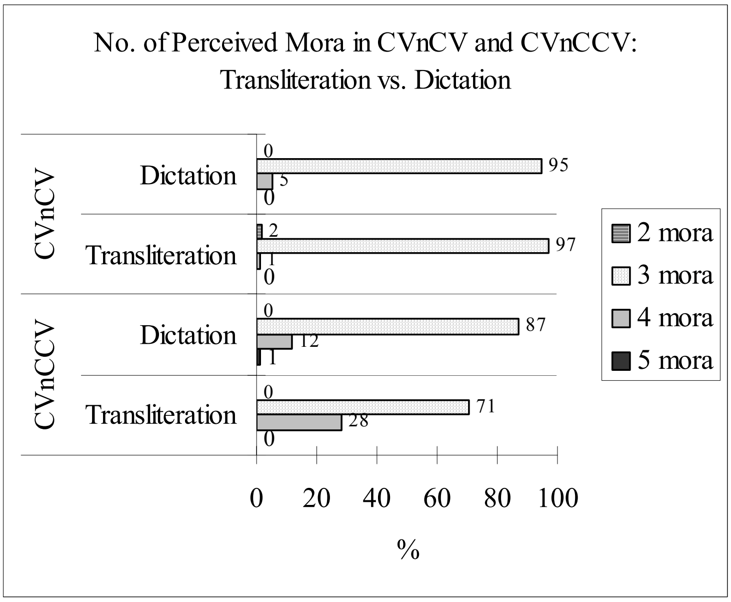

Figure 5.2 Comparison of moraic ratio perceived by 49 Japanese subjects in transliteration and dictation of Finnish /CVnCV/ and /CVnCCV/ words.

In terms of the dictation, nearly 97% of the Japanese subjects perceived /(C)VnCV/ structures as being trimoraic, while less than 87% of them perceived the /CVnCCV/ words as being so. There was a significant difference between their dictation (12%) and transliteration (28%) of /CVnCCV/ words as having four morae. This value of 28% in transliteration might be because the /CVnCCV/ structures used for this experiment do not exist in Japanese, and they attempt to interpret /CC/ as /QC(V)/, i.e., as having two morae. The first part of the /CC/ can be interpreted as /Q/ since the Japanese have been taught to do so.

When comparing the dictation test to the transliteration test, the ratio in the dictation (listening) test was slightly lower (4%) than that in the transliteration test with /(C)VnCV/. It is particularly worth noting that the ratio for perceiving /CVnCCV/ as trimoraic words was as high as approximately 87% in the listening test, whereas that in the transliteration test was 71%, suggesting that there is a clear difference between the test based on listening and that based on orthography.

5.3 Production tests

Isei (1996) studied the durational similarities and the question of whether there is a timing difference in /N, n/ between Japanese and Finnish and /n/ in Finnish /CVnCV/ and /CVnCCV/, using the same materials as in the perception test. In her work, the test words were uttered in isolation. In this study the same test words were embedded in a carrier sentence in order to observe whether there is a difference between these two environments.

According to Lehtonen's (1970) data, the duration of the single /n/ was 59 ms when the test words were uttered in a carrier sentence, while in Aoyama's data (2001) it was 62 ms when the test words were uttered in isolation. Since my purpose was to study. Since my purpose was to study moraic/syllabic ratios within the words, I did not compare the absolute values with their data.

5.3.1 Experiment 1: isolated words

5.3.1.1 The materials and method

For the segmentation, I basically employed the word lists in Tables 5.1 and 5.2 used in the previous perception test, but selected only those words containing the first /CV/ (CV1) and the second /CV/ (CV2). The words with word-medial /nn/ in /CVnCV/ were also eliminated. Six words – *anki*, *inka*, *inki*, *anna*, *konna*, and *kannu* – were thus eliminated from the test words, the number reducing to 23.

Spectrograms were used for segmentations for the durational measurements of /CV-N-CV/, /CV-n-CV/, and /CV-n-CCV/. In terms of /CVnCCV/ it was not possible to test the Japanese speech because such a structure does not exist.

For the durational measurement, I measured three parts of /CV-n/N-CV/ and /CV-n-C^1C^1V/ to get the durational ratios. The measurement value of the word-initial plosives in both word lists did not include the closure part preceding the VOT, but the word-medial plosives did. The words representing the /CVnCCV/ structure contained geminate consonants, /C^1C^1/, and there was no acoustic segmental boundary, for which reason /C^1C^1/ was measured as a long segment. The segmentation was conducted using the spectrogram, while carefully observing pitch and intensity movement at the same time. The word tokens for analysis totalled 111 ((23 + 14 words) x 3 times each). I used the programme *Onsei Rokubunken*[59] for segmentation for the isolated words.

5.3.1.2 Result

Word-initial C and the vowel in the first syllable are presented below as the segment /CV1/, while the word-medial /C(C)/ and vowel in the second syllable are presented as /C(C) V2/ in /CVnC(C)V/. The results for one Finnish and one Japanese speaker are displayed in chart form in Figure 5.3. The numbers in each bar show the mean percentage of each segment (a bar represents the whole word = 100%).

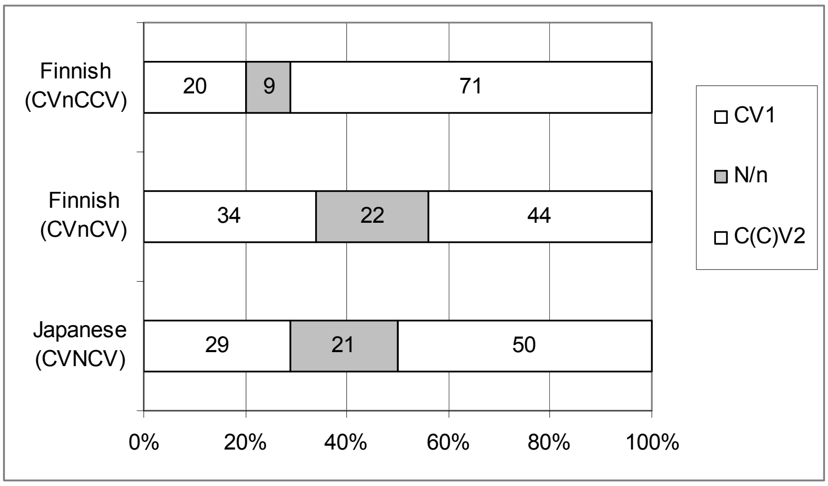

Figure 5.3 Timing relationships between Japanese /CVNCV/ and Finnish /CVnCV/, /CVnCCV/.

The Japanese /CVNCV/ structure is trimoraic, but the temporal distribution in Figure 5.3 shows that /N/ comprises less than a quarter (21%) of the whole word, and the second /CV/ (CV2), which is approximately half the whole word, is much longer than the first /CV/ (CV1, 29%). Hence, no isochronic timing of the morae can be observed. The Finnish /n/ had almost the same durational ratios (22%) as its Japanese counterpart, but the Finnish /CV1/ (34%) was longer than the Japanese /CV1/ (29%) and the Finnish /CV2/ (44%) was shorter than the Japanese /CV2/ (50%) in /CVnCV/. Both the Finnish /CV-n-CV/ and Japanese /CV-N-CV/ had quite similar temporal distributional patterns

[59] Compared to Praat, amplitude movement did not seem to be very reliable.

in ratio within the word. On the other hand, the Finnish /n/ in /CVnCCV/ was much shorter (9%) than its counterpart in /CVnCV/, and /CV1/ was much shorter (20%) and /C(C)V2/ much longer (71%) than their counterparts in /CVnCV/. It is not It is not acoustically possible to compare the Finnish syllable durational ratios between /CVn.CV/ and /CVnC.CV/. However, temporal compensation within the Finnish syllable seems to be obvious as far as these word structures are concerned.

It must be noted that the speech with words was uttered in isolation and that the compensation principle may work within a syllable in Finnish (and Japanese?) or a mora in Japanese (and Finnish?). In addition other factors such as utterance-final lengthening might be involved.

The duration of /N/ varies depending on its environment and thus /N/ is not necessarily isochronous (complementary distribution). Nevertheless, it was revealed that /n/ in /CVnCCV/ was much shorter than /n/ in /CVnCV/.

5.3.2 Experiment 2: test words in a carrier sentence

For the purpose of durational comparison between isolated words and the words read in a carrier sentence, I made another recording.

The recording for this study was made in the recording studio at the Department of Phonetics in University of Helsinki, the recording method being the same as for the isolated words. The informants for the experiment 2 were one Finnish male speaker from Helsinki and one Japanese male (Tokyo dialect) speaker. Their background for each language was the same as in the isolated words.

5.3.2.1 Experimental procedure

For the segmentation, I employed the same word lists as in production test 1 and used the same segmentation method as in that test.

5.3.2.2 The informants, and method

The recording for this study was made in the recording studio at the Department of Phonetics in University of Helsinki, the recording method being the same as for the isolated words. The informants for the experiment 2 were one Finnish male speaker from Helsinki and one Japanese male (Tokyo dialect) speaker. Their background for

each language was the same as in the isolated words.

In the second measurement, the test words were read in a carrier sentence as listed in the word lists and repeated five times. However, I measured only three repetitions, because I did not find significant durational variations between them. The word tokens for an analysis totalled 111 ((23 + 14 words) x 3 times each). I used Praat for the segmentation, and used the same method as for the isolated words for the analysis. The informants, test words, and segmentation method were thus the same.

5.3.2.3 Result

The timing relationships between Japanese /CVNCV/ and Finnish /CVnCV/, /CVnCCV/ are illustrated in Figure 5.4.

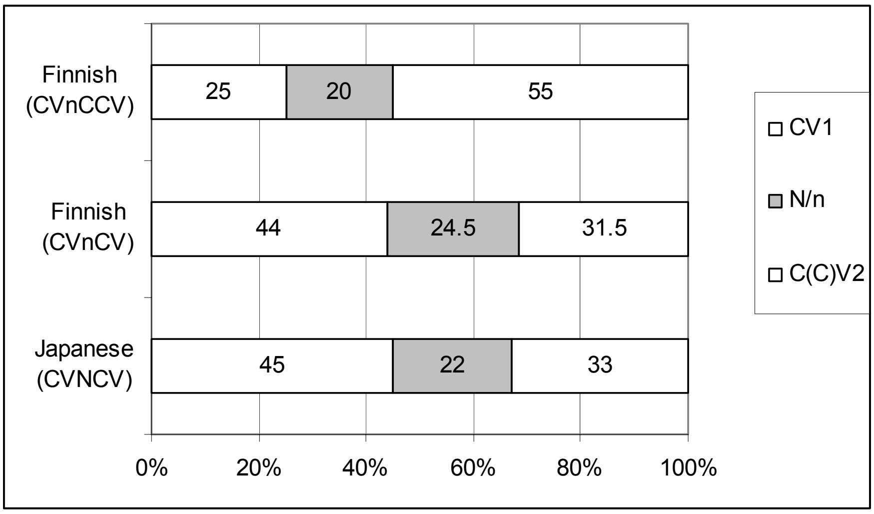

Figure 5.4 Timing relationships between Japanese /CVNCV/ and Finnish /CVnCV/, /CVnCCV/.

The ratio of Finnish /n/ within /CVnCV/ was slightly higher (24.5%) than the Japanese /N/ (22%) in /CVNCV/. The durational ratio patterns within the words representing Japanese /CVNCV/ and Finnish /CVnCV/ were negligible. This result was similar in the test words uttered in isolation. The durational ratio of /n/ in Finnish /CVnCCV/ was higher than that in isolated words, and the durational ratios of CV1 in Japanese /CVNCV/ and Finnish /CVnCV/ were greater than CV2 in a carrier sentence, compared with those in isolated words.

These results confirms that (1) there is a word-final lengthening in the test words uttered in isolation; (2) a temporal compensation works within the word, dependent on the utterance unit.

5.4 Summary and discussion

The above investigations in the perception test and two measurements, based on two speakers in each language (*n*: 2 x 2 = 4) and on 20 test words for Japanese and 29 for Finnish, showed similarities and differences between the bisyllabic word structures: /CVNCV/, /CVnCV/, /CVnCCV/. These 49 meaningful word types were used in perception (2,824 responses) and for segmentation (230 words).

I compared the durations between the Japanese /n/ and Finnish /n/ in the same word structure, and the Finnish /n/ in different word structures, and temporal organisation of moraic/syllabic units within the same and different word structures.

The results revealed that the Japanese mainly perceived both word structures of Finnish, /CVnCV/ and /CVnCCV/, as trimoraic, but more four mora responses were observed in /CVnCCV/ structures compared to those in /CVnCV/. This indicates that Japanese listeners did not particularly apply the /Q/ concept in their auditory interpretation of the foreign segment /-C̲C-/.

In the /CVNCV/ and /CVnCV/ structures the durational ratios of nasal consonants within the word was similar in both Japanese and Finnish words. On the other hand, the durational ratio of Finnish nasals showed a significant difference between the /CVnCV/ and /CVnCCV/ structures. The moraic/syllabic durational ratio, depending on its position, showed a slightly difference in being slightly higher: /CV1/ > /CV2/. /CV1/ was slightly longer than /CV2/ in the /CV-n/N-CV/ structures of a carrier sentence than in isolated words. Considerable temporal reorganisation was observed when /CVnCCV/ was said instead of /CVnCV/, which may suggest that the whole word represents a temporal frame for the temporal compensation (Isei, 1994),[60] but more measurements are needed to show the different influences of syllable, word, and utterance separately. Sato (1992:16) states that temporal compensation does not occur within a syllable where /N/ occurs, e.g., [mɑmː], [mɑnː], and [mɑŋː], and rather temporal compensation

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60 Isei, T. (1994). "Nihongo to Finrandogo no bishiin no hikaku – rizumu to taimingu ni kansuru ichikoosatsu" [A study on rhythm and timing – a comparison of nasal consonants in Japanese and Finnish]. Presented at the 21st Annual Meeting of The Uralic Society of Japan.

takes place at the word level. Port et al. (1987) and Homma (1981) also agree with this point. The result of this study may agree with their statement.

Finally, although the test words were limited, I could confirm that there was a difference depending on whether the test words were uttered either in isolation or in a carrier sentence – an important aspect for the methodology of experimental conditions.

Aoyama (2001) reports that /n/ in Finnish *ana* was 23.8% and /n/ in Japanese *ana* 32.7%. Therefore, the Japanese nasal was longer than that in Finnish. Her result was the opposite to the present result. She used only one isolated word, *hana*, with /CVCV/ structure for the experiment and obtained these ratios, excluding the duration of /h/. She used ten informants who represented various dialect speakers of both languages and the word tokens were 60 for each language. This study had only one informant from a limited area for each language and for each experiment, in isolation and in a sentence. The word structures were /CVn(C)CV/, /CVNCV/, however, with variable phonotactic combinations, the duration of the word-initial consonant was included for calculating the ratio, and the word tokens totalled 42. Thus it is not ideal to compare Aoyama's finding with the present result. In addition, Aoyama's /n/ occurs second syllable-initially. Nevertheless, it is worth noting that the ratio of Finnish /n/ in her research was closer to that in the present case, and the ratio of Japanese /n/ was very different from the present work. As I report in the next chapter, the duration of Finnish word-initial /h/ in /hV/ is much shorter than the Japanese counterpart. If she measured the duration of /h/ in *hana* and included it to obtain the durational ratio of /n/ within the word, the ratio of /n/ within the word would be different for both languages; there would probably not be a large difference between them. Although the ratios of /n/ was clarified between Finnish and Japanese, speakers utter the whole word every time and must control the temporal organisation of each phoneme within the word (see Han 1994, Sato 1992).

6. The special case of /h/

6.1 Introduction

Phonotactically, /h/ occurs word-initially, word-medially, but never syllable-finally in Japanese, but syllable-final /h/ does occur in Finnish. From a phonological point of view, Harrikari (2000:17) states that /h/ - and laryngeals in general– are disfavoured as codas in many languages. Finnish has /h/ in coda position. The Finnish word *nahka* ('leather') exemplifies this, as in Figure 6.1.

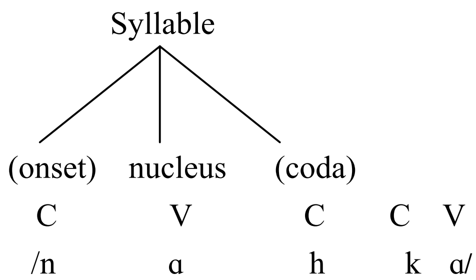

Figure 6.1 Phonological interpretation of the /CVhCV/ structure.

In Finnish a word containing word-medial /h/ can maximally have a /(C)V(V)h(C)V(V)/ structure. On the other hand, a word in Japanese containing /h/ can at most have a /CV(V)hV(V)/ structure in the word-medial position. Example words are shown in Table 6.1.

Table 6.1 Word examples containing /h/ in Finnish and Japanese.

	Word-initial /h/	Word-medial /h/	Syllable-final /h/
Finnish	*hame* ('skirt')	*iho* ('skin')	*tähti* ('star')
Japanese	*ha* ('tooth')	*haha* ('mother')	-

In perceiving words with a /CVhCV/ structure, which does not exist in Japanese, the Japanese tend to count them as trimoraic words. The Japanese might tend to apply the phonetic phenomenon of vowel devoicing to the Finnish coda /h/: Finnish coda /h/ = one mora. Thus, the first question to be asked is whether there is a difference in duration between /h/ in coda position and /h/ occurring in the other environments, particularly a short /h/.

As I discussed in 2.3.2.3, /h/ has a distinctive quantity in Finnish, although it is very rare, but not in Japanese. In this chapter, I investigated the durations of /h/ in two different word structures, /hV/ and /CVhCV/ (Isei-Jaakkola 2003a). A monomoraic word /hV/ sounds impressionistically similar to the speakers of both languages, although the Japanese /h/ has allophonic variations as mentioned in 2.2.1. The second question is whether the duration of coda /h/ has some correspondence to the Japanese auditory mora concept.

6.2 Definitions of /h/

Feature definitions of /h/ have been mostly based upon the non-experimental observation which still forms the basis of the IPA definition, according to which [h] is described as a voiceless glottal fricative and [ɦ] as the voiced counterpart of [h]. In non-experimental observation, /h/ has been considered a voiceless vowel (O'Connor, 1973:143-5), and "a vowel-like consonant", "approximant", "semi-vowel" and "glide" (all terms in Ladefoged & Maddieson, 1996). In his book *A Course in Phonetics*, Ladefoged (1993:65-66) does not assign any features to /h/ in his classification of English, but he later classifies it as mentioned above (Ladefoged & Maddieson, 1996). Maddieson (1984:57) states that "/h/ and /ɦ/ have often been considered members of the class of fricatives, although some linguists have preferred to put them into a special class of "laryngeals" together with /ʔ/, and others have emphasized their similarity to vowels and approximants." Maddieson (1984) describes /h/ as a sound with 'variable place'. Thus, variable descriptions of /h/ appear in the literature. The notion of /h/ being a 'fricative glottal consonant' implies constriction and friction at the glottis. Hayward (2000:190) states that glottal /h/ does not have its own characteristic spectrum and fricatives are classified using two dimensions, place of articulation and voicing (phonation), but [h] does not involve any special positioning of the vocal organs above the larynx (op. cit.:191).

In terms of experimental observation, Iivonen (1975, 1981) analysed the Finnish /h/

using a photoelectroglottograph and confirmed that the glottis is open in the unvoiced Finnish /h/, instead of being produced with a narrowing glottis. It has been proved that the glottis is wide open in producing voiceless geminate consonants /Q/ in Japanese (Sawashima & Miyazaki, 1973. Indeed, the glottis is also wide open in Finnish *hihhuli* ('holy roller') (Iivonen, 1975). The Japanese would describe *hihhuli* /hihhuli/ phonologically as /hiQhuli/. They would also attempt to apply the same principle to Finnish interjections such as *Heh heh*, which would become /heQheQ/, etc.

The phonetic realisations of /h/ depend not only on the environments in which they occur, but also on the degree of involvement of the various articulators, particularly active articulators such as the tongue and lips. When the vocal tract between the tongue and the velum and palate is narrowed, /h/ is velarised or palatalised. If the pharynx is involved, it is pharyngealised. If the lips are closer together, it is labialised. When there are no strictures in the oral tract, the segment can be a vowel. If a corresponding opening occurs in /h/, it may be a vowel or an approximant. These allophonic variants can become phonological consonantal segments, i.e., phonemes for which minimal pairs can be found in Japanese, as stated in Section 2.2.1. [ɦ] can occur as an allophone of /h/ in both Finnish and Japanese.

It is often said that the Japanese /h/ has three phonemic or allophonic variants: [ç], [ɸ], [ɦ] (see, 2.2.1). The phonetic realisations of /h/ vary between languages. The Finnish /h/ is in general realised as a voiced [ɦ] when it occurs intervocalically, e.g., *paha* [pɑɦɑ] ('bad'), or when it occurs between a vowel and a voiced consonant, e.g., and *pahvi* [pɑɦvi] ('cardboard').

On hearing a Finnish /h/, the Japanese may perceive it as louder than their Japanese counterpart, particularly when it occurs in the coda position, e.g., *kahvi* ('coffee'), while the Finnish may perceive it the other way, and the Japanese perceive that the English /h/ sounds stronger than /h/ in their own language. Regarding /h/ Karlsson (1999:11) states that when /h/ occurs in an environment between vowels (V__V), it is pronounced weakly, whereas occurring with consonants it is a stronger sound, particularly if the following consonant is /t/ or /k/. This raises the question of how we can verify the impressions of the weakness and strength of /h/. The loudness impressions of "strength or weakness" can be physically measured in amplitude. Such impressions as 'strong' or 'weak' are related to sonority. While the sonority of /h/ is the weakest among the speech sounds, languages can differ in the relative sonority of /h/. Sonority can be related to loudness[61] in general terms, and loudness can be phonetically represented by intensity

[61] "In general the loudness of a sound depends on the size of the variations in air pressure that

(dB). For the purpose of verifying my impression of the Finnish /h/ and the above claims of as to whether /h/ is a fricative or not, I included the measurements of intensity and zero-crossings of /h/ in the following experiments.

I carried out two kinds of experiment to measure the duration of /h/ in two kinds of word structure. In one experiment /hV/ was tested on Finnish and Japanese speakers.[62] The other experiment included only Finnish test words representing /CVhCV/ structure (Isei-Jaakkola 2003a), because no corresponding structure exists in Japanese.

6.3 Production test 1: hV

6.3.1 Experimental procedure

6.3.1.1 Materials

In /hV/ word structures, the Japanese carrier sentence “Mooikkai hV̲da to ittekudasai (‘Please say hVda (‘be hV’) once more’)” was used for both the Japanese and Finnish speakers. The /h/ was in word-initial position. The V was represented by five vowels /ɑ, e, i, o, ɯ/ for Japanese, and /ɑ, e, i, o, u/ for Finnish. The reason for using five vowels for the Finnish informants was to set up the same conditions for both language speakers since Japanese has only five vowels.

6.3.1.2 Method

In the /hV/ experiments, the Japanese informants were given the Japanese text. For the Finnish speakers, their text was written alphabetically, corresponding to the spelling as in Romanisation. I gave all the informants instructions to read the written text at the normal speed and as naturally as possible. I attended to the informants while recording, asking them not to focus on the test words and to repeat the whole sentence when they forgot these instructions. The carrier sentence with the test word was repeated five

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occur…acoustic intensity is the appropriate measure corresponding to loudness. The intensity is proportional to the average size or amplitude of the variations in air pressure. It is usually measured in decibels (abbreviated as dB) relative to the amplitude of some other sounds”. (Ladefoged 1993:187)

[62] Isei-Jaakkola, T. (2002). “A cross-linguistic study of /h/”. Presented at the Forum of Phonetics in Finland.

times by the informants. There were 150 word tokens (2 languages x 3 informants x 5 vowels x 5 times each) to be measured.

6.3.1.3 Informants

In the /hV/ experiments, the Finnish informants were from Helsinki and its surrounding urban area with no knowledge of Japanese. The Japanese were Tokyo dialect speakers or little or no knowledge of Finnish. The informants are listed in Table 6.2.

Table 6.2 The list of informants for the experiments with /hV/.

Informants	Japanese		Finnish	
No.	Age	Occupation	Age	Occupation
1	29	University student	22	University student
2	37	Civil servant	22	University student
3	46	University lecturer	60	University professor

6.3.1.4 Recording

The recordings were made in the recording room of the Department of Phonetics at the University of Helsinki using a DAT recorder and AKG C420 microphone. The microphone headset was used so that the distance between the mouth and the microphone remained unchanged. The volume setting of the DAT recorder was also unchanged for all informants.

6.3.2 Result and discussion

It was not an easy task to judge the boundary point between the preceding vowel /i/ and the following /V/ in /i#hV/. For a comparison with /h/, I measured the intensity (dB) of /i/ and /V/ in /i#hV/. The intensity around the boundary area between the vowel preceding /h/ and the following /h/ becomes weaker, and the intensity around the boundary area between the /h/ and the following vowel becomes greater. The formants for /h/ were not always clear, unlike vowels. In measuring the intensity of /h/, the cursor was set on the middle area of the whole durational stretch of /h/ and a small time window was used to determine the first formant intensity. The same method was used to measure the intensities of /i/, vowel preceding /h/, and the vowels following /h/.

In terms of measuring intensity, it must be pointed out that intensity values can be valid within intralanguage comparisons (although individual differences are variable), but, in general, our conclusions have to be very careful in interlanguage comparisons, because the individually variable general speaking effort may have an influence. Neither are absolute intensity values comparable between different investigations if no calibration has been applied, but relative intensities within the same investigation are reliable if the experimental set-up is unchanged.

6.3.2.1 Duration of /h/ in /hV/

Table 6.3 shows the mean duration of /h/ and the vowels followed by /h/. The percentage (%) shows the durational ratios in a sentence (= 100%) of two languages.

Table 6.3 The mean durations of /h/ and five vowels preceded by /h/, and their durational ratios in the sentence produced by the speakers of each language.

	Duration (ms)		Ratio (%)	
	Finnish	Japanese	Finnish	Japanese
h	44	69	2.5%	4.2%
V	103	65	5.8%	3.9%
Total	147	134	8.3%	8.1%

The Finnish /h/ (44 ms) was shorter than the Japanese /h/ (69 ms). The durational value of word-initial /h/ in this experiment was much shorter than in Lehtonen's (1970:71) data for the mean value of word-medial short intervocalic /h/ (80 ms) in the words *pa<u>h</u>a*, *pa<u>h</u>an*, *pa<u>h</u>aa*.[63] His word structures did not include word-initial or

[63] Lehtonen's data was obtained in a focused position of carrier sentences using nonsense words. His results (1970:146) showed that sentence stress had no lengthening effect on the initial consonant duration (but did have a variable effect on all later segments of word, when (C)VCV

syllable-final /h/. It must be noted that /h/ in this experiment occurs word-initially and that in Lehtonen's data syllable-initially.

The word-initial /h/ and /V/ form a syllable in Finnish and a mora in Japanese in the experimental conditions. The mean duration of Finnish /hV/ (147 ms) was similar to that in Japanese (134 ms), suggesting that a compensatory durational control may be working within the syllabic/moraic level in both Finnish and Japanese.

In this connection, the durational ratios of the Japanese and Finnish /h/ were calculated within the sentence (100%) using 50 sentence tokens from one Finnish female and one Japanese female. The total ratio value of Finnish hV (8.4%) was close to that (8.1%) in Japanese. These ratios may support the notion that the Japanese perceive Finnish /hV/ as one mora unit[64].

6.3.2.2 The intensity of /h/ in /hV/

Table 6.4 shows the overall mean values of the intensity of the sequences in /i#hV/ – initial /h/ and its surrounding vowels in Finnish and Japanese.

Table 6.4 Intensity (dB) of /h/ and the surrounding vowels in /i#hV/ in Japanese and Finnish.

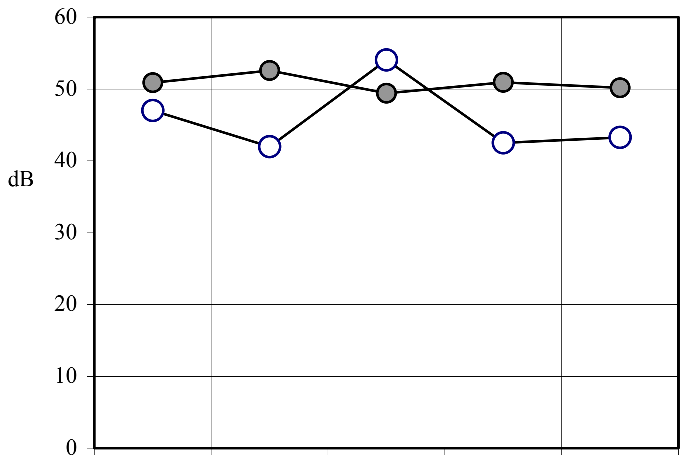
	Japanese (dB)	Finnish (dB)
i#(hV)	54.31	55.29
(i#)h(V)	48.90	50.78
(i#h)V	54.22	55.36

There was less significant difference in the vowels compared to /h/ preceded by and followed by vowels between languages. The dB difference between Japanese /i/ and Finnish /i/ was 0.98 dB (J. > F.). That of V between Japanese and Finnish was 1.14 dB (J. > F.). Finnish V followed by /h/ was higher than /i/ preceded by /h/. These intensity

and (C)VCVV structures were measured. It must be noted that his measurements were carried out more than 30 years ago using entirely different measurement methods.

64 The carrier sentence has 16 morae in Japanese (one mora = 6.25%), which are counted as 11 syllables in Finnish (one syllable = 9.09%).

differences are “a little more than the smallest noticeable change” according to Ladefoged (1993:187). The overall mean value of the Finnish /h/ (50.78 dB) displayed stronger intensity than that of Japanese. The dB difference in /h/ was 1.82 dB between Japanese and Finnish. the Japanese /h/ being weaker than the Finnish. The Finnish Vs had stronger intensity (56.36 dB) than the Japanese (54.22 dB), as did in /i/ (F. 55.29 dB > J. 54.31 dB). All Finnish dB values are greater than in Japanese, based on these values. As explained above, the recording was done under the unchanged experimental set up - the interval between the microphone and mouse, the volume setting, etc. - for all informants, Finnish or Japanese. Hence, the only possible source of error is a greater general speaking effort by the Finnish than the Japanese, which seems to be unlikely. Figure 6.2 shows the mean value of the intensity (dB) of /h/ preceded by the same /i/ but followed by five different vowels.



	(i)h(a)	(i)h(i)	(i)h(u)	(i)h(e)	(i)h(o)
Japanese	46,99	41,96	54,03	42,50	43,23
Finnish	50,85	52,57	49,39	50,92	50,15

Figure 6.2 The mean values of the intensity (dB) of /h/ in /i#hV/.

The intensity of Finnish /h/ was relatively stable no matter what vowels follow. On the other hand, it is remarkable that the Japanese /h/ [ɸ] has the highest value of all when followed by [ɯ] and has a considerably higher value than the other /h/s followed by /ɑ, i, e, o/. Homma (1985) measured the intensity of the Japanese vowels using variable consonantal environments, obtaining 58 dB for /i/, 73 dB for /e/, 72 dB for /ɑ/, 97 dB for /o/, and 66 dB for /ɯ/. The intensity of vowels can thus differ depending on the phonotactic environment.

The results of 'the present' experiment were:

The mean intensity of the Finnish /h/ was stronger than that of Japanese (except for /hɯ/). This might support the impression that the Finnish /h/ sounds stronger than Japanese counterparts under the conditions of this experiment. The Finnish /h/ was longer than that of Japanese, which might indicate that the length of /h/ may affect the Japanese speaker's perception of sonority. The intensity of the Finnish /h/ had a stable intensity level whatever vowel followed, compared to that of Japanese. The Japanese /h/ [ɸ] followed by [ɯ] has the highest value of all.

6.4 Production test 2: /CVhCV/

6.4.1 Experiment procedure

6.4.1.1 Materials

For the second test – /CVhCV/ word structures – the following conditions for test words were chosen: (a) bisyllabic and (b) the syllable structure /CVhCV/, where /h/ was (c) preceded by eight different vowels and was (d) followed by voiceless/voiced consonants. In addition, two conditions were required: (e) the vowel preceding /h/ could not be the same as that in the second syllable, and (f) /h/ could not occur word-initially or syllable-initially in the second syllable. The syllable structure of *möhkäle* is /CVhCV/+CV, but its /CVhCV/ part was used for analysis. The test words became 16 meaningful words, which are listed in Table 6.5. They were embedded in a carrier sentence "Sanokaa ____ taas yhden kerran." ('Please say ____ once more.').

6.4.1.2 Informant

For the test with /CVhCV/, the informant was a 25-year old Finnish male university student from the Helsinki Metropolitan area.

6.4.1.3 Recording

The recording method was the same as in Section 6.3.1.4

6.4.1.4 Methods

In /CVhCV/, the informant repeated the test words five times in a carrier sentence "*Sanokaa* ____ *taas yhden kerran*." ('Please say ____ once more.') Thus there were 80 (16 words x 5 times each) tokens used as test words. The speech was analysed by using SoundScope 2.32, the wide band spectrograms being used to measure segmental durations. For the segmentation of the boundaries between the preceding vowel and /h/ (/i#hV/, /CVhCV/), between the /h/ and following vowel (/i#hV/) and between the /h/ and following consonant (/CVhCV/), the speech waveform, intensity, pitch, and formants were checked. The preceding vowel has a progressive assimilative effect on coda /h/, which can thus have formants that are relatively similar to the preceding vowel. This was confirmed during my experiment. The same method of segmentation was also used as the basis for measuring the zero-crossings. To confirm the amount of friction I analysed the zero-crossings. Observing zero-crossings[65] is generally a good reference for fricatives. My decision to do this for the Finnish coda /h/ is based upon the need to know whether we can confirm the possibility of the existence and amount of friction.

6.4.2 Results

6.4.2.1 Duration of /h/ in /CVhCV/

The mean value for the coda /h/ was 82.8 ms, which is also much longer than the duration of word-initial /h/ (44 ms) in Experiment 1. There was no significant difference in the mean value of /h/ followed by voiceless C or voiced C: 81.6 ms vs. 84.0 ms.[66]

The durational distributions of /CV-h-CV/ are illustrated in Figure 6.3. The mean

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[65] For details, see *Techniques in Speech Acoustics* by Harrington and Cassidy (1999), *The Acoustic Analysis of Speech* by Kent and Read (1992), etc.

[66] Lehtonen's (1970:71) /h/ had a mean value of 80 ms (as I mentioned above), confirming that the Finnish coda /h/ has a duration similar to that of the short intervocalic /h/, although under different experimental conditions.

value of the duration of the first /CV/ (in the stressed syllable) was 152 ms, and the second /CV/ (in the unstressed syllable) 108.6 ms. Since the durational ratio of /h/ was 24.2% when the whole word was counted as 100%, the proportion of /h/ was approximately ¼ within /CV-h-CV/.

This relative duration of /h/ makes it difficult to conclude that /h/ is isochronic with the other relative durations of CV1 and CV2 in the /CVhCV/ structure if /h/ is a mora and if each mora is approximately isochronic within a word. In fact, the duration of CV1 was much longer than CV2 (approx. 40%). One reason for the durational difference between CV1 and CV2 was that the vowel duration in the first syllable (av. 104.1 ms)[67] was much longer (nearly twice as long) as that in the second syllable (52.4 ms)[68] in which only /u, o/ were lacking in the second syllable. However, it must be noted that /CVhCV/ words are bisyllabic with /CVh/ forming a syllable, and that the duration of /CVh/ (235 ms) is approximately double (218%) that of the second syllable /CV/ (108 ms). This might suggest that /CVh/ could be bimoraic, CV2 monomoraic, and thus /CVhCV/ trimoraic according to the Japanese mora-hypothesis interpretation. Also, this ratio difference shows that, strictly speaking, isochronic syllable-timing does not apply to Finnish.

Table 6.5 Test words in the /CVhCV/ structure.

Vowels in the CV1	No.	Voiced C in /CVh<u>C</u>V/	No.	Voiceless C in /CVh<u>C</u>V/
/ɑ/	1	*kahvi* (‘coffee’)	9	*lahti* (‘bay’)
/i/	2	*rihma* (‘thread’)	10	*pihka* (‘resin’)
/u/	3	*tuhma* (‘naughty’)	11	*puhti* (‘vigour’)
/e/	4	*lehmä* (‘cow’)	12	*lehti* (‘leaf’)
/o/	5	*sohva* (‘sofa’)	13	*kohta* (’soon’)
/æ/	6	*lähde* (‘source’)	14	*tähti* (‘star’)
/œ/	7	*töhry* (‘scribble’)	15	*möhkäle* (‘block’)
/y/	8	*tyhjä* (‘empty’)	16	*nyhtö*[69] (‘snub’)

[67] The durational difference within eight vowels was 23.6 ms.
[68] The durational difference within six vowels was 27.2 ms.
[69] It is a derivative from the verb *nyhtää*, which is seldom used in everyday life.

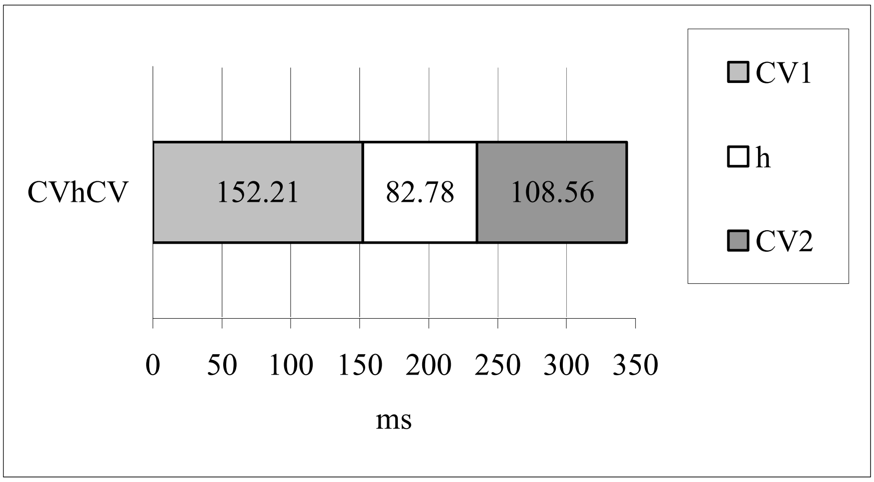


Figure 6.3 Durational distribution of /CV-h-CV/.

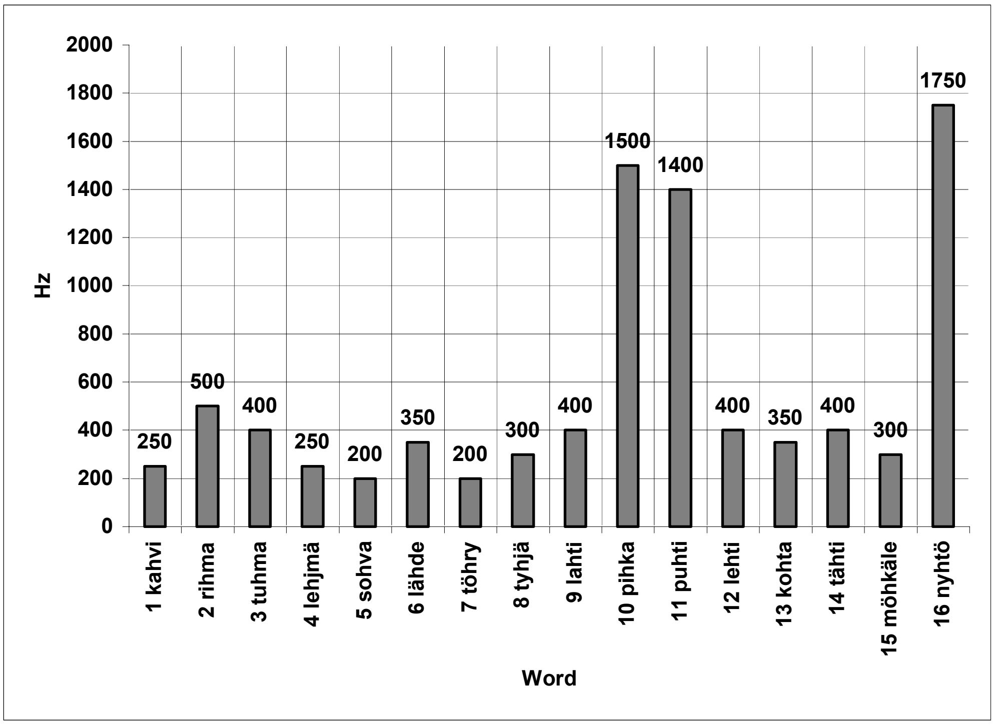
6.4.2.2 Zero-crossings of /h/ in /CVhCV/

The amount of friction in speech sounds can be measured using zero-crossing analysis. The values were obtained by the median of five repetitions. The results were translated into Figure 6.4.

When /h/ was preceded by the close vowels /i, y, u/ and followed by the voiceless consonants /t k/, the mean values had a relatively high frequency (1400-1750 Hz, 200-500 Hz for the vowels). A similar tendency can be seen in fricatives. Zero-crossings generally seem to show a lower frequency for vowels.[70] In general, /h/ has lower frequencies when followed by voiced consonants. The mean values had lower values in all other contexts except for where the preceding vowel was /i, u, y/ and followed by /t/ and /k/. Thus my experiments seem to confirm that the Finnish coda /h/ preceded by /i/ resembles the quality of a palatal [ç][71] and that preceded by the /y, u/ of a labial fricative, implying that the following consonant is voiceless, because of a large degree of friction produced through a narrower constriction (between tongue and palate or at the lips). I observed the zero-crossings of the preceding eight vowels at the same time, since the vowel and /h/ are temporally connected, confirming that these vowels were at a very low level in the zero-crossings.

[70] For the reference, see *The Acoustic Analysis of Speech* by Kent & Read (1992:80).
[71] It could otherwise be transcribed as [h^j].

The ratio values between zero-crossings and intensity of /h/ in /CVhCV/ did not show any correlation (Isei-Jaakkola 2003a).



1 – 8 = /h/ followed by voiced consonants, 9 – 16 = /h/ followed by voiceless consonants.

Figure 6.4 Median value of zero-crossings of /h/ in /CVhCV/.

6.5 Summary and discussion

In this chapter, five nonsense word types for the Japanese and Finnish (150 words) and 16 meaningful word types (80 words) were used. I compared the durations between the Japanese /hV/ and Finnish /hV/, and the Finnish /h/ in /CVhCV/. The measurement of intensity of /h/ in /hV/, zero-crossings of /h/ were also added.

In summary, I could confirm that:

(1) The duration of the Finnish /h/ in /hV/ was shorter than that of the Japanese /h/.

However, the duration of the Finnish /hV/ was close to that of Japanese.

(2) There is no significant durational difference between coda /h/ and word-medial short /h/ (Lehtonen 1970).

(3) It was not possible to verify that the /CV1-h-CV2/ structure, i.e., a word structure with three morae in Japanese, is isochronic and that /CVh-CV/ was isochronic in Finnish syllables.

(4) Word-initial /h/ in /hV/ followed by voiced consonants has greater intensity than that followed by voiceless consonants, which means that a voiced /h/ has a greater intensity than a voiceless /h/. The intensity values of /i/, /h/ and /V/ were larger in Finnish than in Japanese, except for that of /h/ in the Japanese /hɯ/.

(5) /h/ in /CVhCV/ preceded by /i, y, u/ seems to have a fricative quality if the following consonant is a voiceless plosive, which may be an assimilatory effect of the preceding vowel and caused by a narrow constriction in these vowels.

In terms of the experimental conditions, it must be noted that /hV/ was investigated in a non-focused position, but /CVhCV/ in a focused position. As a conclusion, it was found that the duration of the Finnish initial /h/ in /CV/ is much shorter – nearly half the duration of the coda /h/ in /CVhCV/. However, it was revealed that the durational ratio of /hV/ was very close between Finnish and Japanese. This fact might indicate that a temporal compensation works within /hV/ in the two languages as does /CV/ to fix its own timing. I found no evidence that the syllables in the /CVhCV/ structure are isochronous, i.e., syllable-timed in Finnish.

The structure /hV/ consists of one mora in Japanese and one syllable in Finnish. My intention was not to measure the duration of vowels directly, but the findings were that the Finnish vowels were much longer than Lehtonen's data (1970) and the Japanese counterparts much shorter than Sagisaka et al. (1984) and Homma (1985). Lehtonen and Homma used a read text and Sagisaka et al. spontaneous speech. Lehtonen used only the plosive /p/ for the vowel environments (/pVVpV/, /pVpVV/). The intrinsic duration of /p/ seems to be much longer than /h/ (see Chapter 3), indicating that temporal compensation may work within the syllable in Finnish. Sagisaka et al. used /CV/ sequences, but the speaker was only one male Tokyo-dialect speaker with various consonants for the word-initial position. They used /VmV/ and /CVmV/ in isolation,

/CVmV/ in a meaningful natural sentence, and the nonsense word /amVCVmari/ in isolation. In their data, /h/ varied from 70 ms to 120 ms depending on its position under the given conditions. In the present study, the number of informants was three Tokyo dialect speakers. The result is probably understandable because they used the nasal /m/, whose intrinsic duration is rather short compared to plosives or fricatives (see also Chapter 3), and the vowel duration became longer within the mora (compensation within a mora). This may indicate that the temporary compensation work within the mora and word. I cannot find any other reason than temporal compensation within a mora to explain the difference between the result of the present study and their data. It is clear that temporal duration works within a mora, since the duration of the Japanese vowel /i, ɯ/ is much less than the other three vowels (thus the mora is not strictly isochronic in Japanese) and intrinsic consonantal duration varies. On the other hand, the duration of Finnish vowels is more stable than that of their Japanese counterparts. Nevertheless, the result in this study shows that the absolute duration of /hV/ was very similar between Japanese and Finnish under the condition that the carrier sentence and the test words were the same.

7 Summary and discussion

The present research was focused on similarities and differences in lexical quantity between Finnish and Japanese, perhaps the most outstanding common phonological feature between the two languages. A description of the main features of their phonological systems was necessary as a basis for comparison (cf. Chapter 2). The main interest was in the production (Ch. 3) and perception (Ch. 4) of distinctive quantity, but smaller-scale experiments were conducted on two-syllable final consonants (Chs. 5 and 6), in order to show whether systematic similar or different language-specific rules exist in their timing, whether the Japanese listeners can hear a long distinctive Finnish quantity instance not occurring in Japanese, and to discover whether the expected mora timing can be found in these cases.

7.1 Summary of the results

In Chapter 2 some central issues relevant to quantity research on the sound systems of both languages are described: segmental phonemes, syllable structures, and some basic differences in phonotactics. There are more vowels in Finnish (8 basic types) than in Japanese (5) but more consonants in Japanese. The quantity distinction concerns all vowels in both languages. The number of geminate consonants is greater in Japanese (13) than in Finnish (8). Syllable structures are more complicated in Finnish than in Japanese and the number of syllables is greater in Finnish than in Japanese. Once the syllable weight concept was adopted (cf. Kubozono 1992), it could be argued that the number of syllable structure types is relatively similar. However, the structure /(C)VCC/ does not exist in Japanese.

Although there are seemingly many words in which the combinations of vowels and consonants are identical or similar, most of the words are phonotactically different, particularly because there are more types of consonant and vowel sequences (including diphthongs) in Finnish. Chapters 3 and 4 dealt with the production and perception of quantity, utilising the word structures, bisyllabic nonsense words in eight different syllable structures and common to Finnish and Japanese (except for /CVVCCVV/). Different quantity combinations of phonologically short/long vowels and short/long consonants were represented in the test words. Chapter 3 treated their production and Chapter 4 their perception.

In the experiments, I used the /CV, CVCV, CVCVV, CVVCV, CVCCV, CVVCVV, CVVCCV, CVCCVV, CVVCCVV, CVCCCV/ word structures. Of these, the

/CVVCCVV/ and /CVCCCV/ syllable structures, do not exist in Japanese. CV is counted as one syllable in Finnish and one mora in Japanese. All the other types are counted as bisyllabic in Finnish and two to five morae in Japanese, except for the two non-existent types. /CV, CVCV, CVCVV, CVVCV, CVVCVV, CVVCCV, CVCCVV, CVVCCVV/ were used for nonsense and meaningful words in both production and perception.

In Chapter 3, the material used in the experiments consisted of the word tokens of 24 nonsense word types (720 words) spoken by six speakers (three Finnish and three Japanese). The analysis of the spoken realisations representing the /$C^1V^1(V^1)C^1(C^1)V^1(V^1)$/ structure revealed that the segmental duration ratios between single and double categories in both vowels and consonants were higher in Japanese than those of Finnish, excluding /s:ss/, when all segments were pooled. The Japanese long segments were longer than their Finnish counterparts. However, the durational variations varied depending on their position in the structure. The durational variations in the short/long segments depending on word position were smaller in Finnish than in Japanese, and the standard deviations were generally smaller in Finnish than in Japanese. Word durational patterns were similar in each language. The segmental durational distribution in each word structure was similar in both Japanese and Finnish.

In Chapter 4, the perceptual boundaries between the short and long quantity category in each language were tested using eight types of bisyllabic synthetic nonsense words. The same syllable structures /$C^1V^1(V^1)C^1(C^1)V^1(V^1)$/ and phonemes as in Chapter 3 were used. In addition, various F0 and intensity patterns were combined with these nonsense words. The number of listening responses for the 24 nonsense word types and 1,664 synthetic word stimuli was 29,120 in all (*n*: F. 7 + J. 7 = 14). The results revealed that Finnish had wider perceptual boundary ranges than Japanese within the segment and word but the perceptual boundary area often tended to be more stable than Japanese. Finnish listeners reached the minimum long segment, defined as a combined segment consisting of the segment heard as a short category plus the uncertainty area (= boundary range), earlier than the Japanese. Differences in the word structures had more effect in differentiating between short and long segments than the F0 and intensity variations in both Finnish and Japanese. Thus the syllable structures are more involved with length differentiation than the acoustic variations in each language.

In addition, the experiments in Ch. 3 and 4 attested that the Japanese could produce and perceive the non-existent syllable structure /CVVCCVV/ (which does occur in Finnish), using their quantity dichotomy perception. This may indicate a strong correlation between perception and production.

In the Chapters 5 and 6 smaller-scale studies were focused on some positional timing problems. These include the syllable final /n, N/ (Finnish /CVnCV, CVnCCV/ and Japanese /CVNCV/) and the syllable-initial (in both languages) and syllable-final /h/ (only in Finnish). The experiments were carried out in order to discover (1) whether there are language-specific differences in the timing of these segments and (2) whether their timing adjustments and perception can be used as evidence of mora timing or syllable timing.

In Chapter 5, /CVCCV/ (/CVNCV/ for Japanese, /CVnCV/ and /CVhCV/ for Finnish) and /CVCCCV/ (/CVnCCV/) were used for meaningful words in production and perception. Twenty-nine meaningful word types for Finnish (2,842 word responses in perception) and 20 for Japanese (222 word tokens altogether) were analysed. The perception tests by the Japanese listeners showed that Finnish /CVnCV, CVnCCV/ word structures were perceived mainly as three moraic words. The durational differential ratio of /n/ was very similar to the Finnish /CVnCV/ and Japanese /CVNCV/. The durational measurements showed that the durational differential ratio of /n/ in Finnish /CVnCCV/ (and /N/ in Japanese /CVNCV/ as well) was significantly smaller than the Finnish /CVnCV/. The durational compensation may work not simply at a moraic/syllabic level but also at the word level, as in /CVNCV, CVnCV, CVnCCV/ structures. The other findings were that there was a word-final lengthening and temporal compensation at the word level, which was demonstrated by using different methods, test words being uttered in isolation or a carrier sentence.

In Chapter 6, five nonsense word types (150 word tokens) and 16 meaningful word types (80 word tokens) for Finnish were analysed. The measurements of duration showed that the durational ratio of /hV/ was similar, but the segmental duration of /h/ versus /V/ was different. The temporal control of /CV-h-CV/ by the Finnish speaker did not support the Japanese mora concept, i.e., a structure consisting of three morae, because no isochrony in the timing of /CV-h-CV/ was observed. Two interesting additional observations were made. In the /hV/ structure, the intensity of Finnish /h/ was greater than that of Japanese. The zero-crossings of the Finnish coda /h/ in /CVhCV/ structure showed a tendency towards being a slightly fricative consonant before high vowels.

7.2 Discussion

Similarities and differences in production and perception between the Finnish and Japanese lexical quantity were investigated. The experiments carried out revealed remarkable similarities, but some results suggest that differences, though small ones, also exist.

7.2.1 Relationships between production and perception of quantity

From the above work, I attempted to observe the relationships between production and perception of quantity.

7.2.1.1 Perceptual boundary

The variations of the overall mean range (*R*) durations in the production experiments (Ch. 3) among short/long vowels/consonants were in many cases shorter in Finnish than in Japanese. Many of them were less than 40 ms with a few exceptions in Finnish, while those of the Japanese counterparts was often over 40 ms.

The perception boundary area in this study using three choices was largely scattered between 10 ms to 40 ms, but its span reached to 50 – 60 ms. This may suggest that there is a correlation between production and perception. On the other hand, in terms of the minimum long segment (the time span that covers the short segment and the uncertainty area), the overall durational ranges (the time difference between the shortest and longest minimum long segment in respect to all structural categories and variable prosodic conditions investigated) were 32.8 ms (F.) and 31.8 ms (J.) for vowels and 17.5 ms (F.) and 18.3 ms (J.) for consonants[72]. The standard deviation was 14.3 ms (F.) and 13.1 ms (J.) for vowels and 8.08 ms (F.) and 7.8 ms (J.) for consonants. Hence, the overall differences are small and the similarity is very considerable. The Japanese listeners use a narrower time span to differentiate a long segment from a short one than the Finnish counterparts in perception.

In the production test, the Finnish speakers had narrower ranges (*R*) and standard deviations (*SD*) in many cases than the Japanese. The results were the reverse in the perception test, however, the Finns using a wider range in all structures and prosodic conditions to distinguish a long segment from a short one than the Japanese. This may

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[72] In order to determine whether those small overall differences between Finnish and Japanese might be auditorily significant, we can refer to Lehiste (1970:13), who states, on the basis of production experiments, that the just-noticeable differences (JND) in speech sound duration are between 10 and 40 ms. The conclusion is that they cannot be auditorily significant in terms of overall differences.

indicate that the Japanese use their own temporal control to adjust segmental duration according to each word structure more flexibly while the Finnish use more fixed temporal control.

In the perception test, the overall durational ranges were greater in vowels than in consonants in both languages. This tendency was observed in the production test. Standard deviation shows the same results in both perception and production test.

/CVVCCVV/ does not exist in Japanese. Nevertheless, the Japanese could produce and perceive the distinctions between the short and long segments, which may indicate that they have clear-cut phonological short and long categories.

7.2.1.2 Correlation of quantity

Demonstrating whether and how production and perception of short/long quantity are correlated is very problematic. For example, in this work, only the production and perception values between the different syllable structures might be theoretically possible to compare. However, in the quantity perception test, the quantity differentiation of the subjects was tested under prosodically variable conditions: duration, F0, dB. On the other hand, in the quantity production test, the informants were not asked to produce the test words changing the pitch or intensity. Neither would it have been possible to specify the most reliable mean values of short or long segmental durations for comparison.

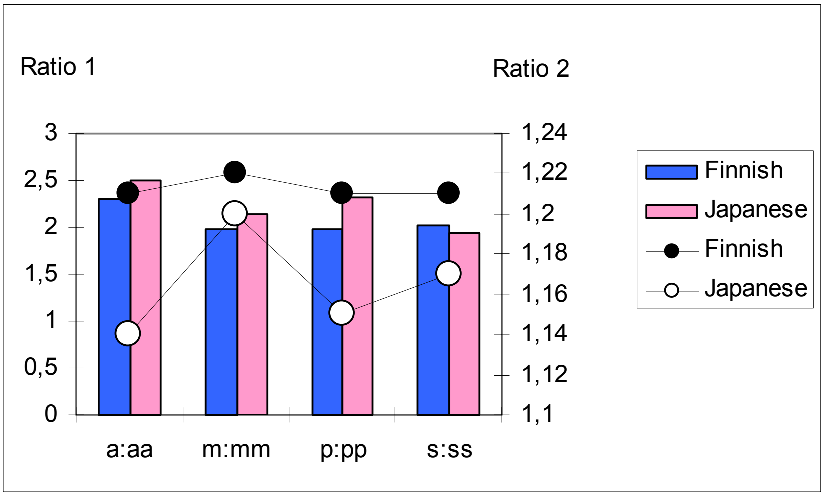
The correlation of quantity may depend on the various surrounding consonants or vowels, i.e., phonotactics, and also on syllable structures and prosodic conditions. There is much variation in the durational values depending on such factors, as seen in the preceding chapters. It may at least be necessary to utilise more variable consonants and vowels surrounded by variable consonants and vowels, and their combinations as well as using other methods in the experiments and analysis to provide stronger evidence of the correlation between production and perception of the two languages.

7.2.1.3 Comparisons of quantity ratios

The durational ratios between short and long are usually smaller in perception, as described in Section 4.1, than their counterparts in production. The work reported in Chapter 4.6 showed the same result, partly because of the method of testing perception. In the perception test, I applied the method of limits, which permitted a narrower

Table 7.1 Quantity comparison between short and long segments in production and perception.

	Production				Perception			
	F.		J.		F.		J.	
	Duration (ms)	Ratio	Duration (ms)	Ratio	Duration (ms)	Ratio	Duration (ms)	Ratio
a:aa	79.6:199.3	1:2.3	79.3: 180.5	1:2.5	96.5: 116.4	1:1.21	109.8: 125.6	1:1.14
m:mm	69.1: 137.3	1:1.99	69.2: 161.4	1:2.14	78.9: 96.6	1:1.22	83.4: 99.6	1:1.20
p:pp	94.4: 188.3	1:1.99	96.4: 206.4	1:2.33	86.6: 105.2	1:1.21	100.8:115.7	1:1.15
s:ss	82.8:168.2	1:2.03	88.5:172.4	1:1.95	83.5: 101.4	1:1.21	98.2: 115.3	1:1.17



Ratio 1 on the right axis = the ratios in production (bars),
Ratio 2 on the left axis = the ratios in perception (circles in line).

Figure 7.1 Ratio difference between short and long segments in different phoneme categories in production and perception.

perceptual boundary, rather than applying the constant method.[73] Consequently, the values of maximum short segments could be shorter than the short segments in production and their minimum long counterparts longer as well. On the other hand, it is usually not possible for speakers to produce neutral quantity when they do not have it, or to produce quantity with an indeterminate part between short and long (e.g., 'U' in the trichotomy concept, cf. Ch.4). Hence, it is very difficult to compare the quantity relation between production and perception since the basis for comparison is different.

Yet, I have attempted to observe the quantity ratios by utilising the overall mean values of short and long segments in production and maximum short and minimum long durations in perception for their counterparts. Their values and ratios are listed in Table 7.1. Only the ratios for production and perception were translated into Figure 7.1, depending on the phoneme.

The results show that there is a large difference in the durations and ratios between production and perception. In perception, there is no significant difference among Finnish ratios in the oppositions of /ɑ:ɑɑ, m:mm, p:pp, s:ss/ compared to their counterparts in Japanese. The Finnish ratios were higher than the Japanese counterparts in perception, although these ratios in the comparison of short/long segments in production were in most cases higher in Japanese than in Finnish.

More comprehensive work is necessary to relate these results on the relationship between production and perception to general theories.

7.2.2 Syllable structure, phonotactics and temporal control

In the production test of this study, the result suggested that the moraic duration varied depending on word structure, and the combinations of morae showed clear linearity according to the number of morae (up to five). This may indicate that the underlying isochronic timing principle is based more on mora in Japanese (Campbell & Sagisaka 1991, Kaiki & Sagisaka 1993, and Sagisaka & Toukura 1984 and many others). However, applying the syllable concept to Japanese cannot be neglected in so far as we observe that segmental durational ratios within the word were very similar to both Japanese and Finnish. Warner and Arai (2001) state that Japanese is still very often described as mora-timed, but evidence is increasing that the mora plays a structural role in Japanese and influences duration only indirectly. In the perception test, it was

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[73] The positive aspect of this method is that while a subject may not be able to predict, it may take much longer to judge the distinction between short and long. On the other hand, there may be an ordinal effect in the method of limits.

revealed that the structural difference had more effect than the prosodic variants in differentiating a long segment from a short one in both Finnish and Japanese. This finding supports Warner and Arai's claim.

Port et al. (1987) state that temporal compensation occurs at a level larger than the /CV/ syllable and that the overall duration of words with the same number of morae is remarkably similar. Sato (1992) and Homma (1981) agree with the previous point. Homma (1981:279) states that it may be more appropriate to say that the domain of duration pattern is not the syllable, but the word. The results in the quantity production test support their claim, but I could confirm that the /CV/ mora/syllable (/hV/) also exhibited temporal compensation (temporal compensation within the mora/syllable), although /hV/ was a word for the Japanese but not for the Finnish speakers. This study had a limited number of morae (from two to five) in a word and linearity was confirmed within five morae. Sagisaka et al. (1984) show that the durational ratio decreases sharply according to the number of morae up to approximately five, but that the moraic duration after that becomes very stable. Finnish durational patterns showed that when the number of phonemes increased within the bisyllabic frame, the linearity decreased according to the increase in the number of phonemes. Minagawa et al. (2003) investigated some temporal features of Japanese long and short vowels in the spontaneous speech corpus, concluding that the accentual conditions had a weak but significant effect on the durations of vowels and morae. Their investigation revealed that a durational contrast between long and short vowels was to be maintained even at a very fast speaking rate. Thus linearity, the number of phonemes, the mora, and the syllable may have to be discussed in a context larger than this study; perhaps within a breath group including pause (e.g., Sugitou 1997) or a long sentence, using a larger corpus and various speech rates.

The production tests revealed that Finnish showed quite similar durational patterns to Japanese in the same word structures /(C^1V^1(V^1)C^1(C^1)V^1(V^1)/, /hV/, /CVNCV/, /CVnCV/), but different patterns in the non-existent word structures in Japanese (/CVnCCV/, /CVhCV/). Comparing the durational ratio patterns of /CVNCV/; /CVnCV/, /CVnCCV/ uttered in isolation or a sentence, temporal compensation and possible word-final lengthening were observed, although the data was limited.

In this study, I used exactly the same combinations of vowels and consonants (/C^1V^1(V^1)C^1(C^1)V^1(V^1)/, /hV/), and the same or different combinations of phonemes in the same syllable structures (/CVNCV/, /CVnCV/). The /CVnCCV/ and /CVhCV/ structures do not exist in Japanese. These experiments revealed that when the phonotactics is different, the temporal control is different between Finnish and Japanese, but when the phonotactics is the same, it produced quite similar durational distribution patterns.

In the bisyllabic nonsense $/C^1V^1(V^1)C^1(C^1)V^1(V^1)/$ structure, one phoneme was added starting with four and rising to seven, using /m, p, s, ɑ/ (in Ch. 3). The position of these phonemes was imposed as one mora constituent within the word structure. There was a clear linearity (cf. Port et al. 1987) according to the stepwise increase corresponding to the number of phoneme/mora in both duration and ratio in Japanese. On the other hand, Finnish showed similar patterns corresponding to the combinations of vowels and consonants within each syllable frame.

In relation to prosodic coordination, Suomi (2002) and Suomi et al. (2003) apply the mora concept to discuss Finnish word stress. They conclude that there may be a lengthening effect in non-focused sentence positions.

7.2.3 Future studies

The experiments in this study showed that the Japanese mora-concept might be applied to Finnish at a particular stage (see Lehtonen 1970) – when syllable structures are the same, but not when they are different. Besides, the Finnish syllable concept could be applied to Japanese within a limited number of syllables. This indicates the importance of syllable structures.

I investigated mainly lexical quantity in this study. For future studies, the quantity features at the sentential level beyond the word level must be investigated further either by citation or spontaneous speech in production and perception, in order to examine the similarities and differences between Finnish and Japanese. The correlation between quantity and prosodic features should also be investigated further, particularly in production. Allen and Hawking (1978) state that rhythm cannot be understood without knowing both the nature of the units and their sequential structures and that sequential structure which includes the sequential units such as segments and syllables, and the organisation of these units which creates rhythmic sequences. Test words with consonant sequences/clusters and diphthongs should be also included for further experiments.

Notes

(1) Morphotactics and loan words between Japanese and Finnish

In terms of words or morphemes, Japanese conjugates verbs and declines adjectives. There are no plural forms or articles. Japanese words can be divided into four categories: native Japanese, Sino-Japanese, mimetic expressions (or adverbs), and loanwords. Native Japanese prefers words and morphemes that are of Japanese origin. The Sino-Japanese words are those that are borrowed from Chinese. Mimetics (onomatopoetic sound) are culturally and language-specifically significant in Japanese, and have their own properties. Japanese, unlike Finnish, does not seem to have vowel harmony, but it must be noted that in mimetics the same vowel is often repeated in the first and second syllables.

For example, there are two ways to say ‘fluently’: (1) the mimetic expression *peraperato* (‘fluently’) and (2) the Sino-Japanese expression *ryuuchooni* (‘fluently’). *Peraperato* fits the native speaker’s feeling better than the Sino-Japanese expression. Loanwords are words borrowed from languages other than Chinese. Hence, the same object or notion can be expressed differently depending on the situation, and maximally using four ways of expression. Hamano (1998) exemplifies these four categories, taking such examples as *kou* [koː] (native-Japanese), *hikari* [hikɑɹi] (Sino-Japanese), *pika* (mimetic), *raito* [ɹɑito] (loanwords) for ‘light’.

In Japanese a vowel is inserted between consonants in loanwords (vowel epenthesis). The following words exemplify English:

C + /ɯ/ ‘mask’ → *masuku* ‘mast’ → *masuto* ‘book’ → *bukku*
‘street’ → *sutoriito* ‘strike’ → *sutoraiku* (in baseball)

/t, d/ + /o/ ‘lead’ → *riido* ‘street’ → *sutoriito*
‘strike’ → *sutoraiku* (in baseball)

/tɕ, dʑ/ + /i/ ‘peach’ → *piichi* ‘badge’→ *baddzi*

Among the Finnish dialects, in the Savo and Northern dialects there is a ‘vowel epenthesis’ (Suomi, 1982) between the consonant in the syllable-final position, i.e., in the coda position /(C)VC/ and the following syllable /CV/ in /(C)VC.CV/. This phenomenon used to be called the *švaa-vokaali* in Finnish (e.g., Pauli Saukkonen 1967, Eeva Yli-luukko 1987). The inserted vowel in the vowel epenthesis becomes the same as the vowel in the first syllable. Let us take some examples.

$/CV^1hCV^{2/}$	→ $/CV^1h\underline{V}^1CV^{2/}$	sohva	→ $/\text{soh}\underline{\text{o}}\text{va}/$		
$/CV^1lCV^{2/}$	→ $/CV^1l\underline{V}^1CV^{2/}$	ilma	→ $/\text{il}\underline{\text{i}}\text{m}\text{ɑ}/$	kylmä → $/\text{kyl}\underline{\text{y}}\text{mæ}/$	

These phenomena can be called progressive assimilation. Another vowel epenthesis is the regressive assimilative effect in northern dialects. For example,

$/CV^1lCV^{2/}$	→ $/CV^1l\underline{V}^2CV^2/$	ilma	→ $/\text{il}\underline{\text{ɑ}}\text{mɑ}/$

The degree, i.e., the duration and quality of the vowel in the vowel epenthesis may depend on the dialect.

On the other hand, Finnish has native Finnish and numerous loanwords dating from earlier periods until the present and recently from Swedish and English. A comparative analysis of these loanwords both in Japanese and Finnish may help understand phonotactics or phonological constraints, which are also connected with the corresponding linguistic rhythm.

The phonological processes are somewhat similar to the language concerned. Let us take some English examples.

English	Finnish	Japanese
'mat'	*matto*	*matto*
'cup'	*kuppi*	*kappu*
'banana'	*banaani*	*banana*
'tomato'	*tomaatti*	*tomato*
'baroque'	*barokki*	*barokku*
'music'	*musiikki*	*myuujikku*
'opera'	*ooppera*	*opera*

Finnish loanwords often have word-final *i* like the above examples and sometimes *o* as well. The word-final *n* is deleted, e.g., 'automation' → *automaatio*, since Finnish loanwords prefer open syllables. Japanese loanwords generally prefer the *u* or *o* ending and as a result most Japanese loan words are open syllables. The only exception is that the word-final *n* is retained, e.g., 'automation' → *ootomeeshon*, 'can' → *kan*, but this type of closed syllable is limited to the *n* ending. The Japanese diphthongs such as /oɯ/,

/ei/, etc. become /oo/, /ee/, etc., respectively. The English [ə] is represented as /ɑ/ and its [əɹ] as /ɑ/. In both Finnish and Japanese the original plosive becomes geminated. As a whole, Finnish loanwords may have a tendency to preserve the original orthography, whereas Japanese loan words tend to be influenced by the original sounds.

(2) The relationship between the orthographic system and pronunciation between Japanese and Finnish

The concord between writing and pronunciation is very high in Finnish. A written text in Finnish is read almost according to the alphabet with a very limited number of exceptions such as the consonants *-nk-* [ŋk] in *Helsinki* and *-ng-* [ŋː] in *Helsingin* ('of Helsinki'), *w* [v].[74] *w* is used only for loan words or person names. If we consider all the other loanwords in relation to pronunciation, there should be more disagreement between the Finnish orthography and pronunciation.

The Japanese writing system, or orthography, consists of four types of symbol: *kanji* (Chinese characters), *hiragana*, *katakana* and *roomaji* (Romanisation). Chinese characters are used for both native Japanese and Sino-Japanese. In Sino-Japanese *kanji* are mostly semantic and phonological units formed by either monomoraic or bimoraic words. Matsunaga (1995) states that the visible effect of *kanji* may not be completely omitted, and that they should not be considered simply as ideographs. *Kana* (*hiragana* and *katakana*) are basically phonetic characters and mostly read as written. The difference between *hiragana* and *katakana* is that *katakana* are used only for foreign names, i.e., as nouns. The Japanese *roomaji* (Romanisation) was based on the *kana* system (*kana* syllabary), and is mostly read according to the alphabet, which makes it somewhat phonemic, though less so than the relationship between the Finnish orthography and its pronunciation. *Roomaji* means Roman letters and is the transliteration of the *kana*, phonetic characters using alphabetic letters.

There is some conflict between the *kana* system and pronunciation in speech. *Roomaji -ou-* [oɯ] is pronounced /oo/ [oː], e.g., *otousan* ('father') /otoosɑɴ/ [otoːsɑɴ]. Similarly *ei* [ei] in *eiga* ('movies') is pronounced /ee/ [eː], *ae* is sometimes pronounced [eː], e.g., *omae* ('you', vul.) [omɑe]→ *omee* [omeː], y is pronounced [j], and *n* contains several phonemes and allophones which are phonologically symbolised as /N/. Nowadays, one single letter for a long vowel is often used to represent a long vowel, which creates confusion among foreigners.

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[74] The vowel *ä* is pronounced [æ] and *ö* [ø].

All these four are based on the *kana* syllabary, which is the inventory underlying the Japanese moraic unit. The *kana* consists of one vowel, a combination of one consonant and one vowel (/CV/), or one consonant (C = /Q/ and /N/). Each *kana* is regarded as having one mora, and many *kana* are meaningful words. Otake et al. (1993) state that the mora also plays a central role in Japanese orthography.

(3) The phonetic realisations of /N/ and /Q/

/N/→	[m]	/__ /p, b, m, b^j, m^j/	*sanpo* ('taking a walk')
			kanban ('signboard')
			anma ('massage')
			sanmyaku ('mountains')
→	[n]	/__ /n, d, n^j/	*konna* ('such a')
			konda ('crowded')
			konnyaku ('devil's tongue')
→	[ŋ]	/ __ /k, g^j, g/	*honki* ('earnest')
			hangyaku ('rebellion')
			manga ('comic-books')
→	[ɴ]	/ __ /j/	*konjaku* ('engagement')
		/__#	*otoosan* ('(your) father')
		/__## (sentence final)	*arimasen* ('not be, pre. neg.')
→	[Ṽ]	/ __ V	*senen* ('one thousand yen').

The phonetic realisations of /Q/ are as follows:

/Qs/	*issatsu* ('a piece of') [isːɑtsɯ]
/Qç/	*hasshin* ('dispatch') [hɑçːiɴ]
/Qt/	*kitte* ('stamp') [kitːe]
/Qk/	*ikkai* ('the 1st floor' or 'one time') [ikːɑi]
/Qp/	*ippun* ('one minute') [ipːɯɴ]
/Qk^j/	*ikkyoku* ('a piece of music') [ik^jːokɯ]
/Qp^j/	*happyaku* ('eight hundred') [$hɑp^j$ːɑkɯ]
/Qts/[75]	*ittsui* ('pair') [itːsɯi]
/Qtç/	*icchi* ('agreement') [itːçi].

[75] It must be noted that /Qts/ is the combination of /Q/ and [ts].

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Appendices

Appendix 1 The Japanese Vowel Formant.

Data are quoted from de Graaf and K.-van Beinum (1982/3) for Japanese vowel formants. ‘a’ = /ɑ/.

(ms)

			a	i	u	e	o
F1	speaker 1	isolated V	765.0	302.0	295.0	517.0	465.0
F1	speaker 2	isolated V	774.0	294.0	326.0	484.0	505.0
F1	speaker 3	isolated V	741.0	270.0	298.0	491.0	491.0
		Mean	760.0	288.7	306.3	497.3	487.0
F1	speaker 1	in words	730.0	355.0	320.0	475.0	462.0
F1	speaker 2	in words	753.0	313.0	375.0	424.0	481.0
F1	speaker 3	in words	624.0	328.0	329.0	443.0	509.0
		Mean	702.3	332.0	341.3	447.3	484.0
F1	speaker 1	in conversation	611.0	348.0	443.0	437.0	464.0
F1	speaker 2	in conversation	676.0	301.0	412.0	427.0	471.0
F1	speaker 3	in conversation	605.0	359.0	446.0	467.0	478.0
		Mean	630.7	336.0	433.7	443.7	471.0
F1		**Total mean**	**697.7**	**318.9**	**360.4**	**462.8**	**480.7**
F2	speaker 1	isolated V	1138.0	2463.0	1071.0	2066.0	794.0
F2	speaker 2	isolated V	1122.0	2311.0	1378.0	1904.0	803.0
F2	speaker 3	isolated V	1282.0	2422.0	1215.0	1913.0	816.0
		Mean	1180.7	2398.7	1221.3	1961.0	804.3
F2	speaker 1	in words	1351.0	2265.0	1032.0	1873.0	915.0
F2	speaker 2	in words	1255.0	2192.0	1428.0	1880.0	884.0
F2	speaker 3	in words	1372.0	2138.0	1284.0	1884.0	876.0
		Mean	1326.0	2198.3	1248.0	1879.0	891.7
F2	speaker 1	in conversation	1322.0	2233.0	1201.0	1788.0	1025.0
F2	speaker 2	in conversation	1221.0	2098.0	1396.0	1628.0	1013.0
F2	speaker 3	in conversation	1356.0	2087.0	1309.0	1767.0	1098.0
		Mean	1299.7	2139.3	1302.0	1727.7	1045.3
F2		**Total mean**	**1268.8**	**2245.4**	**1257.1**	**1855.9**	**913.8**

Appendix 2 Vowel formants.

Table 1:

Overall mean values of five Japanese vowel formants from Fujisaki and Sugitou (1977) and de Graaf and Koopmans-van Beinum (1982/3). The overall mean values from de Graaf and Koopmans-van Beinum's data and the data from Fujisaki and Sugitou are listed in Table 1 for comparison. De Graaf and Koopmans-van Beinum did not have any data on F3.

		F1 (Hz)	F2 (Hz)	F3 (Hz)
/ɑ/	Fujisaki and Sugitou	690	1170	2570
	Graaf & Beinum	698	1269	—
/i/	Fujisaki and Sugitou	310	2050	3040
	Graaf & Beinum	319	2245	—
/ɯ/	Fujisaki and Sugitou	360	1050	2280
	Graaf & Beinum	360	1257	—
/e/	Fujisaki and Sugitou	510	1820	2540
	Graaf & Beinum	463	1856	—
/o/	Fujisaki and Sugitou	490	870	2660
	Graaf & Beinum	481	914	—

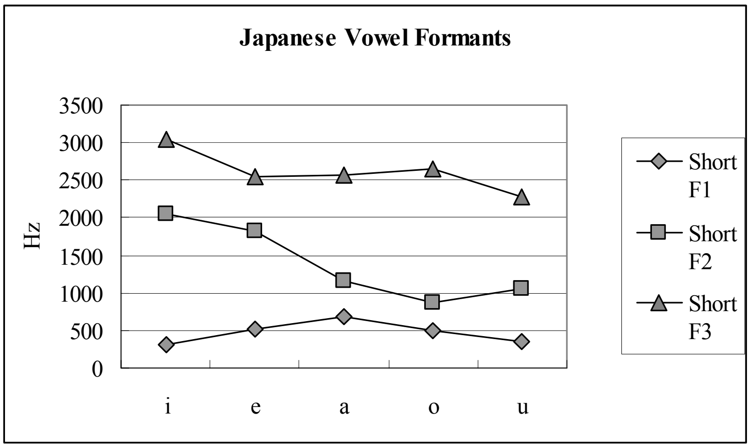

Figure 1 The overeall mean values of Japanese five vowel formants for six males. Data was taken from Fujisaki and Sugitou's values in Table 1.

Table 2:
The mean values of the vowel formants of Finnish monophthongs and "double" vowels (Wiik, 1965). Finnish vowel formants, Wiik (1965: 57) measured the F1, F2 and F3 of monophthongs and "double" vowels (Wiik's term) produced by five Finnish male informants. The mean values of eight vowels are shown in Table 2.2.

		/i/	/y/	/e/	/ø/	/æ/	/ɑ/	/o/	/u/
Monophthongs	F1 (Hz)	340	340	500	510	675	710	535	400
	F2 (Hz)	2355	1920	2070	1705	1825	1345	985	780
	F3 (Hz)	2935	2415	2685	2440	2650	2505	2425	2555
Long vowels		/ii/	/yy/	/ee/	/øø/	/ææ/	/ɑɑ/	/oo/	/uu/
	F1 (Hz)	275	300	450	455	690	720	515	340
	F2 (Hz)	2495	1995	2240	1805	1840	1240	905	605
	F3 (Hz)	3200	2430	2810	2465	2650	2455	2430	2615

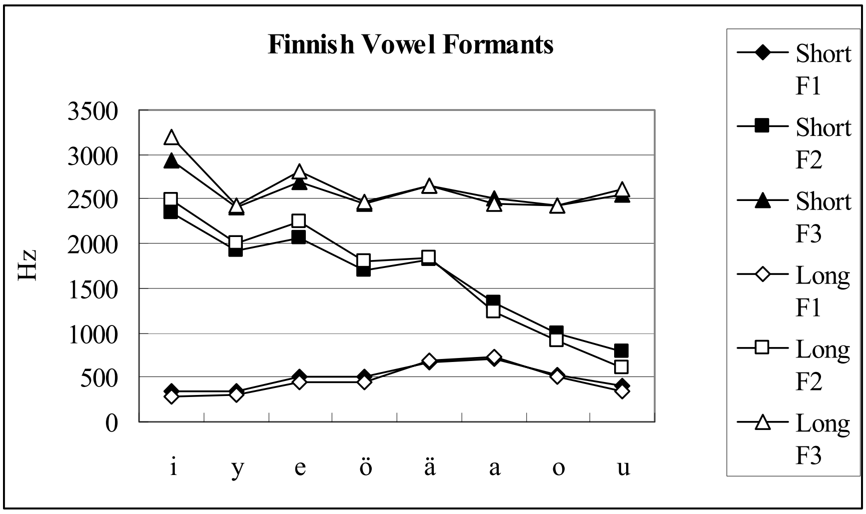

Figure 2 The overall mean values of Finnish eight short/long vowel formants for five males. The data was taken from Wiik's values in Table 2.

Appendix 3 Segmental durations in 'ma(a)m(m)a(a)'.

Finnish (ms)

		'm1'	'a1'/'aa1'	'm2'/'mm'	'a2'/'aa2'	Total
FS1	mama	85.40	88.60	64.00	86.60	324.60
FS2	mama	90.91	99.28	63.30	112.10	365.59
FS3	mama	75.02	78.55	53.36	65.88	272.81
	Mean	**83.78**	**88.81**	**60.22**	**88.19**	**321.00**
	R	**15.90**	**20.72**	**10.64**	**46.22**	**92.78**
FS1	mamaa	81.40	93.40	73.40	162.00	410.20
FS2	mamaa	90.52	100.48	77.10	259.11	527.20
FS3	mamaa	82.84	79.25	59.30	160.11	381.50
	Mean	**84.92**	**91.04**	**69.93**	**193.74**	**439.63**
	R	**9.12**	**21.23**	**17.80**	**98.99**	**145.70**
FS1	maama	91.40	191.80	61.00	60.80	405.00
FS2	maama	89.77	255.21	67.41	90.72	503.10
FS3	maama	77.43	171.23	71.99	53.52	374.17
	Mean	**86.20**	**206.08**	**66.80**	**68.35**	**427.43**
	R	**13.97**	**83.98**	**10.99**	**37.20**	**128.93**
FS1	mamma	84.60	104.00	96.80	60.80	346.20
FS2	mamma	86.07	103.02	178.71	83.55	451.35
FS3	mamma	74.70	84.56	112.98	51.40	323.64
	Mean	**81.79**	**97.19**	**129.50**	**65.25**	**373.73**
	R	**9.90**	**19.44**	**81.91**	**32.15**	**127.71**
FS1	maamaa	84.60	200.60	75.80	165.00	526.00
FS2	maamaa	89.61	240.08	87.83	231.02	648.54
FS3	maamaa	74.85	151.89	74.55	124.55	425.84
	Mean	**83.02**	**197.52**	**79.39**	**173.52**	**533.46**
	R	**14.77**	**88.19**	**13.28**	**106.47**	**222.70**
FS1	mammaa	83.60	108.60	135.60	142.80	470.60
FS2	mammaa	87.67	99.73	210.49	217.77	615.66
FS3	mammaa	71.77	119.63	118.42	146.00	455.82
	Mean	**81.01**	**109.32**	**154.84**	**168.86**	**514.03**
	R	**15.89**	**19.90**	**92.07**	**142.80**	**159.83**
FS1	maamma	93.00	181.60	87.20	58.00	419.80
FS2	maamma	99.84	194.58	161.90	74.64	530.96
FS3	maamma	84.08	152.26	129.19	74.99	440.52
	Mean	**92.31**	**176.15**	**126.10**	**69.21**	**463.76**

	R	**15.76**	**42.32**	**74.70**	**16.99**	**111.16**
FS1	maammaa	90.80	190.80	124.20	159.80	565.60
FS2	maammaa	100.63	193.75	166.38	223.22	683.98
FS3	maammaa	83.31	175.77	125.56	137.90	522.54
	Mean	**91.58**	**186.78**	**138.71**	**173.64**	**590.70**
	R	**17.32**	**17.98**	**42.18**	**85.32**	**161.44**

Japanese (ms)

		‘m1’	‘a1’/‘aa1’	‘m2’/‘mm’	‘a2’/‘aa2’	Total
JS1	mama	85.60	82.00	56.80	85.60	310.00
JS2	mama	78.35	65.42	55.57	75.60	274.95
JS3	mama	75.81	96.01	62.07	101.93	335.82
	Mean	**79.92**	**81.15**	**58.15**	**87.71**	**306.92**
	R	**9.79**	**30.59**	**6.49**	**26.33**	**73.20**
JS1	mamaa	68.40	93.40	73.40	195.20	430.40
JS2	mamaa	82.04	81.18	68.33	178.31	409.86
JS3	mamaa	76.90	95.34	63.86	202.98	439.07
	Mean	**88.24**	**209.42**	**66.35**	**73.51**	**437.52**
	R	**13.64**	**14.15**	**9.54**	**24.67**	**62.00**
JS1	maama	91.20	224.00	72.40	71.80	459.40
JS2	maama	81.41	174.92	63.05	73.28	392.66
JS3	maama	92.11	229.35	63.61	75.44	460.50
	Mean	**99.82**	**75.43**	**122.40**	**69.52**	**367.18**
	R	**10.69**	**54.43**	**9.35**	**3.64**	**67.83**
JS1	mamma	97.80	109.60	155.20	68.80	431.40
JS2	mamma	91.97	49.69	100.50	59.14	301.31
JS3	mamma	109.70	67.01	111.50	80.63	368.84
	Mean	**75.78**	**89.97**	**68.53**	**192.16**	**426.44**
	R	**17.73**	**59.91**	**54.70**	**21.49**	**130.09**
JS1	maamaa	93.40	236.60	84.40	175.20	589.60
JS2	maamaa	83.65	171.24	71.67	158.23	484.78
JS3	maamaa	95.50	268.07	95.80	229.63	689.00
	Mean	**90.85**	**225.30**	**83.96**	**187.68**	**587.79**
	R	**11.85**	**96.83**	**24.13**	**71.40**	**204.22**
JS1	mammaa	107.80	121.00	178.00	187.80	594.60
JS2	mammaa	80.00	117.95	149.29	155.07	502.31
JS3	mammaa	92.13	126.54	203.89	216.00	638.56
	Mean	**93.31**	**121.83**	**177.06**	**186.29**	**578.49**

	R	**27.80**	**3.05**	**54.61**	**60.93**	**136.25**
JS1	maamma	101.40	189.60	183.40	102.20	576.60
JS2	maamma	87.73	212.68	133.76	78.40	512.56
JS3	maamma	99.57	228.95	196.54	75.35	600.42
	Mean	**96.23**	**210.41**	**171.23**	**85.32**	**563.19**
	R	**13.67**	**39.35**	**62.78**	**26.85**	**87.85**
JS1	maammaa	101.80	209.60	172.80	225.20	709.40
JS2	maammaa	93.91	220.50	148.34	201.40	664.15
JS3	maammaa	100.75	235.48	203.02	238.80	778.06
	Mean	**98.82**	**221.86**	**174.72**	**221.80**	**717.20**
	R	**7.89**	**25.88**	**54.68**	**37.40**	**113.90**

Appendix 4 Segmental durations in 'pa(a)p(p)a(a)'.

Finnish (ms)

		'p1'	'a1'/'aa1'	'p2'/'pp'	'a2'/'aa2'	Total
FS1	papa	106.60	92.60	81.40	105.40	386.00
FS2	papa	118.94	81.99	107.81	111.45	420.19
FS3	papa	94.88	74.37	71.57	65.62	306.44
	Mean	**106.81**	**82.99**	**86.93**	**94.16**	**370.88**
	R	**24.06**	**18.23**	**36.25**	**45.83**	**113.76**
FS1	papaa	98.20	87.40	102.20	192.40	480.20
FS2	papaa	128.01	78.80	126.11	212.62	545.54
FS3	papaa	98.33	70.51	89.75	158.04	416.62
	Mean	**108.18**	**78.90**	**106.02**	**187.69**	**480.79**
	R	**29.81**	**16.89**	**36.36**	**54.59**	**128.91**
FS1	paapa	122.00	213.00	80.20	70.40	485.60
FS2	paapa	124.66	216.36	85.58	71.25	497.85
FS3	paapa	93.00	184.75	78.57	36.98	393.31
	Mean	**113.22**	**204.71**	**81.45**	**59.55**	**458.92**
	R	**31.66**	**31.61**	**7.01**	**34.27**	**104.54**
FS1	pappa	107.20	103.60	181.40	65.60	457.80
FS2	pappa	140.64	71.82	224.67	72.37	509.50
FS3	pappa	100.35	69.73	168.87	40.74	379.70
	Mean	**116.06**	**81.72**	**191.65**	**59.57**	**449.00**
	R	**40.29**	**33.87**	**55.80**	**31.62**	**129.80**
FS1	paapaa	122.00	200.20	108.20	184.20	614.60

FS2	paapaa	136.92	206.14	109.04	206.82	658.93
FS3	paapaa	100.82	164.05	92.34	153.19	510.40
	M	**119.91**	**190.13**	**103.19**	**181.40**	**594.64**
	R	**36.10**	**42.09**	**16.70**	**53.63**	**148.53**
FS1	pappaa	110.40	93.20	197.20	151.20	552.00
FS2	pappaa	139.09	67.07	255.47	185.50	647.13
FS3	pappaa	91.88	65.90	182.94	128.23	468.95
	Mean	**113.79**	**75.39**	**211.87**	**154.98**	**556.03**
	R	**47.22**	**27.30**	**72.52**	**57.27**	**178.18**
FS1	paappa	116.80	177.00	145.80	64.40	504.00
FS2	paappa	140.48	157.71	195.59	69.78	563.55
FS3	paappa	109.23	149.10	148.39	49.55	456.27
	M	**122.17**	**161.27**	**163.26**	**61.24**	**507.94**
	R	**31.25**	**27.90**	**49.79**	**20.22**	**107.29**
FS1	paappaa	122.80	191.80	183.40	168.20	666.20
FS2	paappaa	151.71	157.13	204.28	192.43	705.55
FS3	paappaa	106.74	146.82	171.68	156.06	581.30
	Mean	**127.08**	**165.25**	**186.45**	**172.23**	**651.02**
	R	**44.97**	**44.98**	**32.60**	**36.37**	**124.25**

Japanese (ms)

		‘p1’	‘a1’/‘aa1’	‘p2’/‘pp’	‘a2’/‘aa2’	Total
JS1	papa	110.00	69.75	73.75	71.75	325.25
JS2	papa	96.46	57.93	61.82	74.51	290.72
JS3	papa	100.14	62.60	79.49	83.45	325.67
	Mean	**102.20**	**63.43**	**71.68**	**76.57**	**313.88**
	R	**13.54**	**11.82**	**17.67**	**11.70**	**34.95**
JS1	papaa	123.80	68.40	104.20	173.60	470.00
JS2	papaa	110.53	61.28	93.67	165.40	430.88
JS3	papaa	102.11	69.23	109.18	199.57	480.10
	Mean	**112.15**	**66.30**	**102.35**	**179.52**	**460.33**
	R	**21.69**	**7.96**	**10.53**	**34.18**	**49.22**
JS1	paapa	125.25	181.00	95.50	67.75	469.50
JS2	paapa	118.20	156.95	79.83	75.06	430.04
JS3	paapa	128.43	202.86	87.15	63.80	482.25
	Mean	**123.96**	**180.27**	**87.49**	**68.87**	**460.59**
	R	**10.23**	**45.92**	**15.67**	**11.26**	**52.21**
JS1	pappa	123.00	77.40	186.80	58.40	445.60

JS2	pappa	99.78	76.84	177.85	67.49	421.95
JS3	pappa	120.99	87.73	213.32	74.81	496.85
	Mean	**114.59**	**80.66**	**192.65**	**66.90**	**454.80**
	R	**23.22**	**10.90**	**35.47**	**16.41**	**74.89**
JS1	paapaa	126.00	195.80	125.40	169.40	616.60
JS2	paapaa	113.25	156.42	104.18	159.66	533.50
JS3	paapaa	131.73	213.80	142.96	201.21	689.70
	Mean	**123.66**	**188.67**	**124.18**	**176.76**	**613.27**
	R	**18.48**	**57.38**	**38.79**	**41.55**	**156.19**
JS1	pappaa	142.40	84.00	226.20	157.00	609.60
JS2	pappaa	99.84	83.78	207.36	158.65	549.62
JS3	pappaa	144.18	94.63	242.85	190.19	671.85
	Mean	**128.81**	**87.47**	**225.47**	**168.61**	**610.36**
	R	**42.56**	**10.85**	**35.49**	**33.19**	**122.23**
JS1	paappa	150.80	183.00	185.20	60.60	579.60
JS2	paappa	156.27	197.73	165.05	78.99	598.05
JS3	paappa	166.07	228.82	218.61	66.08	679.58
	Mean	**157.71**	**203.18**	**189.62**	**68.56**	**619.08**
	R	**15.27**	**45.82**	**53.55**	**18.39**	**99.98**
JS1	paappaa	149.00	192.40	214.20	192.60	748.20
JS2	paappaa	145.37	212.24	205.12	186.02	748.74
JS3	paappaa	145.70	224.42	234.57	223.20	827.89
	Mean	**146.69**	**209.69**	**217.96**	**200.60**	**774.94**
	R	**3.63**	**32.02**	**29.45**	**37.18**	**79.69**

Appendix 5 Segmental durations in ‘sa(a)s(s)a(a)’.

Finnish (ms)

		‘s1’	‘a1’/‘aa1’	‘s2’/‘ss’	‘a2’/‘aa2’	Total
FS1	sasa	107.20	85.80	76.20	91.20	360.40
FS2	sasa	108.15	106.17	95.34	111.82	421.48
FS3	sasa	77.27	81.10	49.95	63.10	271.43
	Mean	**97.54**	**91.02**	**73.83**	**88.71**	**351.10**
	R	**30.88**	**25.07**	**45.39**	**48.71**	**150.05**
FS1	sasaa	92.20	81.60	98.80	160.60	433.20
FS2	sasaa	101.61	96.02	107.94	241.71	547.28
FS3	sasaa	75.46	76.08	73.62	155.97	381.12
	Mean	**89.76**	**84.57**	**93.45**	**186.09**	**453.87**

	R	**26.15**	**19.94**	**34.33**	**85.74**	**166.16**
FS1	saasa	112.40	187.80	80.40	54.80	435.40
FS2	saasa	105.32	238.65	80.81	78.75	503.54
FS3	saasa	78.53	179.59	50.16	41.11	349.39
	Mean	**98.75**	**202.01**	**70.46**	**58.22**	**429.44**
	R	**33.87**	**59.07**	**30.65**	**37.64**	**154.15**
FS1	sassa	107.00	95.60	127.80	59.20	389.60
FS2	sassa	99.42	98.25	206.84	87.42	491.92
FS3	sassa	79.35	84.02	144.94	47.81	356.12
	Mean	**95.26**	**92.62**	**159.86**	**64.81**	**412.55**
	R	**27.65**	**14.24**	**61.90**	**39.60**	**135.80**
FS1	saasaa	114.20	188.00	101.60	151.60	555.40
FS2	saasaa	110.90	217.53	105.44	226.95	660.82
FS3	saasaa	79.15	162.22	72.90	128.43	442.70
	Mean	**101.42**	**189.25**	**93.31**	**168.99**	**552.97**
	R	**35.05**	**55.30**	**32.55**	**98.52**	**218.12**
FS1	sassaa	102.20	97.80	166.40	135.20	501.60
FS2	sassaa	100.51	93.43	236.00	212.62	642.55
FS3	sassaa	80.23	81.30	171.22	133.72	466.46
	Mean	**94.31**	**90.84**	**191.21**	**160.51**	**536.87**
	R	**21.97**	**16.50**	**64.78**	**78.90**	**176.09**
FS1	saassa	116.80	173.80	147.40	61.40	499.40
FS2	saassa	122.11	180.77	185.42	77.81	566.11
FS3	saassa	101.96	166.76	124.56	44.36	437.64
	Mean	**113.62**	**173.78**	**152.46**	**61.19**	**501.05**
	R	**20.15**	**14.01**	**60.86**	**33.45**	**128.46**
FS1	saassaa	110.60	189.20	168.40	164.40	632.60
FS2	saassaa	121.90	187.66	195.45	218.60	723.60
FS3	saassaa	99.05	170.22	144.42	144.15	557.84
	Mean	**110.52**	**182.36**	**169.42**	**175.72**	**638.01**
	R	**22.85**	**18.98**	**51.03**	**74.44**	**165.77**

Japanese (ms)

		‘s1’	‘a1’/‘aa1’	‘s2’/‘ss’	‘a2’/‘aa2’	Total
JS1	sasa	100.00	71.67	73.00	63.33	308.00
JS2	sasa	90.94	65.92	61.49	60.73	279.09
JS3	sasa	70.38	74.61	79.34	96.86	321.19
	Mean	**87.11**	**70.73**	**71.28**	**73.64**	**302.76**

	R	**29.62**	**5.75**	**17.84**	**36.13**	**42.10**
JS1	sasaa	118.60	74.20	104.40	171.40	468.60
JS2	sasaa	85.86	78.75	95.29	178.72	438.61
JS3	sasaa	78.99	83.17	89.53	204.75	456.45
	Mean	**94.48**	**78.71**	**96.41**	**184.95**	**454.55**
	R	**32.74**	**8.97**	**14.87**	**33.35**	**29.99**
JS1	saasa	118.20	204.80	94.20	79.80	497.00
JS2	saasa	109.20	175.15	79.20	64.31	427.87
JS3	saasa	101.10	228.08	73.42	76.74	479.34
	Mean	**109.50**	**202.68**	**82.27**	**73.62**	**468.07**
	R	**17.10**	**52.93**	**15.00**	**15.49**	**69.13**
JS1	sassa	113.60	84.00	165.00	69.00	431.60
JS2	sassa	98.01	102.96	136.80	74.74	412.51
JS3	sassa	85.35	114.68	158.54	83.63	442.20
	Mean	**98.99**	**100.55**	**153.45**	**75.79**	**428.77**
	R	**28.25**	**30.68**	**28.20**	**14.63**	**29.70**
JS1	saasaa	120.20	215.00	110.40	167.40	613.00
JS2	saasaa	101.44	144.32	90.52	143.81	480.08
JS3	saasaa	110.05	271.56	111.16	218.80	711.58
	Mean	**110.56**	**210.29**	**104.03**	**176.67**	**601.55**
	R	**18.76**	**70.68**	**20.64**	**74.99**	**231.49**
JS1	sassaa	114.00	88.40	207.20	183.60	593.20
JS2	sassaa	81.69	98.82	172.36	155.50	508.37
JS3	sassaa	85.63	117.22	222.54	204.10	629.49
	Mean	**93.77**	**101.48**	**200.70**	**181.06**	**577.02**
	R	**32.31**	**28.82**	**50.18**	**48.60**	**121.12**
JS1	saassa	125.20	214.20	153.60	71.40	564.40
JS2	saassa	121.61	219.69	136.04	71.48	548.83
JS3	saassa	125.23	261.84	176.77	74.21	638.05
	Mean	**124.01**	**231.91**	**155.47**	**72.36**	**583.76**
	R	**3.62**	**47.64**	**40.72**	**2.73**	**89.22**
JS1	saassaa	122.60	217.40	179.40	180.00	699.40
JS2	saassaa	113.33	228.02	176.82	183.16	701.33
JS3	saassaa	125.74	269.81	183.77	220.36	799.69
	Mean	**120.56**	**238.41**	**180.00**	**194.51**	**733.47**
	R	**12.41**	**52.41**	**6.95**	**40.36**	**100.29**

Appendix 6 ANOVA for Table 3.23.

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
V 'a1'	3074	11	279,45355	3,3809372	0,0274514	2,8179272
F/J	90,9	1	90,896546	1,0997016	0,3168263	4,8443383
Error	909	11	82,655647			
Total	4074	23				

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
V 'a2'	1644	11	149,48405	2,5791926	0,0656191	2,8179272
F/J	121	1	121,16629	2,0905988	0,1760914	4,8443383
Error	638	11	57,957693			
Total	2403	23				

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
V 'aa1'	1990	11	180,93469	0,5573987	0,8266554	2,8179272
F/J	3671	1	3671,0066	11,309132	0,0063312	4,8443383
Error	3571	11	324,6055			
Total	9232	23				

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
V 'aa2'	2102	11	191,07689	1,5100012	0,252774	2,8179272
F/J	979	1	978,80436	7,735084	0,0178655	4,8443383
Error	1392	11	126,54088			
Total	4473	23				

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
C 'm1'	395,76838	7	56,5383406	1,510364	0,2999182	3,78705067
F/J	92,014192	1	92,0141923	2,458065	0,1609089	5,59145974
Error	262,03515	7	37,4335928			
Total	749,81773	15				

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ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
C 'm2'	518,78873	3	172,929577	25,40456	0,012369	9,27661858
F/J	0,050301	1	0,05030105	0,00739	0,936912	10,1279625
Error	20,421091	3	6,80703018			
Total	539,26012	7				

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
C 'mm'	1755,7183	3	585,239431	2,24936	0,2613959	9,27661858
F/J	1158,5026	1	1158,50255	4,452689	0,1253505	10,1279625
Error	780,54125	3	260,180418			
Total	3694,7621	7				

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
C 'p1'	2078,7452	7	296,963598	3,493051	0,0604929	3,78705067
F/J	425,84093	1	425,840933	5,008978	0,0602488	5,59145974
Error	595,10868	7	85,0155262			
Total	3099,6948	15				

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
C 'p2'	1580,2003	3	526,733436	4,47515	0,1249957	9,27661858
F/J	8,235795	1	8,235795	0,069972	0,8085103	10,1279625
Error	353,10551	3	117,701838			
Total	1941,5416	7				

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
C 'pp'	1884,768	3	628,256009	6,72468	0,0759272	9,27661858
F/J	656,64669	1	656,646686	7,028566	0,0769185	10,1279625
Error	280,27624	3	93,425413			
Total	2821,691	7				

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
C 's1'	1525,5731	7	217,939009	8,143484	0,0064575	3,78705067
F/J	89,371922	1	89,3719218	3,339461	0,1103621	5,59145974
Error	187,33665	7	26,762379			
Total	1802,2816	15				

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
C 's2'	1026,6622	3	342,220734	14,85942	0,026365	9,27661858
F/J	65,721951	1	65,7219507	2,853684	0,1897467	10,1279625
Error	69,091693	3	23,0305642			
Total	1161,4758	7				

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
C 'ss'	2261,2158	3	753,738601	24,75526	0,0128359	9,27661858
F/J	34,732039	1	34,7320387	1,140715	0,3638127	10,1279625
Error	91,342827	3	30,447609			
Total	2387,2907	7				

Appendix 7 Perceptual boundaries (ms) under different SS.

SS = syllable structures. The mean perceptual boundary durations (BR), range (*R*) durations and *SD* within the segment, in different syllable structures for vowels and consonants between Finnish and Japanese, according to different consonantal environments.

(ms)

			C = /m/		C = /p/		C = /s/	
V/C	Syllable Structure	PC	F.	J.	F.	J.	F.	J.
V	CVCV-CVCVV	Level	21.4	17.1	20.0	14.3	21.4	15.7
		HL	18.6	18.6	20.0	14.3	24.3	15.7
		LH	22.9	14.3	12.9	15.7	18.6	14.3
		SW	18.6	14.3	20.0	14.3	18.6	15.7
		WS	22.9	12.9	21.4	14.3	15.7	14.3
	CVCV-CVVCV	Level	14.3	12.9	18.6	15.7	20.0	14.3
		HL	17.1	18.6	15.7	14.3	15.7	15.7
		LH	15.7	17.1	12.9	18.6	15.7	12.9
		SW	17.1	15.7	17.1	15.7	15.7	12.9
		WS	17.1	11.4	17.1	14.3	18.6	17.1
	CVCVV-CVVCVV	Level	12.9	18.6	12.9	14.3	21.4	20.0
		HL	17.1	18.6	18.6	12.9	17.1	14.3
		LH	18.6	18.6	15.7	12.9	21.4	18.6
		SW	18.6	20.0	20.0	11.4	21.4	15.7
		WS	15.7	17.1	17.1	17.1	21.4	18.6
	CVVCV-CVVCVV	Level	18.6	17.1	27.1	14.3	28.6	18.3
		HL	30.0	17.1	27.1	15.0	25.7	15.0
		LH	14.3	15.0	21.4	15.0	27.1	14.3
		SW	20.0	20.0	27.1	20.0	25.7	18.3
		WS	40.0	17.1	22.9	17.1	24.3	12.9
C	CVCV-CVCCV	Level	28.6	14.3	15.7	14.3	20.0	12.9
		HL	12.9	14.3	15.7	10.0	17.1	20.0
		LH	17.1	17.1	20.0	12.9	17.1	18.6
		SW	18.3	14.3	21.4	12.9	18.6	12.9
		WS	14.3	14.3	17.1	11.4	21.4	17.1
	CVCVV-CVCCVV	Level	18.6	14.3	15.7	14.3	17.1	18.6
		HL	13.3	14.3	18.6	17.1	18.6	20.0
		LH	14.3	17.1	18.6	15.7	20.0	18.3
		SW	15.7	17.1	15.7	14.3	17.1	18.3

		WS	21.4	14.3	20.0	15.7	18.6	13.3
	CVVCV-CVVCCV	Level	18.6	15.7	16.7	17.1	21.4	15.7
		HL	16.0	20.0	18.6	15.7	12.9	18.6
		LH	15.7	17.1	20.0	14.3	18.6	20.0
		SW	14.3	17.1	17.1	14.3	20.0	15.7
		WS	14.3	15.7	22.9	20.0	20.0	18.6
	CVVCVV-CVVCCVV	Level	18.6	15.7	21.4	14.3	18.6	17.1
		HL	21.7	14.3	15.7	15.7	17.1	17.1
		LH	18.6	22.9	22.9	14.3	15.7	12.9
		SW	15.7	15.7	18.6	17.1	15.7	18.6
		WS	25.7	20.0	18.6	15.7	11.4	18.6

Appendix 8 Perceptual boundaries (ms) under different PC.

PC = prosodic conditions. The mean perceptual boundary durations (BR) and range (*R*) durations, and *SD* within the segment in five prosodic variants for vowels and consonants between Finnish and Japanese.

	Vowel			Consonants		
PC	Syllable structure	F. (ms)	J. (ms)	Syllable structure	F. (ms)	J. (ms)
Level	CVCV-CVCVV	21	15.7	CVCV-CVCCV	21.4	13.8
	CVCV-CVVCV	17.6	14.3	CVCVV-CVCCVV	17.1	15.7
	CVCVV-CVVCVV	15.7	17.6	CVVCV-CVVCCV	18.9	16.2
	CVVCV-CVVCVV	24.8	16.5	CVVCVV-CVVCCVV	19.5	15.7
	Mean	**19.8**	**16**	**Mean**	**19.2**	**15.4**
	R	**9.1**	**3.3**	***R***	**4.3**	**2.4**
	SD	**4**	**1.4**	***SD***	**1.8**	**1.1**
HL	CVCV-CVCVV	21	16.2	CVCV-CVCCV	15.2	15.0
	CVCV-CVVCV	16.2	16.2	CVCVV-CVCCVV	17.0	17.1
	CVCVV-CVVCVV	17.6	15.2	CVVCV-CVVCCV	15.8	18.1
	CVVCV-CVVCVV	27.6	15.8	CVVCVV-CVVCCVV	18.0	15.7
	Mean	**20.6**	**15.9**	**Mean**	**16.5**	**16.5**
	R	**11.4**	**1**	***R***	**2.8**	**3.1**
	SD	**5.1**	**0.5**	***SD***	**1.2**	**1.4**
LH	CVCV-CVCVV	18.1	14.8	CVCV-CVCCV	18.1	16.2
	CVCV-CVVCV	14.8	16.2	CVCVV-CVCCVV	17.6	17.0
	CVCVV-CVVCVV	18.6	16.7	CVVCV-CVVCCV	18.1	17.1

	CVVCV-CVVCVV	21	14.7	CVVCVV-CVVCCVV	19.0	16.7
	Mean	**18.1**	**15.6**	**Mean**	**18.2**	**16.8**
	R	**6.2**	**2**	***R***	**1.4**	**0.9**
	SD	**2.6**	**1**	***SD***	**0.6**	**0.4**
SW	CVCV-CVCVV	19	14.8	CVCV-CVCCV	19.5	13.3
	CVCV-CVVCV	16.7	14.8	CVCVV-CVCCVV	16.2	16.5
	CVCVV-CVVCVV	20	15.7	CVVCV-CVVCCV	17.1	15.7
	CVVCV-CVVCVV	24.3	19.5	CVVCVV-CVVCCVV	16.7	17.1
	Mean	**20**	**16.2**	**Mean**	**17.4**	**15.7**
	R	**7.6**	**4.7**	***R***	**3.3**	**3.8**
	SD	**3.2**	**2.2**	***SD***	**1.5**	**1.7**
WS	CVCV-CVCVV	20	13.8	CVCV-CVCCV	17.6	14.3
	CVCV-CVVCV	17.6	14.3	CVCVV-CVCCVV	20.0	14.5
	CVCVV-CVVCVV	18.1	17.6	CVVCV-CVVCCV	19.0	18.1
	CVVCV-CVVCVV	29	15.7	CVVCVV-CVVCCVV	18.6	18.1
	Mean	**21.2**	**15.4**	**Mean**	**18.8**	**16.3**
	R	**11.4**	**3.8**	***R***	**2.4**	**3.8**
	SD	**5.3**	**1.7**	***SD***	**1.0**	**2.1**

F. = Finnish, J. = Japanese.

Appendix 9 Perceptual boundaries (%) within segment.

The mean perceptual boundary range (BR) ratios (%) and range (*R*) ratios (%) within the segment under five prosodic conditions (PC) in different syllable structures for vowels and consonants between Finnish and Japanese.

			C = /m/		C = /p/		C = /s/	
V/C	Syllable Structure	PC	F.	J.	F.	J.	F.	J.
V	CVCV-CVCVV	Level	10.7%	8.6%	10.0%	7.1%	10.7%	7.9%
		HL	9.3%	9.3%	10.0%	7.1%	12.1%	7.9%
		LH	11.4%	7.1%	6.4%	7.9%	9.3%	7.1%
		SW	9.3%	7.1%	10.0%	7.1%	9.3%	7.9%
		WS	11.4%	6.4%	10.7%	7.1%	7.9%	7.1%
		Mean	**10.4%**	**7.7%**	**9.4%**	**7.3%**	**9.9%**	**7.6%**
		R	**2.1%**	**2.9%**	**4.3%**	**0.7%**	**4.3%**	**0.7%**
	CVCV-CVVCV	Level	7.1%	6.4%	9.3%	7.9%	10.0%	7.1%
		HL	8.6%	9.3%	7.9%	7.1%	7.9%	7.9%

		LH	7.9%	8.6%	6.4%	9.3%	7.9%	6.4%
		SW	8.6%	7.9%	8.6%	7.9%	7.9%	6.4%
		WS	8.6%	5.7%	8.6%	7.1%	9.3%	8.6%
		Mean	**8.1%**	**7.6%**	**8.1%**	**7.9%**	**8.6%**	**7.3%**
		R	**1.4%**	**3.6%**	**2.9%**	**2.1%**	**2.1%**	**2.1%**
	CVCVV-CVVCVV	Level	6.4%	9.3%	6.4%	7.1%	10.7%	10.0%
		HL	8.6%	9.3%	9.3%	6.4%	8.6%	7.1%
		LH	9.3%	9.3%	7.9%	6.4%	10.7%	9.3%
		SW	9.3%	10.0%	10.0%	5.7%	10.7%	7.9%
		WS	7.9%	8.6%	8.6%	8.6%	10.7%	9.3%
		Mean	**8.3%**	**9.3%**	**8.4%**	**6.9%**	**10.3%**	**8.7%**
		R	**2.9%**	**1.4%**	**3.6%**	**2.9%**	**2.1%**	**2.9%**
	CVVCV-CVVCVV	Level	9.3%	8.6%	13.6%	7.1%	14.3%	9.2%
		HL	15.0%	8.6%	13.6%	7.5%	12.9%	7.5%
		LH	7.1%	7.5%	10.7%	7.5%	13.6%	7.1%
		SW	10.0%	10.0%	13.6%	10.0%	12.9%	9.2%
		WS	20.0%	8.6%	11.4%	8.6%	12.1%	6.4%
		Mean	**12.3%**	**8.7%**	**12.6%**	**8.2%**	**13.1%**	**7.8%**
		R	**12.9%**	**2.5%**	**2.9%**	**2.9%**	**2.1%**	**2.7%**
C	CVCV-CVCCV	Level	14.3%	7.1%	7.9%	7.1%	10.0%	6.4%
		HL	6.4%	7.1%	7.9%	5.0%	8.6%	10.0
		LH	8.6%	8.6%	10.0%	6.4%	8.6%	9.3%
		SW	9.2%	7.1%	10.7%	6.4%	9.3%	6.4%
		WS	7.1%	7.1%	8.6%	5.7%	10.7%	8.6%
		Mean	**9.1%**	**7.4%**	**9.0%**	**6.2%**	**9.4%**	**8.1%**
		R	**7.9%**	**1.4%**	**2.9%**	**2.1%**	**2.1%**	**3.6%**
	CVCVV-CVCCVV	Level	11.6%	8.9%	7.9%	7.1%	8.6%	9.3%
		HL	8.3%	8.9%	9.3%	8.6%	9.3%	10.0
		LH	8.9%	10.7%	9.3%	7.9%	10.0%	9.2%
		SW	9.8%	10.7%	7.9%	7.1%	8.6%	9.2%
		WS	13.4%	8.9%	10.0%	7.9%	9.3%	6.7%
		Mean	**10.5%**	**9.6%**	**8.9%**	**7.7%**	**9.1%**	**8.9%**
		R	**5.1%**	**1.8%**	**2.1%**	**1.4%**	**1.4%**	**3.3%**
	CVVCV-CVVCCV	Level	11.6%	9.8%	8.3%	8.6%	10.7%	7.9%
		HL	10.0%	12.5%	9.3%	7.9%	6.4%	9.3%
		LH	9.8%	10.7%	10.0%	7.1%	9.3%	10.0
		SW	8.9%	10.7%	8.6%	7.1%	10.0%	7.9%
		WS	8.9%	9.8%	11.4%	10.0%	10.0%	9.3%

		Mean	**9.8%**	**10.7%**	**9.6%**	**8.1%**	**9.3%**	**8.9%**
		R	**2.7%**	**2.7%**	**3.1%**	**2.9%**	**4.3%**	**2.1%**
	CVVCVV-CVVCCVV	Level	11.6%	9.8%	10.7%	7.1%	9.3%	8.6%
		HL	13.5%	8.9%	7.9%	7.9%	8.6%	8.6%
		LH	11.6%	14.3%	11.4%	7.1%	7.9%	6.4%
		SW	9.8%	9.8%	9.3%	8.6%	7.9%	9.3%
		WS	16.1%	12.5%	9.3%	7.9%	5.7%	9.3%
		Mean	**12.5%**	**11.1%**	**9.7%**	**7.7%**	**7.9%**	**8.4%**
		R	**6.3%**	**5.4%**	**3.6%**	**1.4%**	**3.6%**	**2.9%**

Appendix 10 Perceptual boundaries (%) within word.

The mean perceptual boundary range (BR) ratios (%) and range (*R*) ratios (%) within the word in five prosodic conditions (PC) in different syllable structures for vowels and consonants between Finnish and Japanese.

			C = /m/		C = /p/		C = /s/	
V/C	Syllable Structure	PC	F.	J.	F.	J.	F.	J.
V	CVCV-CVCVV	Level	5.8%	4.6%	4.7%	3.3%	5.1%	3.7%
		HL	5.0%	5.0%	4.7%	3.3%	5.8%	3.7%
		LH	6.2%	3.9%	3.0%	3.7%	4.4%	3.4%
		SW	5.0%	3.9%	4.7%	3.3%	4.4%	3.7%
		WS	6.2%	3.5%	5.0%	3.3%	3.7%	3.4%
		Mean	**5.6%**	**4.2%**	**4.4%**	**3.4%**	**4.7%**	**3.6%**
		R	**1.2%**	**1.5%**	**2.0%**	**0.3%**	**2.0%**	**0.3%**
	CVCV-CVVCV	Level	3.9%	3.5%	4.3%	3.7%	5.4%	3.9%
		HL	4.6%	5.0%	3.7%	3.3%	4.2%	4.2%
		LH	4.2%	4.6%	3.0%	4.3%	4.2%	3.5%
		SW	4.6%	4.2%	4.0%	3.7%	4.2%	3.5%
		WS	4.6%	3.1%	4.0%	3.3%	5.0%	4.6%
		Mean	**4.4%**	**4.1%**	**3.8%**	**3.7%**	**4.6%**	**3.9%**
		R	**0.8%**	**1.9%**	**1.3%**	**1.0%**	**1.2%**	**1.2%**
	CVCVV-CVVCVV	Level	2.5%	3.6%	2.2%	2.5%	3.8%	3.5%
		HL	3.3%	3.6%	3.2%	2.2%	3.0%	2.5%
		LH	3.6%	3.6%	2.7%	2.2%	3.8%	3.3%
		SW	3.6%	3.8%	3.4%	2.0%	3.8%	2.8%
		WS	3.0%	3.3%	3.0%	3.0%	3.8%	3.3%

		Mean	**3.2%**	**3.6%**	**2.9%**	**2.4%**	**3.6%**	**3.1%**
		R	**1.1%**	**0.5%**	**1.2%**	**1.0%**	**0.8%**	**1.0%**
	CVVCV-CVVCVV	Level	3.6%	3.3%	4.7%	2.5%	5.0%	3.2%
		HL	5.8%	3.3%	4.7%	2.6%	4.5%	2.6%
		LH	2.7%	2.9%	3.7%	2.6%	4.8%	2.5%
		SW	3.8%	3.8%	4.7%	3.4%	4.5%	3.2%
		WS	7.7%	3.3%	3.9%	3.0%	4.3%	2.3%
		Mean	**4.7%**	**3.3%**	**4.3%**	**2.8%**	**4.6%**	**2.7%**
		R	**4.9%**	**1.0%**	**1.0%**	**1.0%**	**0.8%**	**1.0%**
C	CVCV-CVCCV	Level	5.5%	2.7%	2.7%	2.5%	3.5%	2.3%
		HL	2.5%	2.7%	2.7%	1.7%	3.0%	3.5%
		LH	3.3%	3.3%	3.4%	2.2%	3.0%	3.3%
		SW	3.5%	2.7%	3.7%	2.2%	3.3%	2.3%
		WS	2.7%	2.7%	3.0%	2.0%	3.8%	3.0%
		Mean	**3.5%**	**2.9%**	**3.1%**	**2.1%**	**3.3%**	**2.9%**
		R	**3.0%**	**0.5%**	**1.0%**	**0.7%**	**0.8%**	**1.3%**
	CVCVV-CVCCVV	Level	4.0%	3.0%	2.9%	2.6%	3.2%	3.4%
		HL	2.8%	3.0%	3.4%	3.2%	3.4%	3.7%
		LH	3.0%	3.6%	3.4%	2.9%	3.7%	3.4%
		SW	3.3%	3.6%	2.9%	2.6%	3.2%	3.4%
		WS	4.6%	3.0%	3.7%	2.9%	3.4%	2.5%
		Mean	**3.6%**	**3.3%**	**3.3%**	**2.9%**	**3.4%**	**3.3%**
		R	**1.7%**	**0.6%**	**0.8%**	**0.5%**	**0.5%**	**1.2%**
	CVVCV-CVVCCV	Level	4.0%	3.3%	3.1%	3.2%	4.0%	2.9%
		HL	3.4%	4.3%	3.4%	2.9%	2.4%	3.4%
		LH	3.3%	3.6%	3.7%	2.6%	3.4%	3.7%
		SW	3.0%	3.6%	3.2%	2.6%	3.7%	2.9%
		WS	3.0%	3.3%	4.2%	3.7%	3.7%	3.4%
		Mean	**3.4%**	**3.6%**	**3.5%**	**3.0%**	**3.4%**	**3.3%**
		R	**0.9%**	**0.9%**	**1.1%**	**1.1%**	**1.6%**	**0.8%**
	CVVCVV-CVVCCVV	Level	3.0%	2.5%	3.1%	2.1%	2.7%	2.5%
		HL	3.5%	2.3%	2.3%	2.3%	2.5%	2.5%
		LH	3.0%	3.7%	3.3%	2.1%	2.3%	1.9%
		SW	2.5%	2.5%	2.7%	2.5%	2.3%	2.7%
		WS	4.1%	3.2%	2.7%	2.3%	1.7%	2.7%
		Mean	**3.2%**	**2.9%**	**2.8%**	**2.2%**	**2.3%**	**2.4%**
		R	**1.6%**	**1.4%**	**1.0%**	**0.4%**	**1.0%**	**0.8%**

Appendix 11 PB mean values for ANOVA in Table 4.16.

PB= perceptual boundaries. SS = syllable structures, PC = prosodic conditions.

			m	m	p	p	s	s	**Overall**	**Overall**
SS			F. (ms)	J. (ms)	F. (ms)	J. (ms)	F. (ms)	J. (ms)	**F. (ms)**	**J. (ms)**
	V	CVCV/CVCVV	20.9	15.4	18.9	14.6	19.7	15.1	**19.8**	**15.0**
		CVCV/CVVCV	16.3	15.1	16.3	15.7	17.1	14.6	**16.6**	**15.1**
		CVCVV/CVVCVV	16.6	18.6	16.9	13.7	20.6	17.4	**18.0**	**16.6**
		CVVCV/CVVCVV	24.6	17.4	25.1	16.4	26.3	15.6	**25.3**	**16.4**
			m-mm	m-mm	p-pp	p-pp	s-ss	s-ss	**overall**	**Overall**
	C	CVCV/CVCCV	18.2	14.9	18.0	12.4	18.9	16.3	**18.4**	**14.5**
		CVCVV/CVCCVV	16.8	15.4	17.7	15.4	18.3	17.8	**17.6**	**16.2**
		CVVCV/CVVCCV	15.8	17.1	19.1	16.3	18.6	17.7	**17.8**	**17.0**
		CVVCVV/CVVCCVV	20.0	17.7	19.4	15.4	15.7	16.9	**18.4**	**16.7**
PC			m	m	p	p	s	s	**Overall**	**Overall**
	V	Level	16.8	16.4	19.6	14.6	22.9	17.1	**19.8**	**16.1**
		HL	20.7	18.2	20.4	14.1	20.7	15.2	**20.6**	**15.8**
		LH	17.9	16.3	15.7	15.5	20.7	15.0	**18.1**	**15.6**
		SW	18.6	17.5	21.1	15.4	20.4	15.7	**20.0**	**16.2**
		WS	23.9	14.6	19.6	15.7	20.0	15.7	**21.2**	**15.4**
	C		m-mm	m-mm	p-pp	p-pp	s-ss	s-ss	**Overall**	**Overall**
		Level	21.1	15.0	17.4	15.0	19.3	16.1	**19.2**	**15.4**
		HL	16.0	15.7	17.1	14.6	16.4	18.9	**16.5**	**16.4**
		LH	16.4	18.6	20.4	14.3	17.9	17.4	**18.2**	**16.8**
		SW	16.0	16.1	18.2	14.6	17.9	16.4	**17.4**	**15.7**
		WS	18.9	16.1	19.6	15.7	17.9	16.9	**18.8**	**16.2**

Appendix 12 ANOVA for Table 4.16.

SS = syllable structure, V = vowel, F/J = the language difference between Finnish and Japanese, 'm, p, s, mm, pp, ss' being the surrounding consonants for the vowels and consonants tested.

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
SS V m	28,32988	3	9,443292	1,086861	0,47351	9,276619
F/J	17,37526	1	17,37526	1,99978	0,252236	10,12796
Error	26,06577	3	8,68859			
Total	71,77091	7				

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
SS V p	35,93085	3	11,97695	2,038018	0,286792	9,276619
F/J	35,19278	1	35,19278	5,988463	0,091914	10,12796
Error	17,63029	3	5,876764			
Total	88,75392	7				

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
SS V s	28,53488	3	9,511626	1,380151	0,398755	9,276619
F/J	54,84411	1	54,84411	7,957962	0,066684	10,12796
Error	20,67518	3	6,891728			
Total	104,0542	7				

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
SS C m	9,545203	3	3,181734	1,53221	0,367189	9,276619
F/J	3,940633	1	3,940633	1,897669	0,262119	10,12796
Error	6,229695	3	2,076565			
Total	19,71553	7				

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
SS C p	7,740652	3	2,580217	2,333465	0,252302	9,276619
F/J	27,24957	1	27,24957	24,64362	0,015698	10,12796
Error	3,317236	3	1,105745			
Total	38,30746	7				

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
SS C s	4,387546	3	1,462515	1,258245	0,427357	9,276619
F/J	0,951461	1	0,951461	0,81857	0,432292	10,12796
Error	3,487036	3	1,162345			
Total	8,826042	7				

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
PC V m	13,18878	4	3,297194	0,503408	0,738723	6,388234
F/J	21,96747	1	21,96747	3,353944	0,141002	7,70865
Error	26,19898	4	6,549745			
Total	61,35523	9				

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
PC V p	7,480867	4	1,870217	0,639935	0,662025	6,388234
F/J	44,40051	1	44,40051	15,19258	0,017575	7,70865
Error	11,69005	4	2,922513			
Total	63,57143	9				

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
PC V s	6,779337	4	1,694834	7,574822	0,037629	6,388234
F/J	67,66192	1	67,66192	302,4054	6,42E-05	7,70865
Error	0,894983	4	0,223746			
Total	75,33624	9				

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
PC C m	7,673951	4	1,918488	0,384178	0,81166	6,388234
F/J	4,866723	1	4,866723	0,974564	0,379431	7,70865
Error	19,97497	4	4,993743			
Total	32,51565	9				

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
PC C p	4,657029	4	1,164257	1,04984	0,481768	6,388234
F/J	34,04904	1	34,04904	30,70288	0,005187	7,70865
Error	4,435941	4	1,108985			
Total	43,14201	9				

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
PC C s	0,499575	4	0,124894	0,057669	0,991405	6,388234
F/J	1,27551	1	1,27551	0,588957	0,485616	7,70865
Error	8,66284	4	2,16571			
Total	10,43793	9				

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
SS overall mean V	27,41949	3	9,139831	1,457881	0,382093	9,276619
F/J	34,05266	1	34,05266	5,431687	0,102092	10,12796
Error	18,80778	3	6,269259			
Total	80,27993	7				

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
SS overall mean C	1,542958	3	0,514319	0,564931	0,674681	9,276619
F/J	7,43588	1	7,43588	8,167612	0,064688	10,12796
Error	2,731232	3	0,910411			
Total	11,71007	7				

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
PC overall mean V	2,758645	4	0,689661	0,886452	0,545089	6,388234
F/J	42,57999	1	42,57999	54,72992	0,001781	7,70865
Error	3,112009	4	0,778002			
Total	48,45065	9				

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
PC overall mean C	2,171696	4	0,542924	0,544946	0,714519	6,388234
F/J	9,344444	1	9,344444	9,379249	0,037565	7,70865
Error	3,985157	4	0,996289			
Total	15,5013	9				

Appendix 13 Minimum long segmental durations.

The mean minimum long segmental durations (ms) within the segment in different syllable structures for vowels and consonants, according to the different consonants in the perception test (Section 4.5).

			/m/ (ms)		/p/ (ms)		/s/ (ms)	
V/C	Syllable Structure	PC	F.	J.	F.	J.	F.	J.
V	CVCV-CVCVV	Level	108.6	110.0	84.3	110.0	87.1	111.4
		HL	108.6	107.1	82.9	111.4	85.7	112.9
		LH	97.1	110.0	84.3	105.7	84.3	107.1
		SW	88.6	101.4	82.9	111.4	91.4	105.7
		WS	92.9	111.4	85.7	101.4	92.9	107.1
	CVCV-CVVCV	Level	91.4	95.7	78.6	85.7	81.4	92.9
		HL	94.3	101.4	91.4	100.0	90.0	97.1
		LH	92.9	102.9	88.6	95.7	91.4	110.0
		SW	85.7	92.9	90.0	94.3	87.1	97.1
		WS	74.3	87.1	77.1	90.0	84.3	91.4
	CVCVV-CVVCVV	Level	111.4	104.3	100.0	108.6	100.0	108.6
		HL	104.3	108.6	87.1	121.4	101.4	107.1
		LH	95.7	122.9	97.1	122.9	98.6	118.6
		SW	100.0	111.4	91.4	100.0	97.1	105.7
		WS	92.9	108.6	95.7	110.0	101.4	107.1
	CVVCV-CVVCVV	Level	127.1	127.1	107.1	134.3	101.4	126.7
		HL	104.3	115.7	110.0	121.7	114.3	123.3
		LH	124.3	108.3	114.3	113.3	100.0	125.7
		SW	102.9	115.7	104.3	127.1	94.3	123.3
		WS	101.4	130.0	128.6	135.7	125.7	134.3
C	CVCV-CVCCV	Level	71.4	81.4	111.4	117.1	98.6	112.9
		HL	77.1	84.3	111.4	135.0	98.6	110.0
		LH	75.7	81.4	102.9	124.3	105.7	117.1
		SW	71.7	77.1	111.4	117.1	97.1	110.0
		WS	71.4	80.0	104.3	112.9	90.0	107.1
	CVCVV-CVCCVV	Level	85.7	87.1	120.0	118.6	105.7	117.1
		HL	101.7	88.6	114.3	125.7	111.4	118.6
		LH	90.0	88.6	121.4	131.4	114.3	118.3
		SW	81.4	88.6	118.6	131.4	105.7	111.7
		WS	82.9	91.4	125.7	130.0	108.6	118.3

	CVVCV-CVVCCV	Level	91.4	90.0	118.3	128.6	105.7	120.0
		HL	100.0	104.3	114.3	131.4	112.9	125.7
		LH	82.9	92.9	121.4	134.3	111.4	125.7
		SW	78.6	90.0	128.6	135.7	105.7	127.1
		WS	88.6	97.1	124.3	134.3	107.1	117.1
	CVVCVV-CVVCCVV	Level	108.6	98.6	114.3	138.6	104.3	132.9
		HL	98.3	102.9	125.7	145.7	115.7	135.7
		LH	95.7	100.0	117.1	148.6	117.1	144.3
		SW	91.4	97.1	115.7	137.1	98.6	117.1
		WS	82.9	95.7	111.4	138.6	105.7	127.1

Appendix 14 Minimum long vowels under SS.

The table shows the mean durations (ms) and ratios (%)of minimum long vowels within the segment according to syllable structure (SS) and five prosodic conditions (PC) within each syllable structure between Finnish (F.) and Japanese (J.). Only the ratios were used for Figure 4.16.

Syllable Structure	PC	F. (ms)	J. (ms)	F.	J.
CVCV-CVCVV	Level	114.3	126.2	57.1%	63.1%
	HL	113.3	126.7	56.7%	63.3%
	LH	106.7	122.4	53.3%	61.2%
	SW	106.7	121.0	53.3%	60.5%
	WS	110.5	120.5	55.2%	60.2%
	Mean	**110.3**	**123.3**	**55.1%**	**61.7%**
	R	**7.6**	**6.2**	**3.3%**	**2.9%**
	SD	**3.6**	**2.9**	**1.8%**	**1.5%**
CVCV-CVVCV	Level	101.4	105.7	50.7%	52.9%
	HL	108.1	115.7	54.0%	57.9%
	LH	105.7	119.0	52.9%	59.5%
	SW	104.3	109.5	52.1%	54.8%
	WS	96.2	103.8	48.1%	51.9%
	Mean	**103.1**	**110.8**	**51.6%**	**55.4%**
	R	**11.9**	**15.2**	**6.0%**	**7.6%**
	SD	**4.6**	**6.5**	**2.3%**	**3.2%**
CVCVV- CVVCVV	Level	119.5	124.8	59.8%	62.4%
	HL	115.2	127.6	57.6%	63.8%
	LH	115.7	138.1	57.9%	69.0%

	SW	116.2	121.4	58.1%	60.7%
	WS	114.8	126.2	57.4%	63.1%
	Mean	**116.3**	**127.6**	**58.1%**	**63.8%**
	R	**4.8**	**16.7**	**2.4%**	**8.3%**
	SD	**1.9**	**6.3**	**0.9%**	**3.1%**
CVVCV- CVVCVV	Level	136.7	146.0	68.3%	73.0%
	HL	137.1	135.8	68.6%	67.9%
	LH	133.8	131.1	66.9%	65.5%
	SW	124.8	141.5	62.4%	70.8%
	WS	147.6	149.0	73.8%	74.5%
	Mean	**136.0**	**140.7**	**68.0%**	**70.3%**
	R	**22.9**	**18.0**	**11.4%**	**9.0%**
	SD	**8.2**	**7.3**	**4.1%**	**3.7%**
Overall	**Mean**	**116.4**	**125.6**	**58%**	**63%**
	R	**18.1**	**11.8**	**9.0%**	**6.1%**
	SD	**2.66**	**1.95**	**1.3%**	**0.97%**

Appendix 15 Minimum long consonants under SS.

The table shows the mean durations (ms) and ratios (%)of minimum long consonants within the segment according to syllable structure (SS) and five prosodic conditions (PC) within each syllable structure between Finnish (F.) and Japanese (J.). Only the ratios were used for Figure 4.17.

Syllable Structure	PC	F. (ms)	J. (ms)	F.	J.
CVCV-CVCCV	Level	115.2	117.6	72.8%	73.5%
	HL	111.0	123.5	71.0%	75.8%
	LH	112.9	123.8	71.8%	75.8%
	SW	114.0	114.8	71.8%	72.4%
	WS	106.2	114.3	69.2%	72.3%
	Mean	**111.8**	**118.8**	**71.3%**	**74.0%**
	R	**9.0**	**9.5**	**3.7%**	**1.2%**
	SD	**3.5**	**4.6**	**1.4%**	**1.7%**
CVCVV-CVCCVV	Level	94.3	96.7	65.3%	66.1%
	HL	99.0	101.4	67.1%	67.8%
	LH	99.5	103.0	67.2%	68.6%
	SW	91.4	100.5	64.1%	67.7%

	WS	99.0	101.0	67.0%	67.9%
	Mean	**96.7**	**100.5**	**66.1%**	**67.6%**
	R	**8.1**	**6.3**	**3.1%**	**2.5%**
	SD	**3.6**	**2.3**	**1.4%**	**0.9%**
CVVCV-CVVCCV	Level	97.5	102.4	66.9%	68.2%
	HL	97.4	111.9	66.2%	72.2%
	LH	96.7	108.1	65.9%	70.4%
	SW	94.8	106.7	65.1%	69.8%
	WS	99.0	107.6	66.9%	70.3%
	Mean	**97.1**	**107.3**	**66.2%**	**70.2%**
	R	**4.2**	**9.5**	**1.8%**	**4.0%**
	SD	**1.6**	**3.4**	**0.7%**	**1.4%**
CVVCVV-CVVCCVV	Level	101.9	112.4	68.8%	72.0%
	HL	104.5	117.1	69.1%	73.8%
	LH	102.4	121.0	68.5%	75.3%
	SW	91.9	107.6	64.5%	70.3%
	WS	91.9	111.9	64.6%	71.9%
	Mean	**98.5**	**114.0**	**67.1%**	**72.7%**
	R	**12.6**	**13.4**	**4.6%**	**5.1%**
	SD	**6.1**	**5.1**	**2.3%**	**1.9%**
Overall	**Mean**	**101.0**	**110.2**	**68%**	**71%**
	R	**8.4**	**7.1**	**2.8%**	**3.90%**
	SD	**1.9**	**1.3**	**0.7%**	**0.4%**

Appendix 16 Minimum long vowels under PC.

The table shows the mean durations and ratios of minimum long vowels within the segment according to five prosodic conditions (PC) in four syllable structures (SS) within each prosodic condition between Finnish and Japanese. Only the ratios were used for Figure 4.18.

PC	Syllable structure	Finnish (ms)	Japanese (ms)	Finnish	Japanese
Level	CVCV-CVCVV	114.3	126.2	57%	63%
	CVCV-CVVCV	101.4	105.7	51%	53%
	CVCVV-CVVCVV	119.5	124.8	60%	62%
	CVVCV-CVVCVV	136.7	146.0	68%	73%
	Mean	**118.0**	**125.7**	**59%**	**63%**
	R	**35.2**	**40.3**	**18%**	**20%**

	SD	**14.6**	**16.5**	**7%**	**8%**
HL	CVCV-CVCVV	113.3	126.7	57%	63%
	CVCV-CVVCV	108.1	115.7	54%	58%
	CVCVV-CVVCVV	115.2	127.6	58%	64%
	CVVCV-CVVCVV	137.1	135.8	69%	68%
	Mean	**118.5**	**126.4**	**59%**	**63%**
	R	**29.0**	**20.1**	**15%**	**10%**
	SD	**12.8**	**8.2**	**6%**	**4%**
LH	CVCV-CVCVV	106.7	122.4	53%	61%
	CVCV-CVVCV	105.7	119.0	53%	60%
	CVCVV-CVVCVV	115.7	138.1	58%	69%
	CVVCV-CVVCVV	133.8	131.1	67%	66%
	Mean	**115.5**	**127.6**	**58%**	**64%**
	R	**28.1**	**19.0**	**14%**	**10%**
	SD	**13.0**	**8.6**	**7%**	**4%**
SW	CVCV-CVCVV	106.7	121.0	53%	60%
	CVCV-CVVCV	104.3	109.5	52%	55%
	CVCVV-CVVCVV	116.2	121.4	58%	61%
	CVVCV-CVVCVV	124.8	141.5	62%	71%
	Mean	**113.0**	**123.4**	**56%**	**62%**
	R	**20.5**	**32.0**	**10%**	**16%**
	SD	**9.4**	**13.3**	**5%**	**7%**
WS	CVCV-CVCVV	110.5	120.5	55%	60%
	CVCV-CVVCV	96.2	103.8	48%	52%
	CVCVV-CVVCVV	114.8	126.2	57%	63%
	CVVCV-CVVCVV	147.6	149.0	74%	75%
	Mean	**117.3**	**124.9**	**59%**	**62%**
	R	**51.4**	**45.2**	**26%**	**23%**
	SD	**21.7**	**18.7**	**11%**	**9%**
Overall	**Mean**	**116.5**	**125.6**	**58%**	**63%**
	R	**32.8**	**31.3**	**16.6%**	**15.8%**
	SD	**14.3**	**13.1**	**7.2%**	**6.4%**

Appendix 17 Minimum long consonants under PC.

The following table shows the mean durations and ratios of minimum long consonants within the segment according to five prosodic conditions (PC) in four syllable structures within each prosodic condition between Finnish and Japanese. Only the ratios were used for Figure 4.19.

PC	Syllable structure	Finnish (ms)	Japanese (ms)	Finnish	Japanese
Level	CVCV-CVCCV	115.2	117.6	73%	74%
	CVCVV-CVCCVV	94.3	96.7	65%	66%
	CVVCV-CVVCCV	97.5	102.4	67%	68%
	CVVCVV-CVVCCVV	101.9	112.4	69%	72%
	Mean	**102.2**	**107.3**	**68%**	**70%**
	R	**21.0**	**21.0**	**8%**	**7%**
	SD	**9.2**	**9.5**	**3%**	**3%**
HL	CVCV-CVCCV	111.0	123.5	71%	76%
	CVCVV-CVCCVV	99.0	101.4	67%	68%
	CVVCV-CVVCCV	97.4	111.9	66%	72%
	CVVCVV-CVVCCVV	104.5	117.1	69%	74%
	Mean	**103.0**	**113.5**	**68%**	**72%**
	R	**13.6**	**22.1**	**5%**	**8%**
	SD	**6.1**	**9.3**	**2%**	**3%**
LH	CVCV-CVCCV	112.9	123.8	72%	76%
	CVCVV-CVCCVV	99.5	103.0	67%	69%
	CVVCV-CVVCCV	96.7	108.1	66%	70%
	CVVCVV-CVVCCVV	102.4	121.0	68%	75%
	Mean	**102.9**	**114.0**	**68%**	**73%**
	R	**16.2**	**20.8**	**6%**	**7%**
	SD	**7.1**	**10.0**	**3%**	**4%**
SW	CVCV-CVCCV	114.0	114.8	72%	72%
	CVCVV-CVCCVV	91.4	100.5	64%	68%
	CVVCV-CVVCCV	94.8	106.7	65%	70%
	CVVCVV-CVVCCVV	91.9	107.6	65%	70%
	Mean	**98.0**	**107.4**	**66%**	**70%**
	R	**22.6**	**14.3**	**8%**	**5%**
	SD	**10.8**	**5.8**	**4%**	**2%**
WS	CVCV-CVCCV	106.2	114.3	69%	72%
	CVCVV-CVCCVV	99.0	101.0	67%	68%
	CVVCV-CVVCCV	99.0	107.6	67%	70%
	CVVCVV-CVVCCVV	91.9	111.9	65%	72%

	Mean	**99.0**	**108.7**	**67%**	**71%**
	R	**14.3**	**13.3**	**5%**	**4%**
	SD	**5.8**	**5.8**	**2%**	**2%**
Overall	**Mean**	**101.02**	**110.2**	**67.4%**	**71.2%**
	R	**17.5**	**18.3**	**6.4%**	**6.2%**
	SD	**8.08**	**7.8**	**3%**	**3%**