PRECISENESS OF TEMPORAL COMPENSATION IN JAPANESE MORA TIMING

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ABSTRACT

This study was motivated by a hypothesis that mora-timed Japanese would show a stronger tendency to keep CV length equal than other languages, because CV must not be too long in Japanese where CV and CVC / CVV have a durational contrast. Thus from this hypothesis, the magnitude and preciseness of the temporal compensation effect is expected to be larger for Japanese than those for other languages. Previous studies only examined the existence of temporal compensation; the issue of how differently temporal compensation is performed depending on a language has not been considered. Comparing Japanese with Korean and Chinese that have different timing patterns from Japanese, the results of this study confirmed the above hypothesis holds true at least within the speech context in this experiment. The magnitude of V changes to compensate for the C differences was larger in Japanese than the other two languages. Furthermore such temporal compensation was more consistently performed, resulting in stable CV length.

1. INTRODUCTION

It has been questioned in the literature whether moras in Japanese are constant in duration. While some experimental results showed that Japanese mora timing keeps each mora equal in duration [2], other researchers found no acoustic evidence to support the mora as a constant time unit [1]. Among these studies some researchers claimed that a temporal compensation effect between consonant and vowel (vowel duration is inversely related to consonant duration) is an acoustic evidence for Japanese mora timing. For example, Port et al. (1980)[6] and Homma (1981) [3] claimed that the temporal compensation effect between consonants and vowels within the –VCV- level or the word level is a unique characteristic of Japanese mora timing. On the other hand, other researchers such as Otake (1988)[5] claimed that it is simply a universal phenomenon that can be observed in any language. These studies, however, have not considered to what extent temporal compensation is realized depending on the language. It is possible that mora-timed Japanese controls CV units more precisely to make these rhythmic units isochronous than languages of other rhythmic types such as syllable timing, because mora-timed Japanese must maintain a durational contrast between CV (1 mora) and CVC or CVV (2 moras). If consonant or vowel segment in CV units in Japanese were too long, CV would be mistaken for CVC or CVV. Such cases frequently happen in the productions of Japanese by nonnative speakers (Minagawa-Kawai & Kiritani, 1998) [4] ; e.g. "katana" (3 moras) produced by nonnative speakers are sometimes perceived as "kattana" (4 moras). Consequently, a stronger tendency for temporal compensation, in other words, more constant CV unit despite the large differences in inherent duration of different segment types, may be expected for Japanese productions.

The present study is a preliminary experiment examining the extent and preciseness of temporal compensation within the CV level, the –VCV- level and the word level for Japanese, Chinese and Korean. Comparing the extent and preciseness of temporal compensation in Japanese to those of Chinese and Korean that have different timing control from Japanese, we discussed to what extent Japanese maintains CV moras equal despite the various segment types.

2. METHODS

2.1. Materials

The nonsense words “maCVka” and “maCVnka” where the CV is /ra, ba, sa, ri, bi, si/ was inserted in a carrier sentence in the production experiment. As a liquid consonant, /l/ was used for Chinese speakers, because /l/ in Chinese is more phonetically similar to /r/ in Korean and Japanese than Chinese /r/. To make the acoustical conditions of the target word in each language uniform, the accent was assigned to the initial syllable that resulted in the HLL structure. Furthermore, for Chinese materials, Chinese characters for the target word chosen have the third tone to prevent large differences in pitch contour depending on the language groups. This study only dealt with the results of “maCVka” words. All the words where each word was repeated five times were randomized in the word list for the recording. These words were written in Kana orthography for Japanese subjects and Hangul orthography for Korean subjects and Chinese characters for Chinese subjects. The carrier sentences used were "moo ichido --- to itte kudasai." for Japanese and "han pyeondyeo ---- ra go malhae juseyo." for Korean. This means " Say ---- once again".

2.2. Subjects

Six standard Japanese speakers from Tokyo, seven speakers of Mandarin Chinese from Beijing and six speakers of Korean from Seoul attended the recording. All were students, and the Chinese and Korean speakers were currently living in Japan.

2.3. Recordings

Subjects were recorded in a sound proof-room using a digital audiotape recorder and microphone. To keep a constant speech rate both within the word list and across subjects and language groups, a reference speech was given by PC before the recording and also at every five words during the experiment. The target word in the reference speech was "nanana" embedded in the same carrier sentence as that for the recordings. The recordings began after the instruction and trial session in which whether the correct accent was assigned and proper speech rate was realized, was checked.

2.4. Analysis

The recorded materials were digitized onto a computer with a sampling rate of 22 kHz and accuracy of 16 bits. This was then analyzed via wideband spectrograms (5ms / 200Hz) and waveforms using Multi Speech (KAY). Segmental durations of the recorded utterances were measured. To make the speech rate in one language uniform, the production data of one subject in each language who had a different speech rate from the averaged value was discarded. Finally, the production data of five Japanese, five Korean and six Chinese speakers were considered in this study.

3. RESULTS

3.1. Temporal compensation between C_2 and V_2

In Figure 1, the duration of C_2 (e.g. /b/ in /mabaka/) and the duration of its following vowel V_2 in each utterance were plotted for Japanese productions. Durations of C_2 and V_2 are almost inversely related to each other and the longer the C_2 duration, the shorter the V_2 duration. The correlation is strong and the correlation coefficient is -0.87 (p>.001).

Figure 1 was re-plotted with the Chinese and Korean data as shown in Figures 2 and 3 to compare the tendency of temporal compensation effect across language. Regression analysis of C_2 and each segment such as V_2 was carried out. Tables 1 and 2 indicate the correlation coefficients and the slope between C_2 and following vowel (V_2), preceding vowel (V_1), duration of V_1 plus V_2 (V_1+ V_2), and the total word duration minus C_2 (Word- C_2). Since in Japanese and Korean /i/ in /masika/ is often devoiced, the duration of some /i/ vowels was 0 ms. Inclusion of a zero value sometimes increases the coefficient value, therefore for V_2, two patterns of analysis were done: one in which all vowels including 0 ms (V_2) and one in which all vowels excluding all /i/ in /masika/ (V_2SI) were calculated. Figures 4 and 5 indicate the relation between C_2 and V_2SI, comparing the Japanese, Chinese and Korean data.

From Figures 2 and 4, it is shown that the extent of

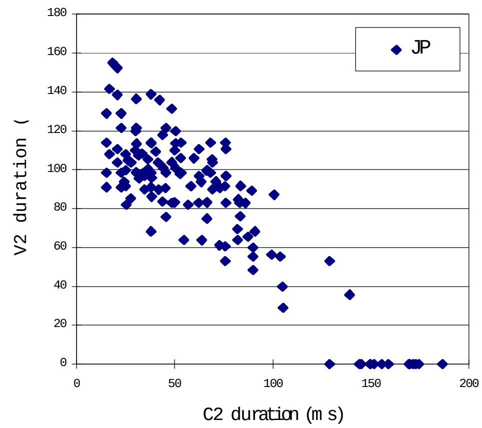

Figure 1. Correlation between duration of C_2 and V_2 for Japanese.

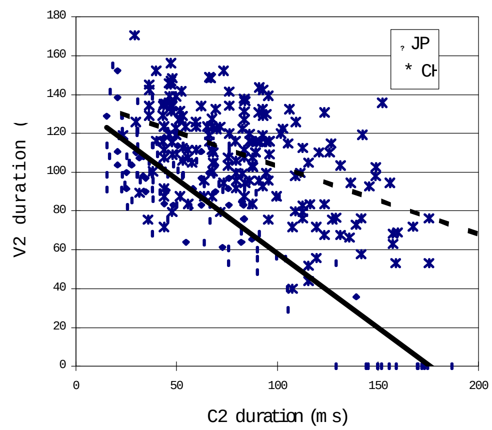

Figure 2. Correlation between duration of C_2 and V_2 for Chinese and Japanese.

temporal compensation is larger for Japanese than for Chinese. This can also be understood from the slope value in Table 2. From Table 2 it is observed that for the 100 ms C_2 lengthening, V_2 length was 75 ms shorter in Japanese, and 35 ms in Chinese. This means the difference in CV length is smaller for Japanese than for Chinese. The values of correlation coefficients can be interpreted to indicate the stability of such temporal compensation effects, i.e., how consistently the same CV syllable durations are realized. Table 1 shows that the correlation coefficients are higher for Japanese than for Chinese. This phenomenon is consistent to every subject, according to the Tables 3 and 4 that show the correlation coefficients and slope for every subject.

As for comparison between Korean and Japanese speakers, a similar tendency as that of Chinese and Japanese speakers is observed. Namely, the correlation between C_2 and V_2 as well as V_2SI is stronger and slope values are higher for Japanese than for

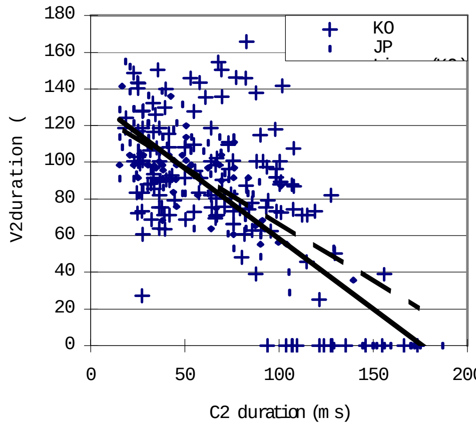

Figure 3. Correlation between duration of C_2 and V_2 for Korean and Japanese.

Korean (Figures 3 and 5). However, the differences are smaller in this case particularly for C_2 and V_2.

The longest C_2 V_2 syllable in this experiment, expected from the inherent segment duration, is /sa/ and the shortest syllable is /ri/. Since the extent of the temporal compensation effect may reflect the durational differences between the /sa/ and /ri/ syllables, the durational difference between the averaged length of /sa/ and /ri/ for each subject was calculated. This value was then divided by the averaged one syllable length for each subject, in order to normalize the variation of speech rate. This normalized value was 0.17 for Japanese (averaged from five subjects), 0.25 for Chinese (averaged from six subjects) and 0.27 for Korean (averaged from five subjects). To examine the statistical difference in these values, t-tests were conducted. According to the results, statistically significant differences were observed between Japanese and Chinese ($t=1.88$, $p>.05$) as well as Japanese and Korean subjects ($t=2.03$, $p>.05$).

3.2 Range of temporal modification

Tables 1 and 2 show that the correlation coefficients and slope value are higher for V_2 and V_1 V_2 in every language group. Those values are rather low for V_1 and Word- C_2. This means there is a tendency to maintain a stable duration at the CV or -VCV- level, but not at the -VC- and word level. However, only one Japanese and one Chinese subject showed different characteristics and their correlation coefficients and slope values are rather high for both V_2 and V_1.

4. DISCUSSION

This study was motivated by a hypothesis that mora-timed Japanese would show a stronger tendency to keep CV length equal than other languages, because CV must not be too long in Japanese where CV and CVC / CVV have a durational contrast. Thus from this hypothesis, the magnitude and preciseness of the temporal compensation effect is also expected to be larger for Japanese than those for other languages. Previous studies only examined the existence of temporal compensation; the issue of how differently temporal compensation is performed depending on a language has not been considered. Comparing Japanese with Korean and Chinese that have different timing patterns from Japanese, the results confirmed that the above hypothesis holds true at least within the speech context in this experiment. The magnitude of V_2 changes to compensate for the C_2 differences was larger in Japanese than the other two languages. Furthermore such temporal compensation was more accurately (consistently) performed, resulting in stable C_2 V_2 length. The accuracy with which moraic units are controlled in Japanese, in other words, how strongly temporal compensation is realized as observed in this study, might be one of the acoustic characteristics of Japanese mora-timing.

The determination of in which unit or which direction a temporal compensation take place in Japanese is sometimes a controversial problem. Several previous studies [6,7,8] reported different results. The results in this study using CVCVCV context were similar to those of Sagisaka & Tohkura (1984) in terms of the direction (a following vowel compensates more than a preceding vowel) as well as the magnitude of temporal compensation effect. Further studies using various speech contexts as materials are required to clearly explain these problems regarding range of temporal modification.

ACKNOWLEDGMENTS

This work was supported by JSPS (7849).

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Table 1. Correlation coefficients between C_2 duration and each segment.

	V_2	V_2SI	V_1	V_1V_2	Word-C_2
Japanese	-0.87	-0.54	-0.14	-0.76	-0.13
Chinese	-0.52	-0.22	-0.22	-0.67	-0.27
Korean	-0.57	-0.15	-0.15	-0.51	-0.28

* V_2SI does not include /si/ tokens.

Table 2. Slope between C_2 duration and each segment

	V_2	V_2SI	V_1	V_1V_2	Word-C_2
Japanese	-0.75	-0.47	-0.07	-0.87	-0.16
Chinese	-0.35	-0.17	-0.13	-1.04	-0.44
Korean	-0.63	-0.15	-0.15	-0.90	-0.64

Table 3. Correlation coefficients between C_2 and V_2 for each subject.

	Japanese		Chinese		Korean	
subject	V_2	V_2SI	V_2	V_2SI	V_2	V_2SI
1	-0.92	-0.68	-0.41	-0.22	-0.76	-0.11
2	-0.79	-0.66	-0.68	-0.62	-0.44	-0.44
3	-0.84	-0.51	-0.57	-0.13	-0.70	-0.06
4	-0.87	-0.56	-0.73	-0.50	-0.77	-0.53
5	-0.95	-0.70	-0.60	-0.30	-0.70	-0.47
6			-0.65	-0.27		

Table 4. Slope between C_2 and V_2 for each subject.

	Japanese		Chinese		Korean	
subject	V_2	V_2SI	V_2	V_2SI	V_2	V_2SI
1	-0.71	-0.41	-0.29	0.2	-0.76	-0.08
2	-0.57	-0.57	-0.32	-0.35	-0.5	-0.51
3	-0.82	-0.45	-0.45	-0.09	-0.86	-0.06
4	-0.85	-0.55	-0.44	-0.29	-0.63	-0.28
5	-0.87	-0.65	-0.36	-0.17	-0.57	-0.33
6			-0.45	-0.18		

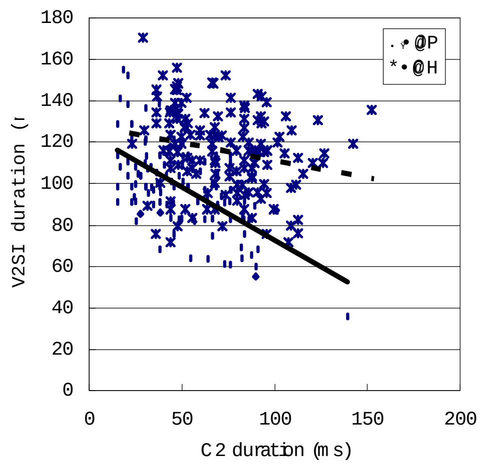

Figure 4. Correlation between duration of C_2 and V_2SI for Chinese and Japanese.

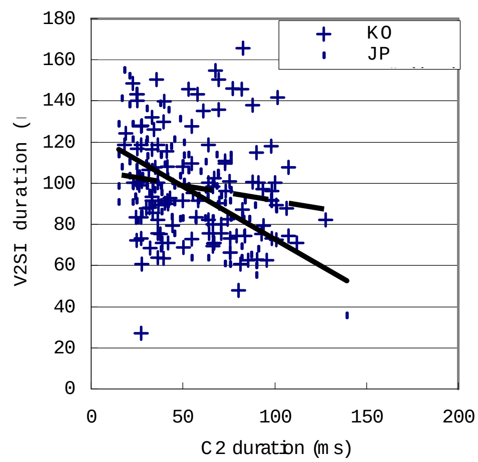

Figure 5. Correlation between duration of C_2 and V_2SI for Korean and Japanese.