MORA-BASED TEMPORAL ADJUSTMENTS IN JAPANESE

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This study looks for evidence of mora timing in Japanese from a phonetic point of view. Partly replicating an experiment by Port et al. 1987, the current study posits several hypotheses which support a less strict version of the mora hypothesis. Key points of those hypotheses are: (1) word duration is controlled by mora-based timing; but (2) temporal compensation in segments, to keep the word duration equal in respect to the number of moras, can be observed beyond a mora boundary. An experiment was conducted on 3 native Japanese speakers and 4 native English speakers and the results supported most of the hypotheses for Japanese speakers but not for English speakers, indicating that the former use mora-based timing in a non-traditional way.*

1. ISOCHRONY AND TIMING OF LANGUAGES. Speakers of a language use various cues when they perceive an utterance. Rhythm in a language is one of those cues much discussed in phonetics and phonology. Crystal (1992:185) defines the term ISOCHRONY as follows: 'In isochronous rhythm, the stressed syllables fall at approximately regular intervals throughout an utterance.' Isochrony is most realistically interpreted from the viewpoint of perception (termed SUBJECTIVE ISOCHRONY by Crystal (ibid.)

As the above definition shows, isochrony in terms of stress is said to be one characteristic of the rhythm in English. Ladefoged (1993:95) states that it is 'the general tendency in English to equalize the lengths of syllables that differ in the number of segments they contain.' Although he does not clearly point out the SUBJECTIVE aspect of isochrony, this tendency is widely accepted among researchers because many of them have observed its phonetic realization, that is, isochrony is observed in the production of an utterance as the measurable identity (termed OBJECTIVE ISOCHRONY by Crystal 1992:185). In the literature dealing with linguistic rhythm, English is often called a STRESS-TIMED language.

Moreover, other languages exhibit different types of rhythm. For example, Otake et al. classifies French as a SYLLABLE-TIMED language on the grounds that 'the evidence from many studies of speech processing by French listeners suggests that their speech segmentation proceeds syllable by syllable' (Otake et al. 1993:260). Also, Hoequist 1983a classifies Spanish as a syllable-timed language based on the results of his experiment on production rather than based on perception.

However, a syllable may not be the appropriate unit by which to discuss rhythm in certain other languages. Sugito 1989 remarks that the division of syllables is not clear in many languages, and in some cases, sonority is used as one of the criteria because the syllable has a subjective nature in itself. Thus, she argues that contradiction may result if the notion of 'syllable' is applied to all languages.

2. GENERAL REVIEW OF THE 'MORA'. Instead of syllable, Japanese linguists have been using the term MORA as a unit more suitable to describe rhythm in Japanese. Ladefoged (1993:251) defines a mora as 'a unit of timing. Each mora takes about the same length of time to say.' Also, it is 'a unit of length that is relative with respect to speech tempo' (Yoshiba 1981:241). Sugito 1989 gives a similar account of mora by mentioning that the average duration of words uttered by a single person is proportional to the number of moras contained within them. Thus, the mora is not an absolute unit but a RELATIVE one, depending on the speakers and their speaking rate at the time of utterance.

A mora is different from a syllable in that the latter is defined in terms of an essential peak with optional onset and coda: thus, the word *pin* has an onset /p/, a peak /i/, and a coda /n/. A typical mora consists of a consonant and a vowel (CV) but it is possible to have a mora which consists of either one vowel or one consonant. Otake et al. (1993:258) defines the mora as follows: 'In Japanese, a language with a very restricted phonological inventory, there are 108 distinct morae, and they are of only 5 types: CV, CCV, V, nasal coda (which we can represent as N), and geminate (doubled) consonant (represented as Q).' Hoequist 1983a relates syllables to moras by using LIGHT syllables for 1-mora syllables, and HEAVY syllables for 2-mora syllables. Thus a word like *dooro* 'a road' has 3 moras but only 2 syllables, one heavy and one light.[1]

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* I would like to thank all the participants in this experiment done in 1988, as well as Dr. Robert F. Port at Indiana University, Bloomington, who was a thesis advisor at the time the former version (Asano 1988) was written. I am also grateful to Dr. Alan Bell at the University of Colorado at Boulder for helping me with data analysis and giving me various suggestions on the current study. This is a revised version of Asano 1988.

[1] The second half of a long vowel in this word is written with the character (*kana*) for the /u/ in Japanese orthography. However, because it is pronounced as /o/, I will use /o/ instead. Hereinafter, the same applies to this kind of case.

Some researchers seek phonological evidence of the mora in Japanese by observing the language in common usage. Katada 1990 found such evidence from a language game called *Shiritori* 'hip-taking'. In this sound-matching game, a unit is not a syllable but a mora. He claims that 'moras are essential units operating at a certain point in Japanese grammar' (Katada 1990:645). He argues that the word *pan* 'bread' must have the following phonological representation:

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(1)     m      m
       / |     |
      p  a     N
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where m̲ stands for a mora and N̲ for a moraic nasal. Poser 1990 found other evidence for the mora in hypocoristic formations (suffixes of affection tacked onto one's first name), kinship terms, geisha/bargirl client names (names derived from a client's last name and used by geishas and bargirls when they call their clients), a secret language (used by musicians), and so forth. He argues that even Japanese, which is not considered to have a stress system, has evidence of foot structure and proposes a BIMORAIC foot.

However, others seek phonetic evidence of the mora. Sugito 1989 pointed out that the controversial elements within Japanese 'syllables' are mainly long vowels, moraic nasals and moraic consonants. Hoequist 1983b carried out an experiment by using a technique known as REITERANT SPEECH (see Larkey 1983) and found that some Japanese speakers treated those syllables in question differently. In a pilot project for the experiment for the current study, I found that there was a difference between a SPECIAL mora (a lengthened part of a long vowel, a moraic nasal and a moraic consonant) and a FULL mora (a mora which consists of exactly a CV configuration). In that project, data were collected from Japanese speakers, using the above-mentioned reiterant speech. Subjects were told to replace every mora of a given word with [ta]. Therefore, all the 3-mora words should become [tatata] regardless of their segmental components. However, all the subjects reported difficulty in doing this for certain types of mora. That is, words like *tooki* 'china, ceramics', *bukka* 'the price of commodities', and *bunka* 'culture' did not straightforwardly become [tatata]. Instead, they replaced those words with [taata], [tatta], and [tanta], respectively. This was because the second moras in those words were perceived as different from ordinary full moras.

Especially, geminate consonants (Qs) are worth mentioning here. Although the first element of geminates (called *soku-on* in Japanese) is written with a character (so-called small *tsu*), it is basically an interval with no acoustic entity. Geminate consonants occur in English at a word or a morpheme boundary, such as in the word *bookcase* or the phrase a *good driver*, whereas those in Japanese appear at a morpheme boundary within a word, such as in *hakken* 'discovery' (Masuko & Kiritani 1992),[2] and they do not appear at a word boundary (with the exception of nasals). Sugito 1989 compared the durations of geminate consonants in *ba-t-ta-a* 'batter' and *pi-t-tʃa-a* 'pitcher' spoken by Japanese speakers with those of medial consonants in *batter* and *pitcher* spoken by English speakers; she concluded that the former ones are much longer than the latter.

From various studies on phonetic aspects of mora, two versions of mora hypothesis are suggested. Port & Hardy 1989 classify the views into the TRADITIONAL version, in which all moras are equal in duration, and the CONTEMPORARY version, in which moras are different each other in that they follow 'universal intrinsic durations of segment types' (p. 3), such as durational differences in high vowels vs. low vowels and voiced segments vs. voiceless segments. From a non-linguistic point of view, moras are thought to be something like bricks to BUILD a word or a sentence; but as Hoequist (1983a:26) states, 'syllable durations are not exactly proportional to the number of moras in a syllable.'

Sato 1993 compactly summarizes some previous studies on the mora. According to her, Han 1962a, 1962b claims a strict isochrony of the mora (all moras are equal in duration); however, this claim is currently unaccepted. Beckman 1982 denies the phonetic reality of the mora. On the other hand, Port et al. 1980, 1987, and Homma 1981 posit a less strict version of the mora, in which TEMPORAL COMPENSATION in a unit as large as a word should be involved in the mora timing in Japanese. Thus the current discussions on the mora are divided into two camps: those which deny its phonetic reality, and those which accept it on condition that temporal compensation occurs beyond the border of a single mora.

3. PURPOSES OF THE CURRENT STUDY. The main purpose of the current study is to replicate the results of Port et al. 1987, to support it by finding further evidence for mora timing in Japanese, especially with respect to temporary compensation at levels larger than a syllable. Therefore, the aim of this study is to find evidence for a LESS STRICT version of the mora hypothesis, which will be described in the next section. Also, a new set of

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2 *hak-* is derived from *hatsu* 'start' and [tsu] in *hatsu* is assimilated to the following [k] to become a geminate consonant.

meaningful words was added to check the validity of using nonsense words, on which the study by Port et al. 1987 was mainly based.

Moreover, the current study has aimed at discovering how English-speaking learners of Japanese can manipulate timing when they speak their second language. It is expected that this may reveal some differences between native speakers and learners in dealing with timing.

4. THE EXPERIMENT

4.1. PREVIOUS STUDIES. Port et al. 1987 studied Japanese 3-mora words with a structure of $C_1V_1V_MC_2V_2$ (where V_M denotes a moraic vowel, which is represented by /R/, in some cases,[3] as in Imaishi 1992) and $C_1V_1C_MC_2V_2$ (where C_M denotes a moraic consonant, which is often represented by /Q/ as in Vance 1987 and Imaishi 1992). They found that in these words both moraic segments were much shorter than moraic CVs and that compensation was formed for the short moras by lengthening other segments in order to maintain an overall length equivalent to 3-mora words with full CV moras. This result implies that a traditional view of mora described in the previous section, which defines a single mora as a temporal unit for Japanese, is not quite accurate at the acoustic level of representation. It also implies the existence of some larger temporal unit to control the total length so that the length is the same for words with the same number of moras, even though such words may have a different number of syllables. That is, a word with CVC_MCV or CVV_MCV has 2 syllables but its duration is almost the same as one with CVCVCV, which has 3 syllables. Thus Port et al. supported a LESS STRICT version of mora timing.

4.2. HYPOTHESES. In particular, if the mora is phonetically realized in Japanese in the way described as above, the following phenomena may be observed in the speech of native speakers:

(2) a. 2-mora words are only slightly more than 2/3 the duration of 3-mora words.
b. 3-mora words containing 2 syllables are very nearly equal in duration to 3-mora words containing 3 syllables.
c. V_1 in $C_1V_1C_MC_2V_2$ words is longer than that in $C_1V_1C_2V_2$ words.
d. C_1 in $C_1V_1V_MC_2V_2$ words is longer than that in $C_1V_1C_2V_2$ words.
e. C_1 in $C_1V_1C_MC_2V_2$ words is longer than that in $C_1V_1C_2V_2$ words.

The first two phenomena (2a and 2b) support a mora hypothesis in general, which supposes isochrony based on mora. The rest of them (2c, 2d, and 2e) deal with temporal compensation by segments as motivated by mora timing. These also serve to illustrate the compensation at a level larger than a syllable or a mora, i.e., at the word level. Moreover, it is expected that all phenomena will not be observed or, if observed at all, will be very weak in data obtained from English-speaking learners of Japanese.

4.3. SUBJECTS. Participants in this experiment included 3 native speakers of Japanese [J1-J3], 2 males and 1 female, and 4 native speakers of English [E1-E3 and Ea], 3 males and 1 female. All subjects were in their 20's or early 30's at the time the experiment was carried out.

The native speakers of Japanese were all graduate students at Indiana University, Bloomington, and were all from the *Kanto* district (Metropolitan Tokyo area), where the standard dialect prevails. None of them had lived longer than 5 years in the United States at the time of the experiment.

Among the English speakers, 2 were graduate students at Indiana University and 2 were second-year students at the East Asian Summer Language Institute (EASLI) at the University. One of the graduate students, labeled 'Ea' for 'English speaker - advanced', was a very fluent speaker of Japanese. This subject was an instructor of Japanese at the University. The other graduate student, E1, had lived in Japan for a few years but had returned several years earlier to the United States and did not use Japanese on a regular basis.

Two of Japanese subjects, J1 and J3, were students in the Department of Linguistics and had previously had a course of phonetics. They also had participated in this kind of experiment before. However, they did not know the purpose of this experiment in advance. The remaining subjects were not in the department and had had no such experiences.

4.4. MATERIAL. The material used in this experiment was 2 sets of 4 words as shown in 3.

3 /R/ is used when V_1 and V_M are the same, i.e., V_1 is a long vowel.

(3)	a.	*buku*	(nonsense word)
		buuku	(nonsense word)
		bukku	'book' (a loan word from English)
		bukudo	(nonsense word)
	b.	*koku*	'hard; severe; cruel'
		kooku[4]	'a school district; a mining area; Coke (a loan word from English as in *kooku hai* "whisky and Coke")'
		kokku	'toil; labor; a faucet ("cock"); a cook (last two being loan words from English)'
		kokudo	'a country; a territory'

The first word in each set has 2 syllables and 2 moras (hereinafter abbreviated as 2S2M words) and the fourth one has 3 syllables and 3 moras (3S3M words); thus the numbers of syllables and moras are identical. The second and the third ones have 2 syllables but 3 moras (2S3M words); thus the numbers of syllables and moras are not identical. The former has a long vowel and the latter a long (geminate) consonant, which are counted as 2 moras in both cases.

Word list 3a is the same as the one of those used in Experiment 4 in Port et al. 1987. This is because one of the purposes of the current experiment is to replicate the previous one. However, since most of the words in the set 3a are nonsense (but phonologically possible), the set 3b, which consists of all meaningful words, was prepared to check the effect of meaningful words on the results.

The test words were placed in the following carrier sentence written in Japanese *hiragana* orthography:

(4) *kore* *wa* ______ *desu*.[5]
this TOPIC is
'This is ______.'

Although there is no orthographically standard way to denote a pitch accent in Japanese and the subjects were not particularly instructed where to put an accent, 6 out of 7 subjects always put a high pitch accent on the first syllable (or the first mora) of these test words. One speaker was inconsistent and occasionally pronounced the words with the accent on the second or third syllable. However, this inconsistency was not seen to cause any problem, because the accent is known to have no effect on the duration of a syllable if the word is in context (i.e. not in citation; Sugito 1989:174).

4.5. PROCEDURE

4.5.1. RECORDING SESSIONS. All the recordings were made in the Phonetics Laboratory in Indiana University, Bloomington. Each subject was tested individually in a quiet room.

In a practice session, the experimenter asked the subject to practice reading from a list of 20 sentences at the most comfortable speed. Each sentence contained one test word and was preceded by a number from 1 to 20. The subject was to read the number and the sentence because the reading of numbers was supposed to help the subject maintain a rhythm between sentences and facilitate identification of the sentences during analysis. Also, during the practice session, the recording level was adjusted and, especially for the English speakers, mistakes in reading particular hiragana characters were corrected. Before a final recording of the list was made, each subject read his/her name and other information for identification.

Each list contained 20 sentences in randomized order, in which the target words were inserted into a given slot. The experimenter prepared 4 different randomizations of the lists and the subject read all of 4 lists. The order of the lists was counterbalanced so that the effect of the position of the words in the list might be avoided. Thus a total of 80 sentences (tokens) per subject were obtained. The recordings were made using a Revox A700 open-reel tape recorder and an Electrovoice Model 627 microphone.

4.5.2. CRITERIA FOR MEASUREMENT. Wide-band spectrograms were made from each subject's recording with a Voice Identification 700 series spectrograph. Except for some cases of bad recording quality or unintelligible

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4 In Japanese orthography, the second /o/ (a lengthened part) for this word is written with a character for /u/ (as mentioned in fn. 1 above) IF THE WORD IS NOT A LOAN WORD. In this experiment, the word is regarded as a Japanese (non-loan) word and the character for /u/ has been used.

5 In Japanese, it is known that the vowels /u/ and /i/ tend to be devoiced (especially in the Tokyo dialect) when they occur between voiceless consonants or at the end of an utterance (see Beckman 1982:118, fn. 3). However, before /d/ in *desu*, /u/ did not become devoiced in the data collected here.

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pronunciation (yielding less than 4% of the total), spectrograms were made for all the tokens. Although most words had 10 tokens per subject, the word *bukudo* had only 9 tokens, and *kokudo* had 11 due to an error in the lists.

The measurement of the segments in each token is followed by the criteria described in 5:

(5) a. *buku* series -- basically the same as the criteria in Port et al. 1987
1. /b/ closure duration. From the end of the previous vowel (/a/ in *wa*) in the carrier sentence to the release of the first spike for the consonant.
2. /u/ duration. From the end of the release of the previous consonant to the next closure for /k/. The voice onset time for the previous /b/ was included in the vowel.[6]
3. /k/ or /kk/ closure duration. From the end of /u/ to the release of the first spike for the consonant.
4. VOT for /k/ or /kk/. From the end of the release of the previous consonant to the beginning of a clear second formant of the next vowel; otherwise, to the end of fuzzy part where the second and the third formants should be observed.
5. /u/ duration. From the end of VOT for the previous consonant to the next closure for /d/.
6. /d/ closure duration (for 3S3M word). From the end of /u/ to the release of the first spike for the consonant.
7. /o/ duration (for 3S3M word). From the end of the release of the previous consonant to the next closure for /d/ of *desu* in the carrier sentence. VOT for the previous /d/ was included in the vowel.[6]

b. *koku* series -- only the first syllable is different
1. /k/ closure duration. The same as 1, above.
2. VOT for /k/. The same as 4, above.
3. /o/ duration. From the end of VOT for the previous consonant to the next closure for /k/ or /kk/.

All the measurements were done by hand, using a ruler with a millimeter scale so that each interval was measured independently. The durations on the spectrograms were read to the nearest half of a millimeter by the experimenter and then converted to milliseconds at 7.69 ms/mm. Thus the raw measurements were made to the nearest 3.85 ms. Whenever it was difficult to determine a boundary between segments, the measurement was done by using other criteria such as the existence of a voice bar. When a boundary was completely fuzzy, the tokens were discarded. A few words had only 8 tokens measured.

5. RESULTS

5.1. COMPARISON WITH PORT ET AL. 1987

5.1.1. COMPARISON OF *buku* SERIES. One of the purposes of the current study is to replicate the experiment in Port et al. 1987. Table 1 (overleaf) compares the mean durations of each segment and the mean total durations, both pooled across Japanese speakers, in Port et al. 1987 (labeled 'Port') and those obtained in the current study (labeled 'Current').

Although some segments show differences of more than 10 ms between the two experiments, most of the segmental durations and the word durations are quite similar. The mean difference of the durations of each segment in both experiments is only about 3 ms (SD = 5.58).

The total word duration for each word is similar across the two experiments. Port et al. 1987 presents the data which gives a ratio of a 2S2M word (*buku*) to a 3S3M word (*bukudo*) to be about 69% (269 ms/389 ms), while the current study found this ratio to be about 68% (264 ms/387 ms). These ratios are only slightly longer than a value expected in the traditional version of the mora hypothesis, i.e., 2/3 (66.6%). In addition, ratios of 2S3M words (e.g., *bukku*) to a 2S2M word are about 72% in both experiments. The 2S3M words are just as long as their 3S3M counterpart but are only slightly (3%-4%) shorter than the latter in relation to the 2S2M word.

5.1.2. USE OF NONSENSE/MEANINGFUL WORDS. The other purpose of the current study directly relating to Port et al. 1987 is to see whether the nonsense words used in their experiment have any effect on the durations in general. Table 2 (overleaf) shows the mean durations of each segment by word in the *koku* series, pooled across 3 Japanese speakers. Just as in the previous section, the duration of a 2S2M word (*koku*) is slightly longer than that of a 3S3M word (*kokudo*) with a ratio of about 68%, and longer than those of 2S3M words (*kooku* and *kokku*) with a ratio of about 70%.

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[6] The treatment of VOT, whether it should be included in the preceding consonant or in the following vowel, depends on the researcher (Han 1992:113). In this particular case, I followed the treatment by Port et al. 1987 for the sake of convenience of comparison.

Word	b		u		k (kk)		u		d		o		Total	
	P	C	P	C	P	C	P	C	P	C	P	C	P	C
buku	70	64	68	70	65	66	67	64	--	--	--	--	269	264
s.d.	15	10	9	5	12	8	16	7					29	13
buuku	81	70	159	153	72	79	62	57	--	--	--	--	374	368
s.d.	20	5	21	15	17	8	15	12					46	5
bukku	80	67	86	81	149	153	62	61	--	--	--	--	376	362
s.d.	21	9	14	9	25	8	17	14					46	6
bukudo	70	61	68	70	62	61	66	64	35	37	89	95	389	387
s.d.	14	11	14	10	13	11	18	7	10	1	16	11	51	12

TABLE 1. Comparison of data in Port et al. 1987 and in the current study (ms). Notes: s.d. stands for a standard deviation for the mean which is given right above it. In the second row, P stands for Port and C stands for Current.

	C1	VOT1	V1	C2	VOT2	V2	/d/	/o/	W.dur.
koku	65	24	66	59	17	40	-	-	270
kooku	80	37	142	69	19	36	-	-	383
kokku	67	23	84	151	19	39			384
kokudo	64	23	67	56	18	40	41	88	397

TABLE 2. Mean durations of segments and total mean word durations by word in *koku* series, pooled across 3 Japanese speakers (ms).

5.2. COMPARISON OF WORD DURATION

5.2.1. WORDS WITH THE SAME SEGMENTAL STRUCTURE. The mean word durations for word pairs with the same segmental structure are very close for the Japanese speakers. For example, the means for *buku* and *koku* for J1 are 271 ms and 270 ms, respectively. Few of those pairs have a difference of 30 ms or longer, which amounts to about 8-10% of the mean word duration. Thus, in terms of a simple comparison of mean durations, these pairs are similar.

However, this similarity cannot hold true when t-tests are performed on those pairs of words. The results of a t-test on pairs of mean word durations for *buku-koku*, *buuku-kooku*, *bukku-kokku* and *bukudo-kokudo* are mixed in terms of their identity. Table 3 has a summary of results of t-tests for utterances by Japanese speakers. According to this table, J1 shows a perfect case in which none of the pairs are significantly different; however, others do not have such a perfect identity.

	J1	J2	J3
buku-koku	N	N	N
buuku-kooku	N	Y	Y
bukku-kokku	N	Y	N
bukudo-kokudo	N	Y	N

Note: The symbol Y stands for the case which the durations of the pair are significantly different ($p < .01$) whereas N stands for that which the durations are not significantly different ($p > .01$).

TABLE 3. Results of t-test by word and by speaker.

One of the striking results from the data collected by Japanese speakers is that all the mean durations for words of the same segmental structure showed values very close to one another among speakers. This is not applicable to those from English speakers except the speaker Ea, who consistently showed very close values to those of Japanese speakers. For example, the mean durations of *bukku-kokku* obtained from the speakers J1, J2, J3 and Ea are 270 ms, 265 ms, 274 ms and 287 ms, respectively, whereas those from E1, E2 and E3 are 638 ms, 391 ms and 410 ms, respectively.

5.2.2. WORDS WITH A DIFFERENT NUMBER OF MORAS. Figure 1 shows the mean durations of each test word pooled across the speaker groups (JAve and EAve). The most remarkable difference between the two groups is that the EAve has considerable differences among the test words, regardless of the number of moras, while the JAve has some difference between the 2-mora words and the 3-mora but little within the words of the same number of moras.

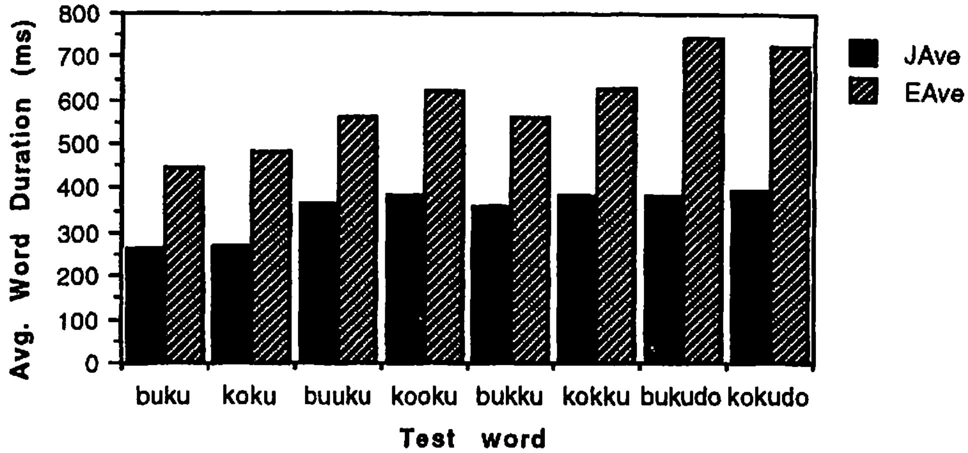

FIGURE 1. Mean durations of each test word, pooled across the speaker groups. (EAve does not include Ea.)

The ratios of durations of a 2-mora word to 3-mora words are compared for Japanese speakers and English speakers and the difference between the two groups is also observed in these ratios. Table 4 shows the ratios of a 2-mora words to various 3-mora words, by speaker.

Words	J1	J2	J3	JAve	E1	E2	E3	EAve	Ea
buku/buuku	74	68	78	73	85	68	75	77	68
koku/kooku	71	68	72	70	85	67	77	76	77
buku/bukku	74	68	76	73	84	72	76	77	65
koku/kokku	71	67	74	71	81	71	75	76	78
buku/bukudo	68	67	69	68	63	63	52	59	61
koku/kokudo	69	65	69	68	68	65	63	65	68

TABLE 4. Ratios of mean durations of a 2-mora word (either *buku* or *koku*) to corresponding 3-mora words by speaker (%). Note: JAve and EAve are means of the 3 values on their left.

The values in the JAve are relatively consistent throughout and close to the ideal 67%, whereas those in the EAve are varied and deviant from the ideal value. In addition, some values in Ea are close to the JAve but others are close to the EAve.

5.2.3. WORDS WITH THE SAME NUMBER OF MORAS. Finally, the 3-mora words are checked for their identity. Analysis of variance on word pairs *buuku-bukku* and *kooku-kokku* by speaker showed that the mean durations of those word pairs are not significantly different (i.e., all pairs had p-values of .05 or larger). Moreover, analysis of variance was performed on all 3-mora words separately for each series. The results are given in Table 5.

	buuku-bukku-bukudo			kooku-kokku-kokudo		
Speaker	df	F	p	df	F	p
J1	2,26	19.52	.000	2,28	0.97	.392
J2	2,26	1.21	.315	2,28	1.87	.174
J3	2,25	15.85	.000	2,28	4.54	.020
E1	2,23	61.03	.000	2,28	28.22	.000
E2	2,26	13.10	.000	2,27	3.33	.051
E3	2,23	20.45	.000	2,28	5.00	.014
Ea	2,26	4.87	.016	2,28	8.90	.001

TABLE 5. Results of analysis of variance for 3-mora words for each series by speaker.

These results are not clear-cut in terms of significance (p-values). Only J2 in the *buku* series, and J1 and J2 in the *koku* series, are supposed to be of the same word durations (also marginally E2 in the *koku* series).

5.3. TEMPORAL COMPENSATION

5.3.1. COMPENSATION IN VOWELS FOR MORAIC CONSONANTS (C_M). In respect to Hypothesis 2c in §4.2, durations of V_1 in $C_1V_1C_MC_2V_2$ words (i.e., *bukku* and *kokku*) were compared with that in the 2S2M words (*buku* and *koku*) by speaker. Figure 2 shows the differences of V_1 durations by speaker, calculated by subtracting the latter from the former. The results of a t-test on these vowels showed that Japanese speakers and the speaker Ea had significantly longer V_1's in $C_1V_1C_MC_2V_2$ word (except J3 for the *buku* series),[7] whereas none of the English speakers did. A ratio of compensation (V_1 in the $C_1V_1C_MC_2V_2$ word divided by V_1 in the 2S2M word) was found to vary by speaker. For example, V_1 of *bukku* for J1 (88 ms) is 16% longer than that of *bukku* for the same speaker (76 ms) while the same ratio jumps up to 27% for the same word pair for J2 (85 ms/67 ms). In general, about 16% to 19% compensation was observed in the said V_1's by Japanese speakers. In the case of English speakers, the said V_1's are either approximately the same or even shorter than that of the 2S2M word. This is a striking difference between the two speaker groups.

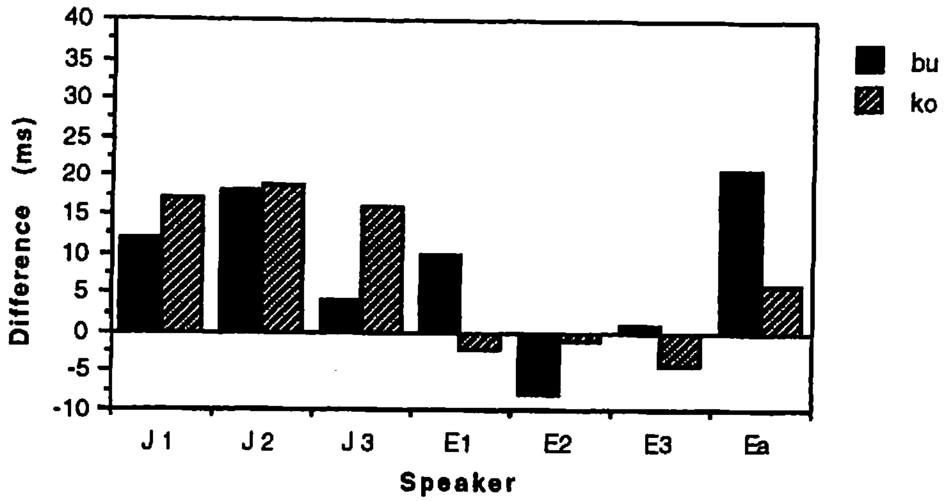

FIGURE 2. Differences of V_1 durations in $C_1V_1C_MC_2V_2$ words and 2S2M words, by speaker (ms).

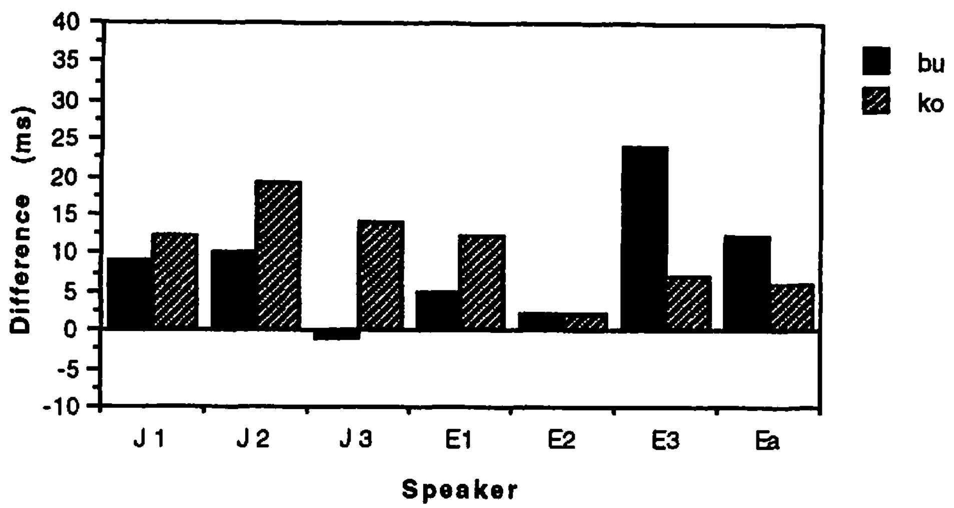

FIGURE 3. Differences of C_1 durations in $C_1V_1V_MC_2V_2$ words and 2S2M words, by speaker (ms).

5.3.2. COMPENSATION IN CONSONANTS FOR MORAIC VOWELS (V_M). This time, durations of C_1 in $C_1V_1V_MC_2V_2$ words (i.e., *buuku* and *kooku*) were compared with that in the 2S2M word by speaker, in respect to Hypothesis 2d in §4.2. Figure 3 shows the differences of C_1 durations by speaker, calculated by subtracting the latter

[7] For the *koku* series, VOT1 was included under V1 for analysis. However, the same results were obtained by a separate analysis with V1 without VOT1.

from the former. The results of a t-test on these consonants were very similar to those described in the previous section on V_1's. That is, Japanese speakers had significantly longer C_1's in $C_1V_1V_MC_2V_2$ words (except J3 for the *buku* series),[8] whereas few cases produced by English speakers did. A ratio of compensation (C_1 in the $C_1V_1V_MC_2V_2$ word divided by C_1 in the 2S2M word) again varied by speaker, as in the previous section. For example, C_1 of *buuku* for J1 (73 ms) is 14% longer than that of *buku* for the same speaker (64 ms) while the same ratio jumps up to 32% for the *koku/kooku* pair for J2 (77 ms/58 ms). In general, about 14% to 22% compensation was observed in the said C_1's by Japanese speakers. For this same compensation, the data from the speaker Ea was mixed: the *buku* series had about 17% (84 ms/72 ms) compensation while the *koku* series was nonsignificant. This again is a noteworthy difference between the two speaker groups.

5.3.3. COMPENSATION IN CONSONANTS FOR MORAIC CONSONANTS (C_M). Finally, durations of C_1 in $C_1V_1C_MC_2V_2$ words (i.e., *bukku* and *kokku*) were compared with that in the 2S2M word by speaker, in respect to Hypothesis 2e in §4.2. Figure 4 shows the differences of C_1 durations by speaker, calculated by subtracting the latter from the former. The results of a t-test run on these durations were quite different from those described in the previous two sections. In only one case did a Japanese speaker have significantly longer C_1's in a $C_1V_1C_MC_2V_2$ word,[8] whereas most cases by English speakers did. This is the completely reverse of the previous cases. A ratio of compensation (C_1 in the $C_1V_1C_MC_2V_2$ words divided by C_1 in the 2S2M words) varied by speaker, as in the previous section.

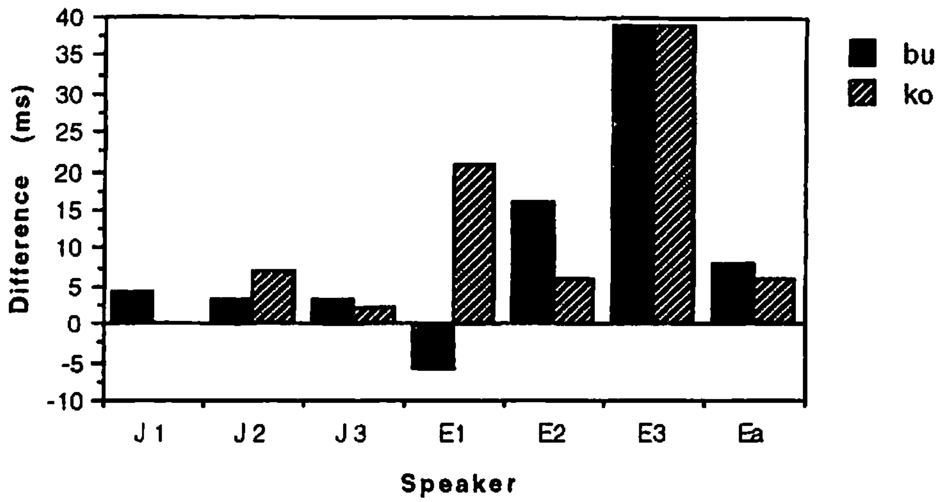

FIGURE 4. Differences of C_1 durations in $C_1V_1C_MC_2V_2$ words and 2S2M words, by speaker (ms).

However, the variation in compensation is very different from the previous cases. For example, C_1 of *bukku* for E3 (137 ms) is as much as 40% longer than that of *buku* for the same speaker (98 ms) while the same ratio goes down to only 8% for the *koku/kokku* pair for E2 (86 ms/80 ms). The compensation ratios are much larger than those obtained by Japanese speakers in the previous sections. For this compensation, the data from the speaker Ea was just like those from Japanese speakers: no significant compensations were observed in either series. Thus the two speaker groups once again produced different results, but in this time in a different manner.

6. DISCUSSION. For convenience, the hypotheses given in §4.2 are duplicated here.

(2) a. 2-mora words are only slightly more than 2/3 the duration of 3-mora words.
b. 3-mora words containing 2 syllables are very nearly equal in duration to 3-mora words containing 3 syllables.
c. V_1 in $C_1V_1C_MC_2V_2$ words is longer than that in $C_1V_1C_2V_2$ words.
d. C_1 in $C_1V_1V_MC_2V_2$ words is longer than that in $C_1V_1C_2V_2$ words.
e. C_1 in $C_1V_1C_MC_2V_2$ words is longer than that in $C_1V_1C_2V_2$ words.

[8] VOT1 was not included in C1.

6.1. WORD DURATIONS

6.1.1. COMPARISON WITH PORT ET AL. 1987. The results of the current study were very similar to those in Port et al. 1987 in all the data analyzed. The segmental durations of the *buku* series in both experiments demonstrated little difference; the added testing of meaningful words showed that they had the same tendency to keep the durations of the words with the same number of moras equal, just as nonsense words used in their experiment. Absolute values for the segmental durations obtained from the two completely separate experiments are very similar. This leads to the speculation that Japanese speakers may use a similar tempo in speaking, not to mention the timing. This is conceivable because both studies were done in an experimental setting. Non-natural, careful speech may be a factor in accounting for the similarity. At any rate, the first purpose of the current study, i.e., replication of Experiment 4 in Port et al. 1987, was successfully accomplished. The results show that it is not the traditional version but Hypothesis 2a that is supported in this particular case. Moreover, the durations of 2S3M words (*buuku* and *bukku*) are close to that of the 3S3M word in each series, indicating that Hypothesis 2b is also supported in this case.

The effect of nonsense words in Port et al. 1987 seems to be negligible. An additional set of meaningful words used for the current study showed the same tendency as the set of nonsense ones in the former study. Japanese speakers can treat nonsense words just like meaningful words, at least in the experimental setting. Moreover, the ratios of a 2-mora to other 3-mora (about 68-70%) suggest that, within the same series, Hypothesis 2a can be maintained.

From the above results, the current study can be said to be compatible in part with Port et al. 1987. The results from both studies found evidence for a less strict version of the mora hypothesis.

6.1.2. OTHER COMPARISONS OF DURATIONS. The results from another comparison seem to show some deviations from the mora hypothesis, in other words, even a less strict version of it. The mora hypothesis in general predicts that all the words with the same number of moras should be of about the same duration in a given speaking tempo, regardless of their segmental components. Thus, in the case of the current study, those words such as *buku* and *koku* for a particular speaker (a particular speaking tempo implied) should have about the same duration. The mean durations calculated for those words for Japanese speakers follow the hypothesis in terms of the absolute values (in ms). They are similar when all the mean durations from Japanese speakers are compared. However, as shown in Table 3, there are some individual differences in identity of these mean durations. This seems to indicate that some mean durations from some speakers (especially from J2) depend on the segmental components. The two sets of words (i.e. the *buku* and *koku* series) are quite different in the intrinsic durations of each segment. Intrinsically, voiceless consonants are longer than their voiced counterparts and mid vowels are longer than high ones. It seems that the mora-based temporal adjustment cannot beat these differences, and they fail to maintain their expected durations. This discrepancy, however, may stem from the small number of samples. When pooled across 3 Japanese speakers, as can be seen in Fig. 1, the results from them show striking similarities among the words with the same number of moras, despite the fact that /bu/ should be intrinsically shorter than /ko/. If the mora-based adjustment is regarded as a GENERAL TENDENCY, this kind of discrepancy can be ignored.

In the previous section on comparison with Port et al. 1987, Hypothesis 2a was supported for the *buku* series. As to overall results including other word sets, the results were quite compatible with the hypothesis. Japanese speakers were consistent in the ratios of durations of 2-mora words to 3-mora words, as in Table 4. Moreover, Hypothesis 2b was supported by Fig. 1 and the results given in §5.2.3. The former shows the similarity of 2S3M words and 3S3M words relatively clearly, whereas the latter does show it but rather weakly.

6.2. TEMPORAL COMPENSATION. While many researchers seek direct evidence of mora-based timing by comparing durations of single consonants and geminate ones (e.g. Han 1992) or of syllable-initial and syllable-final (moraic) nasals (e.g. Sato 1993), not many durations other than those have been investigated. Beckman 1982 states that she predicted variation in segmental duration to compensate for inherent difference of adjacent segments to equalize the mora, but she could not find any evidence of compensation in adjacent segments. However, Port et al. 1980 concluded that compensation occurs beyond syllable boundaries. Namely, compression or stretching takes place in segments and whole moras, for compensating long or short moras, although the compensation is not perfect (Port & Hardy 1989). Likewise, Sato (1993:57) found that 'not only the syllable-final nasals, but also other segments in the test words show temporal compensation.' The current study found evidence to support the view of Port et al., of compensation beyond syllable or mora boundaries, at least to a limited extent.

First of all, Hypothesis 2c predicts that compensation may occur in an immediately adjacent but non-tautosyllabic segment. The results reported in §5.3.1. show that a moraic consonant (C_M) is compensated by a lengthening of the first vowel (V_1) in both sets of words. Because V_1 in this case belongs to neither the following syllable nor the following mora, this can be claimed as an instance of compensation by one of the adjacent segments, which Beckman 1982 failed to observe. This lengthening is not due to accentuation because all Japanese speakers put the accent on the first syllable and, as Sugito 1989 states, the placement of accent is known to have no effect on the duration of a syllable in Japanese. Thus speakers seem to anticipate the moraic consonant and the adjacent vowel must be lengthened to compensate for the consonant. Of course, this assumes that a mora consisting of a moraic consonant IS shorter than a full CV mora but this point has been investigated by many researchers and shown to be so (e.g. Han 1992).

One of the puzzling results of this effect of compensation by V_1 is the difference in the amount of compensation among speakers. Figure 2 indicates that J3 did not compensate much for *buku* but did just as the other Japanese speakers for *koku*. However, this is not surprising because the total word duration for this word is indeed shorter than those given by other speakers. Thus the geminate consonant was simply incompletely compensated to yield a shorter duration for the entire word.

Then, a compensation by a remotely-located segment is supposed in Hypotheses 2d and 2e to look for a more remarkable effect of mora-based timing. These hypotheses predict that the first consonant (C_1) in the first syllable may be longer in the words which contain a long vowel or a geminate consonant.

A compensation by C_1 for V_M seems to be taking effect. Figure 3 shows the same kind of results for Japanese speakers as seen in Fig. 2. A compensation is observed in a segment even as distant as the first consonant in those words with a long vowel. However, this is not an extraordinary phenomenon because the C_1 in question still belongs to the same syllable as the one with V_M if /CV:/ is regarded as a legitimate unit. Thus this compensation can be interpreted as that which simply took place within the same syllable (although across a mora boundary).

The result from J3 was again deviate from that of the other Japanese speakers, according to Fig. 3. In this instance, the speaker's total word duration for *buku* is not quite different from that of the other two speakers. However, C_1's in J3 are all longer. (The mean C_1 durations [and their standard deviation] across test words by J1, J2, and J3 are 62 ms [7.39], 60 ms [8.35] and 79 ms [8.21], respectively.) Therefore, the compensatory effect might not show up as conspicuously because of J3's already-long C_1's.

Finally, Hypothesis 2e was totally unsupported for Japanese speakers by the results in §5.3.3. No compensation was seen in C_1 in words with a geminate consonant. One big difference from the above two compensations is that these results are consistent. All 3 speakers had the same nonsignificant effects. It is possible that the compensation effect cannot go as far as the C_1 position in this instance. Notice that the previous two cases are observed in either an immediately adjacent position or within the same syllable. Because this C_1 position is too far from the position of the segment to compensate for, there may be less effect.

6.3. SECOND LANGUAGE SPEAKERS. So far, I showed that Hypotheses 2a to 2d are supported for Japanese speakers. In this section, these hypotheses will be checked against utterances by the English speakers.

As mentioned in §5.2.1, the mean word durations for words of the same segmental components obtained by English speakers were not similar, whereas those for Japanese speakers were quite similar to each other. Of course, the English speakers spoke a foreign language, so it is possible that they kept the tempo according to their level of mastery in the second language. Indeed, the advanced learner, Ea, had a similar mean duration as Japanese speakers for all the words. This suggests that the speaking tempo the English speakers used was varied and may depend on the level of acquisition.

The direct comparison of the data from English speakers with those from Japanese speakers in §5.2.2 revealed that Hypothesis 2a cannot be applicable to the former, implying that English speakers did not demonstrate a mora-based timing. As Fig. 1 indicates, English speakers seem to be more affected by the difference in the segmental component of the words. Moreover, English speakers had higher percentages of the mean word durations when comparing 2S2M words and 2S3M words as seen in Table 4. This is because either (1) 2S2M words were longer relative to 2S3M words; or (2) 2S3M words were shorter, relative to 2S2M words, than those produced by Japanese speakers. I suppose that the latter case (case 2 above) should be plausible. If English speakers carry on timing with a somewhat familiar unit, i.e. a syllable, they tend to shorten a syllable with extra length. Thus, no matter how they syllabify 2S3M words, CVC-CV or CV-CCV in one case, or CVV-CV in another, 2S3M words become closer to 2S2M words. This may be an instance of interference in which they use an alternative timing when they come across a language with different timing.

Contrary to the above, the results given in §5.2.3 for Hypothesis 2b were similar to those by Japanese speakers. English speakers did not make all the 3-mora words equal in length, but did make those with the same number of syllables, i.e. all the 2S(3M) words, equal. This must be rather easy for them, for the same reason as stated above. However, it seems that the Japanese speakers did a little better job of keeping 3S3M words equal to those 2S3M words because 3 out of 6 cases are observed as nonsignificantly different, implying that Japanese speakers showed a mora-based timing.

Finally, as I have described in §5.3, there are differences between the two language groups as to Hypotheses 2c-2e on temporal compensations. (Refer to Figs. 2-4 for review.) Japanese speakers generally showed relatively strong tendency for compensations in Hypotheses 2c and 2d, whereas English speakers did not. However, more interesting results were obtained in respect of Hypothesis 2e. Contrary to an expectation, English speakers demonstrated a significant compensation in the case of Hypothesis 2e. I speculate that this can also be explained by the difference in use of timing by both groups of speakers. Take, for example, the word *bukku*. Suppose English speakers syllabify the word as *bu-kku* and they try to make /bu-/ and /-kku/ equal in length, according to the syllable-timing strategy described above. Because Hypothesis 2c does not apply to this case (for reasons unknown to me), the resulting compensation might occur.

6.4. FOR FURTHER STUDY. The current study is by no means free from the flaws which are unavoidable to this kind of study. For example, Han 1992 states that discrepancies in the earlier studies on the mora hypothesis come from the following: (1) treatment of VOT, (2) selection of test material and subjects, and (3) size of experimental corpus.

Han claims that Beckman's rejection of the mora hypothesis (Beckman 1982) comes from inclusion of VOT to stop consonants. The current study does not fully consider this point, which the two researchers are in debate over. However, VOT is defined as 'the moment at which the voicing starts relative to the release of a closure' (Ladefoged 1993:142). According to this definition, VOT seems to be a part of vowel because it marks the START of voicing. Especially in the case of an intervocalic voiceless stop (/k/ or /kk/) as analyzed in the current study, it may be more appropriate to include VOT with the vowels.

The problem with the current study lies rather on Han's other two points. As seen in §6.1.2, the number of samples must have been too small. Experiment 4 in Port et al. 1987, on which the current study is based to some extent, used 10 speakers, and so did an experiment in Han 1992. Beckman 1982 used 5 speakers, but her experiment tested with many more words (tokens) than the current study. More observations would have been needed for statistically more reliable results.

In addition, as briefly described above, it is often pointed out that mora is SUBJECTIVE. Hoequist 1983b questions the position where the mora starts. In his 1983a study, Hoequist claims that physical foot duration may not coincide with a hearer's point of reference. The current study assumes, just as do other studies, that the mora-based timing is closely related to segments and that the start of a syllable coincides with the start of mora. This point needs more investigation, especially from a psychological point of view.

7. CONCLUSION. The current study verifies and further supports the argument of Port et al. 1987, asserting that mora timing exists in Japanese. The following points summarize some of the findings:

(1) Japanese speakers showed fairly constant durations for the words with the same number of moras. That is, Japanese 3-mora words were all similar in overall word duration regardless of the segmental composition. The compensatory effect on words with SPECIAL moras (/Q/ and /R/), which was found in Port et al. 1987, was also observed in the results here. However, the temporal compensations which are as large as a word level could not be found in the current study.

(2) The data from English speakers speaking Japanese were considerably different from those from Japanese native speakers. Overall durations did not generally follow the mora hypothesis and temporal compensations took place in a different manner from Japanese speakers. As English speakers lack a mora-based timing control, they seem to follow a syllable-timing strategy as an alternative. Moreover, the fact that an advanced learner could show some aspects of mora timing indicates that the mora-timing strategy may be learnable to some extent, even by an adult.

The complexities surrounding mora timing in Japanese have not been sufficiently studied so far. Beckman 1982 concluded with a statement that the mora is heavily influenced by the Japanese writing system *kana*, and its lack of syllable-structure complexity. However, many researchers admit the existence of the mora in a less traditional way. For example, Yoshiba admits that 'the existence of the mora segment is psychologically real' (Yoshiba 1981:244).

Moreover, the current study has opened up some questions on how learners of Japanese deal with pronunciation, especially with moras. In this respect, Han (1992:103) clearly states this issue as follows: 'A foreign accent detected in the pronunciation of geminate stops involves the stop closure duration, or a silent period, as the primary cue.' Because there are growing needs for studies in the field of so-called 'Teaching Japanese as a Foreign Language', studies such as Han 1992 and Masuko & Kiritani 1992 would be welcomed more than ever.

REFERENCES

ASANO, YOSHITERU. 1988. Japanese as a mora-timed language. M.A. thesis, Indiana University, Bloomington.

BECKMAN, MARY. 1982. Segment duration and the 'mora' in Japanese. Phonetica 39.113-35.

CRYSTAL, DAVID. 1992. A dictionary of linguistics and phonetics, 3rd ed. Oxford: Blackwell.

HAN, MIEKO S. 1962a. Japanese phonology: An analysis upon sound spectrogram. Tokyo: Kenkyusha.

———. 1962b. The feature of duration in Japanese. Study Sounds 10.65-80.

———. 1992. The timing control of geminate and single stop consonants in Japanese: A challenge for nonnative speakers. Phonetica 49.102-27.

DOI: https://doi.org/10.25810/2ddh-9161

HOEQUIST, CHARLES, JR. 1983a. Durational correlates of linguistic rhythm categories. Phonetica 40.19-31.

———. 1983b. Syllable duration in stress-, syllable- and mora-timed languages. Phonetica 40.203-37.

HOMMA, YAYOI. 1981. Durational relationship between Japanese stops and vowels. Journal of Phonetics 9.273-81.

IMAISHI, MOTOHISA. 1992. Nihongo no onsei – Jikken onseigaku teki tachiba kara [Sounds in Japanese – Viewed from the standpoint of experimental phonetics]. Nihongo-gaku [Studies of Japanese], ed. by Shozo Nagao, 27-64. Osaka: Izumi Shobo.

KATADA, FUSA. 1990. On the representation of moras: Evidence from a language game. Linguistic Inquiry 21.641-46.

LADEFOGED, PETER. 1993. A course in phonetics. 3rd ed. New York: Harcourt Brace Jovanovich.

LARKEY, LEAH S. 1983. Reiterant speech: An acoustic and perceptual evaluation. Journal of the Acoustical Society of America 73.1337-45.

MASUKO, YUKIE, and SHIGERU KIRITANI. 1992. The duration of sequences of two identical consonants in Indonesian in comparison with geminates in Japanese. Annual Bulletin, Research Institute of Logopedics and Phoniatrics, Faculty of Medicine, University of Tokyo, 26.39-44.

OTAKE, TAKASHI; GIYOO HATANO; ANNE CUTLER; and JACQUES MEHLER. 1993. Mora or syllable? Speech segmentation in Japanese. Journal of Memory and Language 32.258-78.

PORT, ROBERT F.; SALMAN AL-ANI; and SHOSAKU MAEDA. 1980. Temporal compensation and universal phonetics. Phonetica 37.235-52.

———; JONATHAN DALBY; and MICHAEL O'DELL. 1987. Evidence for mora timing in Japanese. Journal of the Acoustical Society of America 81.1574-85.

———; and JANE E. HARDY. 1989. Moras and segmental features in Japanese. Draft read at the Acoustical Society of America, May 25, 1989.

POSER, WILLIAM. 1990. Evidence for foot structure in Japanese. Language 66.78-105.

SATO, YUMIKO. 1993. The durations of syllable final nasals and the mora hypothesis in Japanese. Phonetica 50.44-67.

SUGITO, MIYOKO. 1989. Onsetsu ka haku ka – Choo-on, hatsu-on, soku-on [Syllables or moras – Long vowels, nasals and geminate consonants]. Kooza: Nihongo to nihongo kyooiku; dai 2-kan, Nihongo no onsei, on-in (1) [Seminar on Japanese and education of Japanese language; Vol. 2, Sounds and phonology of Japanese (1)], ed. by Miyoko Sugito, 154-77. Tokyo: Meiji Shoin.

VANCE, TIMOTHY J. 1987. An introduction to Japanese phonology. Albany: State University of New York Press.

YOSHIBA, HIROSHI. 1981. The mora constraint in Japanese phonology. Linguistic Analysis 7.241-62.

APPENDIX

The following tables are the results of the experiment. They are given by word and all the values are in milliseconds. Except those labels for subjects (speakers) and for segments, the following abbreviations are used:

avJ = mean of values for 3 Japanese speakers (J1-J3)
sdJ = standard deviation of the above
avE = mean of values for 3 English speakers (E1-E3, Ea is excluded)
sdE = standard deviation of the above
S1, S2, S3 = duration of each CV-syllable
For $C_1V_1V_MC_2V_2$ words, S1 has 2 moras.
For $C_1V_1C_MC_2V_2$ words, S2 has 2 moras.
W.dur. = word duration for the word

buku

	C1	VOT1	V1	C2	VOT2	V2	/d/	/o/	S1	S2	S3	W.dur.
J1	64.21	-	75.75	65.75	17.69	47.30	-	-	139.96	130.74	-	270.74
J2	53.83	-	66.91	58.06	16.92	52.68	-	-	120.74	127.66	-	248.40
J3	73.44	-	67.68	74.98	15.00	41.14	-	-	141.12	131.12	-	272.24
E1	140.73	-	140.73	166.49	50.37	119.97	-	-	281.46	336.83	-	618.29
E2	85.75	-	106.51	87.28	39.22	50.76	-	-	192.25	177.26	-	369.52
E3	98.43	-	79.21	69.98	49.99	42.30	-	-	177.64	162.27	-	339.91
Ea	71.52	-	47.68	58.16	18.84	38.84	-	-	119.20	115.84	-	235.04
avJ	63.83		70.11	66.26	16.54	47.04			133.94	129.84		263.79
sdJ	9.81		4.90	8.47	1.39	5.77			11.45	1.90		13.35
avE	108.30		108.82	107.92	46.53	71.01			217.12	225.45		442.57
sdE	28.79		30.82	51.46	6.33	42.61			56.20	96.75		152.89

koku

	C1	VOT1	V1	C2	VOT2	V2	/d/	/o/	S1	S2	S3	W.dur.
J1	54.21	20.00	74.98	53.45	18.84	48.83	-	-	149.20	121.12	-	270.32
J2	58.05	28.46	69.60	54.99	19.23	34.61	-	-	156.10	108.82	-	264.92
J3	82.29	23.84	51.91	67.29	13.46	35.38	-	-	158.04	116.13	-	274.16
E1	104.59	67.67	139.19	146.50	53.06	127.27	-	-	311.45	326.83	-	638.28
E2	79.88	54.22	89.21	73.43	45.37	48.83	-	-	223.40	167.64	-	391.04
E3	134.10	55.75	73.06	69.69	43.74	33.16	-	-	262.91	146.60	-	409.50
Ea	71.90	46.14	48.07	48.07	24.70	48.83	-	-	166.11	121.60	-	287.71
avJ	64.85	24.10	65.50	58.58	17.18	39.61			154.45	115.36		269.80
sdJ	15.23	4.24	12.07	7.59	3.22	8.00			4.65	6.19		4.64
avE	106.19	59.21	100.49	96.54	47.39	69.75			265.92	213.69		479.61
sdE	27.15	7.36	34.48	43.31	4.98	50.42			44.10	98.55		137.72

buuku

	C1	VOT1	V1	C2	VOT2	V2	/d/	/o/	S1	S2	S3	W.dur.
J1	73.44	-	166.11	75.75	21.15	29.61	-	-	239.55	126.51	-	366.05
J2	63.83	-	156.49	73.06	23.84	47.30	-	-	220.32	144.19	-	364.52
J3	71.91	-	136.50	88.82	19.23	31.15	-	-	208.41	139.20	-	347.60
E1	146.11	-	199.94	198.98	49.03	133.14	-	-	346.05	479.67	-	727.19
E2	88.05	-	248.01	84.98	53.45	63.45	-	-	336.06	201.87	-	537.93
E3	122.08	-	134.10	95.65	64.89	39.89	-	-	256.18	200.42	-	456.60
Ea	83.82	-	132.66	74.98	23.46	33.84	-	-	216.48	132.28	-	348.75
avJ	69.73		153.03	79.21	21.41	36.02			222.76	136.63		359.39
sdJ	5.16		15.10	8.43	2.32	9.80			15.71	9.12		10.43
avE	118.75		194.02	126.54	55.79	78.83			312.76	293.99		573.91
sdE	29.17		57.19	62.96	8.18	48.49			49.26	160.81		138.84

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	C1	VOT1	V1	C2	VOT2	V2	/d/	/o/	S1	S2	S3	W.dur.
J1	65.75	36.53	164.57	58.83	17.31	35.76	-	-	266.85	111.89	-	378.74
J2	76.90	36.15	142.65	70.37	24.61	42.30	-	-	255.70	137.27	-	392.97
J3	96.13	38.07	119.97	79.13	14.23	29.99	-	-	254.16	123.35	-	377.51
E1	116.51	69.60	199.17	166.88	56.14	141.11	-	-	385.27	364.13	-	749.40
E2	81.52	83.52	236.47	71.14	56.52	54.60	-	-	401.50	182.26	-	583.76
E3	140.73	70.75	140.35	93.44	55.75	33.07	-	-	351.82	182.26	-	534.08
Ea	77.67	58.06	103.82	68.83	26.53	39.99	-	-	239.55	135.35	-	374.90
avJ	79.59	36.92	142.40	69.44	18.72	36.02			258.90	124.17		383.07
sdJ	15.37	1.02	22.30	10.18	5.33	6.16			6.92	12.71		8.59
avE	112.92	74.62	192.00	110.49	56.14	76.26			379.53	242.88		622.41
sdE	29.77	7.73	48.46	50.09	.39	57.18			25.33	105.00		112.74

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bukku

	C1	VOT1	V1	C2	VOT2	V2	/d/	/o/	S1	S2	S3	W.dur.
J1	68.44	-	88.05	160.34	18.46	32.30	-	-	156.50	211.10	-	367.59
J2	57.29	-	84.59	144.15	20.38	56.14	-	-	141.88	220.71	-	362.59
J3	75.62	-	71.78	153.80	17.09	37.17	-	-	147.40	208.06	-	355.46
E1	135.43	-	150.81	275.99	48.28	126.03	-	-	286.24	450.30	-	736.54
E2	101.90	-	98.82	208.79	46.14	55.37	-	-	200.71	310.30	-	511.02
E3	137.27	-	80.36	127.66	53.06	46.14	-	-	217.63	226.86	-	444.49
Ea	79.59	-	68.83	152.65	21.92	36.91	-	-	148.42	211.48	-	359.90
avJ	67.12		81.47	152.76	18.64	41.87			148.59	213.29		361.88
sdJ	9.24		8.57	8.14	1.65	12.60			7.38	6.60		6.10
avE	124.87		110.00	204.15	49.16	75.85			234.86	329.15		564.02
sdE	19.91		36.53	74.27	3.54	43.70			45.29	112.91		153.07

kokku

	C1	VOT1	V1	C2	VOT2	V2	/d/	/o/	S1	S2	S3	W.dur.
J1	53.83	21.92	90.36	159.96	23.46	32.30	-	-	166.11	215.71	-	381.83
J2	64.60	26.15	90.36	151.11	18.07	46.91	-	-	181.10	216.10	-	397.20
J3	83.82	20.54	71.14	142.27	16.15	37.68	-	-	176.49	196.10	-	372.60
E1	126.12	66.52	138.42	275.69	47.68	136.89	-	-	331.06	460.26	-	791.32
E2	86.13	47.30	94.20	214.55	49.22	59.22	-	-	227.63	322.99	-	550.61
E3	173.03	55.37	69.98	152.26	51.14	41.91	-	-	298.38	245.32	-	543.69
Ea	77.67	43.45	56.91	136.22	22.30	34.22	-	-	178.03	192.75	-	370.78
avJ	67.42	22.87	83.95	151.11	19.23	38.96			174.57	209.30		383.88
sdJ	15.19	2.92	11.10	8.85	3.79	7.39			7.68	11.44		12.43
avE	128.43	56.40	100.87	214.17	49.35	79.34			285.69	342.86		628.54
sdE	43.50	9.65	34.70	61.72	1.73	50.59			52.87	108.84		141.01

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	C1	VOT1	V1	C2	VOT2	V2	/d/	/o/	S1	S2	S3	W.dur.
J1	60.24	-	81.60	55.54	22.64	48.70	37.60	88.86	141.84	126.89	126.46	395.19
J2	49.56	-	66.65	53.83	17.94	42.30	35.89	107.24	116.21	114.07	143.12	373.41
J3	71.78	-	62.38	73.48	15.38	43.58	38.03	88.86	134.15	132.44	126.89	393.49
E1	151.24	-	151.67	186.27	48.71	137.99	98.26	212.76	302.91	372.79	311.02	986.90
E2	89.29	-	99.97	73.96	46.57	50.84	41.01	188.41	189.27	171.38	229.42	590.07
E3	125.93	-	80.27	76.90	58.64	58.64	66.33	186.00	206.19	194.18	252.33	652.70
Ea	69.64	-	48.28	48.70	21.37	36.74	31.19	129.88	117.92	106.82	161.07	385.81
avJ	60.53		70.21	60.95	18.65	44.86	37.17	94.99	130.73	124.47	132.16	387.36
sdJ	11.11		10.09	10.88	3.68	3.39	1.13	10.61	13.15	9.42	9.50	12.11
avE	122.15		110.64	112.38	51.31	82.49	68.53	195.72	232.79	246.17	264.26	743.22
sdE	31.15		36.88	64.01	6.44	48.22	28.69	14.80	61.31	110.40	42.09	213.34

kokudo

	C1	VOT1	V1	C2	VOT2	V2	/d/	/o/	S1	S2	S3	W.dur.
J1	54.18	19.58	74.11	51.73	23.07	44.74	35.66	84.94	147.87	119.55	120.60	388.02
J2	56.98	25.87	76.90	50.68	17.48	33.56	42.30	102.77	159.75	101.72	145.07	406.54
J3	79.70	23.42	48.94	65.72	13.29	42.30	44.39	77.60	152.06	121.30	121.99	395.36
E1	117.80	71.31	128.98	141.57	61.17	116.75	93.33	202.39	318.09	319.49	295.72	933.30
E2	77.95	59.43	92.98	68.16	42.65	45.09	38.10	176.52	230.36	155.90	214.62	600.88
E3	127.93	62.13	73.06	75.15	48.24	37.75	66.07	161.49	267.12	161.14	227.56	651.82
Ea	66.42	48.24	42.30	51.74	22.72	41.25	35.31	113.26	156.95	115.71	148.56	421.22
avJ	63.62	22.96	66.65	56.04	17.95	40.20	40.78	88.44	153.23	114.19	129.22	396.64
sdJ	14.00	3.17	15.40	8.40	4.91	5.88	4.56	12.94	6.03	10.83	13.74	9.33
avE	107.89	64.29	98.34	94.96	50.69	66.53	65.83	180.13	271.86	212.18	245.97	728.67
sdE	26.42	6.23	28.34	40.52	9.50	43.65	27.62	20.69	44.06	92.97	43.57	179.04