研　究　成　果　報　告　書

発話リズムの制御と知覚における

韻律単位の機能と役割の検証

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はしがき

本研究は、音声知覚と産出における韻律単位の役割を検証し、音声発話と知覚との関係を考察したものである。特に拍と音節が発話と知覚に与える影響を検証し、音声産出と音声知覚と韻律単位の関係の解明を試みる。本研究では韻律制御の特色が無意識に現れやすい外国語の発話のデータを基に、リズムの制御と韻律単位との関係を調査し、特に日本語話者の発話リズムの基本となる単位の認識が、知覚のどの段階で起き、どの韻律単位が発話の韻律制御にどのように影響を及ぼすのか、韻律制御における知覚と発話との関連について検証した。日本語と韻律、特に発話リズムの制御法の異なる英語とフランス語を対象言語とし、発話にとっての拍と音節と発話リズムとの関連と、知覚との関係を考察。また拍及び音節以外に、発話と知覚に影響を持つ要素は何か、特に音素配列規則との関係も考察する。

これまで、発話リズムにおいては、日本語では拍、英語においてはフット、仏語においては音節の重要性が検証されている。本研究統括者が現在進めている研究では、日本語母語話者の仏語には、拍を基準としたフレーズ長の制御が見られる。本研究では、これらの結果を受け、英語話者と仏語話者の発話と比較しながら、(1)日本語話者の発話における拍と音節の干渉、(2)日本語話者の知覚における拍と音節の干渉、(3)音声産出と知覚における音節と音素配列の干渉、を中心に研究したものである。

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1. Background of the Study

This research project investigated the relationship between speech perception and production, in particular the relationship in second language (L2) acquisition and the effect of the phonological unit of a first language (L1) on second language perception and production. The study focused on prosody, in particular speech rhythm of a second language. First of all phonological units for speech production and perception in Japanese were identified, and then the study examined how Japanese speakers use these units to analyse speech strings in other languages and how this was reflected in their L2 production.

The organisation of prosody, especially the timing of speech, is important in terms of intelligibility of speech. However, achieving temporal organisation of L2 speech is not easy for L2 learners because each language employs a different prosodic unit for timing. It is important for a non-native speaker to acquire the correct rhythm of a target language as it enhances intelligibility of the language significantly and improves native speakers' judgement on fluency, because native speakers are sensitive to temporal organization of speech rather than the accuracy of segmental pronunciation. Tajima et al. (1997) examined the effect of speech timing on intelligibility using English spoken by a Chinese speaker. They changed temporal features based on the data of American English speaker's utterance but kept other segmental features of the original Chinese speaker's English utterance. Their results found that the native speaker's judgement on intelligibility of the utterance improved significantly, despite quite different acoustic features of the segments, by manipulating only its temporal features.

Temporal organisation of speech varies from language to language. This presents problems for foreign language learners, especially adult learners. This is because adult language learners have already acquired temporal organisation of their first language and tend to transfer the habits of their first language to a second language. In terms of temporal organisation of speech, the main difference between languages is very often the unit of timing, for example, between Japanese and English. The unit of timing in English is the foot, and there is a tendency for stressed and unstressed syllables to be spaced apart at more or less regular intervals. In Japanese, the unit of speech rhythm is the mora. In Japanese works the durations of morae are not necessarily equal, but the durations of whole words are proportional to the number of morae, despite consisting of segments of different durations and a different number and structure of syllables (Port et al. 1987). In other words, two-mora words are approximately twice the duration of one-mora word, and three-mora words are approximately three times the duration of one-mora words. This timing control is consistent even when vowels in a word are devoiced, despite the fact that morae with devoiced vowels are significantly shorter than the equivalent morae with fully voiced vowels. The short duration of a devoiced mora was compensated to a certain extent at the word level as long as it did not occur consecutively (Kondo, 1995 and 2003). This occurred despite the fact that morae with devoiced vowels are significantly shorter than the equivalent morae with fully voiced vowels. Moreover, the duration of a pause in an utterance is proportional to the duration of a mora in the utterance (Kaiki and Sagisaka 1992). Thus, phonological structure with underlying vowels was reflected in the durational control.

Studies have also shown that durational differences between morae tend to be reduced, if they are not completely eradicated (Sato 1993; Campbell and Sagisaka 1991; Han 1994). For example, Sato (1993) found that in Japanese there was a significant

difference in the durations of nasals in syllable-initial and syllable-final positions. In Japanese a syllable-final nasal is moraic, and therefore is significantly longer than the syllable-initial nasal, which is non-moraic. A strong tendency to try to equalise the duration of morae was found in Japanese utterances. Campbell and Sagisaka (1991) found that durational compensation worked within CV sequences (a moraic unit) rather than C-V sequences (i.e. across a mora boundary). However, durational adjustment in proportion to mora count in Japanese appears to operate more significantly at the word level rather than the mora level. This means that speakers can not consciously control the durations of individual sounds or morae as their durations are stretched or reduced in relation to adjacent sounds. It is also essential to be able to recognise every mora in a word because the duration of a whole word is determined by the number of morae in the word.

Mora rhythm is deeply rooted in Japanese speech rhythm. Smith (1995) found the control of language speech rhythm was actually more complex than just a matter of duration. For instance, Smith (1995) found that articulatory movements were organised in terms of the basic rhythmic unit of speech of a language. She examined articulatory movement of lip aperture, rear tongue body, and lower jaw during the sequences of geminate consonants in Japanese and Italian. Geminate consonants, such as /pp/ and /tt/, occur commonly in both languages, but they are phonologically interpreted differently. In Japanese, the first element of the geminate consonants occurs in the syllable final position, but consists of a mora on its own. On the other hand, in Italian, it also occurs syllable finally but it does not have any phonological significance as the mora does not play any role in Italian phonology. During the production of sequences such as /ma.p-pa/, /mi.p-pi/, /ma.m-mi/ and /mi.m-ma/ (hereafter a mora boundary is indicated by a dot (/./) and a syllable boundary by a hyphen (/ - /) where necessary), there were separate articulatory gestures for the first /p/, which is moraic, in Japanese speakers' utterances, but not in

Italian speakers' utterances. Italian speakers did not show separate articulatory gestures for the first /p/, but showed syllable-based articulatory organisation during the same sequences. It was because the basic unit of speech rhythm in Italian is a syllable.

This study investigated timing compensation phenomena in Japanese and French because the two languages are quite different in terms of temporal orgainsation of speech. First of all, Japanese and French use different phonological units as the fundamental unit for speech rhythm. In Japanese, the unit of speech rhythm is the mora, and many studies have found that there is a strong tendency to equalise the duration of morae in Japanese utterances. However, in a language like French, it was once believed that the unit of speech rhythm was the syllable, and the duration of each syllable was similar. However, Wenk and Wioland (1982) claimed that there is a tendency to equalize phrase durations regardless of number of syllables that they contain. This current study will present results that conflict with the theory of equalized phrase durations.

With regard to perception, several psycholinguistic studies have shown that Japanese adult listeners parse incoming speech strings into morae. The main hypothesis in these studies was that speech is prelexically segmented into rhythmic units specific to each language (Cutler and Norris 1988; Mehler et al. 1981). Hence, French is segmented into syllables; English into trochaic stress feet. Mochizuki-Sudo and Kiritani (1991) showed that Japanese adult listeners analyse sound sequences into morae (Mochizuki-Sudo and Kiritani, 1991). Following previous studies for French and English, Otake et al. (1993) and Cutler and Otake (1994) examined moraic segmentation by Japanese native listeners by using target detection tasks. They concluded that Japanese listeners segment speech into morae whereas English listeners do not. However, moraic segmentation is not the only parsing found in Japanese. Rather, segmentation into the sub-unit of a syllable develops after syllabic segmentation. Meta-linguistic experimental results showed that Japanese

speaking children's awareness for moraic segmentation developed after their awareness for syllabic segmentation, but before they had learned kana syllabary, which is a moraic writing system (Ito and Kagawa 1991). Another study reported new-born babies' insensitivity to moraic segmentation (Yamasaki 1996), which suggests that the syllable is the only default rhythmic unit for segmentation (Bertoncini et al. 1995). It is, thus, interesting to test whether Japanese adults employ moraic or syllabic segmentation when they hear non-moraic languages like French.

The aim of this study is to explore how Japanese speakers parse foreign sound strings into rhythmic units and to clarify the relationship between phonological parsing and timing control in production. French utterances made by Japanese speakers were analysed to determine these effects. The paper will discuss if there are any differences in phrase duration among different types of moraic renditions predicted by phonological analysis of foreign word adaptation.

2. Phonological Parsing of Loanwords

Before discussing the experimental details it is important to consider the adaptation process underlying moraic counts of foreign sound strings. Mochizuki-Sudo and Kiritani (1991) showed that when durations of English vowels are altered by accent (cf. 'Interstress Interval'), Japanese listeners can only detect the change when it is large enough to shift from a long vowel (two morae) to a short vowel (one mora), or vice versa. This clearly indicates that there is an underlying phonemic adaptation process in English vowels where English vowel distinctions are encoded by moraic segmentation. There are three types of moraic renditions of foreign sound sequences that would create an extra mora compared to the vowel count in the original words. There is a phonological difference in terms of moraic specification in the input among these three types. In the first case, phonemic length difference must be encoded in the input. Thus, long vowels require moraic specification, and this is straightforward.

(1) First of all, the adaptation process underlying moraic count of foreign sound strings is explained. Shinohara (1997) showed that phonological study of Japanese adaptation of English words clearly indicates that some English vowel phonemes correspond to two morae and the others to one: pita |pɪtə| > /pita/ vs. Peter |pi:tə| > /piita/ (| | indicates foreign input forms; / / indicates Japanese adapted forms in phonemic representation). In adaptations of French words, this mapping process is deviated by orthography. Certain vowels, either spelt with more than one letter or written with an accent-circumflex, are optionally rendered as long vowels by Japanese speakers: *au, eau* > /oo/, *ou* > /uu/, *ê* > /ee/ etc.

(2) There is another well-known moraic rendition in Japanese loanwords. Foreign words ending in a single consonant are perceived (regardless of phonetic duration of the final C) and adapted with consonant gemination: pit |pɪt#| > /pit.to/ (Hirozane, 1992). The

phonological interpretation adopted here for this phenomenon is that the prefinal lengthening is the result of alignment between the stem edge (#) and a syllable edge (.) (Tsuchida, m.s.) -- a cross-linguistically common process. This explains why the first syllable of words such as *picnic* does not lengthen in the Japanese adapted form.

(i) Pre-final lengthening

pit |pɪt#| > /pit.to/ . # alignment

picnic > /pikunikku/ */pikkunikku/

When phonotactic constraints make it impossible to geminate the final consonant of the input, e.g. in the case of the liquid /r/, then the mora on the final consonant re-associates to the preceding vowel to maintain the weight of the prefinal syllable.

A closer look at this phenomenon reveals that the same type of moraic lengthening is masked when a preceding vowel is already a long one: Pete |pi:t| > /pi:.to/. In both cases the prefinal syllables in adapted forms are heavy. This is called 'prefinal lengthening' (see below).

(ii) Compensatory lengthening

gare |gaʀ#| > */gar.ru/ by *[rr] > [gaaru]

This compensatory lengthening indicates that the final consonant acquires moraic specification and hands it over to the preceding vowel before it reaches the output level. This allows the vowel-lengthened form such as /gaaru/ to resemble a form with C-gemination, which more clearly indicates the alignment effect.

(3) Another factor adding extra morae (and for this matter, syllables) in Japanese rendition of foreign words is the syllabification of complex syllable structures. The Japanese syllable structure is the following: $(C_1)(j)V_1(V_2)(C_2)$. $(C_1)(j)V_1$ typically consists of a mora, and exceptionally, both V_2 and C_2 can constitute a mora on their own, but only when V_2 is either the second half of a long vowel or of a diphthong, and C_2 is either N

(moraic nasal) or the first half of a geminate consonant. Since Japanese syllables allow only simple onsets and can be closed with the first half of a geminate or a nasal, the codas and clusters of foreign words are syllabified through vowel epenthesis: extra > /ekusutora/ (the epenthesised vowels are underlined).

Phonemic correspondence and 'prefinal lengthening' create vowel or consonant gemination in Japanese adapted forms. Syllabification of stray consonants also creates morae. When Japanese speakers process foreign words they do so using Japanese morae, and it should be possible to detect this process by analyzing foreign word utterances. The experiments in this study tested whether this durational compensation by mora is reflected in French phrases, as spoken by Japanese learners. The experimental materials exploited the differences introduced into pairs of phrases by these extra morae, when the phrases are parsed and produced by Japanese learners.

'Pre-final lengthening' is important in adaptations of French words. In Japanese, the following elements count as a mora: (C)(j)V; N (moraic nasal); first half of a geminate consonant; last half of a long vowel or of a diphthong. When a French word ends in a single consonant, in the adapted form the rime corresponding to this syllable is lengthened (a similar case is observed for word final obstruent-liquid clusters, while other word-final clusters do not trigger any lengthening). This prefinal syllable can be heavy in the following ways (lengthened rimes are underlined):

It ends in the first half of a geminate consonant:

/arusjubekku/ < *archevêque* |aRʃəvɛk| 'archbishop'.

It contains a long vowel: /madureenu/ < *madeleine* |madlɛn| 'a type of cake'.

The type of lengthening obtained depends on two factors:

a) Nature of the consonant;

b) Whether the vowel is 'lengthening' or not (see below).

Below we give examples of consonant gemination, vowel lengthening and variation patterns.

(a) Voiceless obstruent:

When a French word ends in a voiceless obstruent, this obstruent is consistently geminated in the adapted output.

lac	|lak|	'lake'	/rakku/
mèche	|mɛʃ|	'lock'	/messju/

(a') Voiceless obstruent preceded by a lengthening vowel:

There are special cases to add to the preceding one: when the vowel in the final closed syllable is spelled with more than one letter (*au*, *ou*, etc.) or with a circumflex accent (*ê*, *â*, etc.), the vowel can optionally lengthen instead of the consonant. We will call these vowels 'lengthening vowels'.

haute	|ot|	'high'	/ooto/	or	/otto/
fête	|fɛt|	'party'	/ɸeeto/	or	/ɸetto/

The variation in this particular case is explained as follows. The choice depends on whether the vowel is recognised by the speaker as a lengthening vowel or not. If it is, then, the vowel is lengthened; otherwise, the regular consonant gemination in (a) above applies. The lengthening vowels can be optionally adapted as a long vowel in any position. It is considered as a case of phonemic duration for some speakers apparently deviated by orthography.

(b) Voiced fricative:

When the final consonant is a voiced fricative, it is always the vowel that is lengthened.

rose	|Roz|	'rose'	/roozu/
terre	|tɛR|	'earth'	/teeru/

c) Voiced plosive or nasal stop, variation patterns:

robe	|Rɔb|	'dress'	/robbu/ or /roobu/
aide	|ɛd|	'help	/eddo/ or /eedo/
pomme	|pɔm|	'apple'	/pommu/ or /poomu/
reine	|Rɛn|	'queen'	/rennu/ or /reenu/

Along with Japanese syllabification of illegal French syllable types, the prefinal lengthening creates specific timing counts in Japanese speakers' French utterances.

Three types of moraic renditions of foreign sound sequences which would create an extra mora compared to the vowel count in the original words.

However, the third case, namely the syllabification process, does not require any moraic specification in the input level. In phonological analysis, syllable structure is assumed to be absent in the input because of its fully predictable nature. Constraints on the surface forms such as *CC and No Deletion are sufficient to derive the output with epenthesis. Consequently morae on the epenthetic vowels are acquired only on the output level.

To summarise, phonemic correspondence, 'prefinal lengthening' and syllabification of stray consonants all create extra morae in Japanese renditions of foreign words. However, only the first two types require mora specification in the input form. We shall compare our experimental results in relation to these three moraic renditions and assess the consequences of different phonological properties in the input form.

3. Methods of Experiments

An experiment was carried out to examine how the mora-based parsing of sound sequences by Japanese speakers is reflected in their production of French, and in which prosodic units the moraic parsing is most obvious. Six pairs of French phrases, listed in [1] ~ [4] below, were used in the experiment. Both phrases in each pair (a and b) in [1] and [2] and the three phrases (a, b and c) in [4] consisted of the same number of syllables, but each phrase could be potentially perceived by Japanese speakers as having different numbers of morae, according to parsing rules in Section 2 above. The pair phrases [3a] and [3b] consisted of the same number of syllables and the same number of morae in their potential Japanese interpretation. The typical phonological interpretation of each phrase by Japanese speakers is shown after the original phrase, and the number of morae is shown in brackets.

If Japanese speakers parse L2 sound sequences by the mora, there will be a difference in duration at the syllable level. Japanese speakers would parse the single underlined syllable in phrase (a) of each pair in [1] and [2] as one mora and the double underlined syllable in phrase (b) as two morae. This difference would also affect the whole duration of the French phrases, because the moraic interpretation of the rest of the phrases are identical and Japanese phrase duration is proportional to the number of morae in a phrase. In the examples below the commas indicate mora boundaries.

[1] 5 syllable phrases

1a. *le muscat perdu* 'the lost muscat'

/lə myska pɛʀdy/ (Jp) /ru, mju,su,ka, pe,ru,dju/ (7 morae)

1b. *le musc a perdu* 'the musc is lost.'

/lə mysk a pɛʀdy / (Jp) /ru, mju,su,ku, a, pe,ru,dju/ (8 morae)

2a. *le ferret français* 'the French metal tag'

/lə fɛʀɛ fʀɑ̃sɛ/ (Jp) /ru, fe,re, fu,ra,N,se/ (7 morae)

2b. *le fer est français* 'that iron is French.'

/lə fɛʀ ɛ fʀɑ̃sɛ/ (Jp) /ru, fe,e,ru, e, fu,ra,N,se/ (9 morae)

3a. *le couplet complet* 'the complete verse'

/lə kuplɛ kɔ̃plɛ/ (Jp) /ru, ku,(p,)pu,re, ko,N,pu,re/ (8~9 morae)

3b. *le couple est complet* 'the couple is complete.'

/lə kupl ɛ kɔ̃plɛ/ (Jp) /ru, ku,p,pu,ru, e, ko,N,pu,re/ (10 morae)

[2] 6 syllable phrases

4a. *les garçons dessinés* 'boys who were drawn'

/le gaʀsɔ̃ desine/ (Jp) /re, gja,ru,so,N, de,si,ne/ (8 morae)

4b. *les gares sont dessinées* 'the stations that are being drawn'

/le gaʀ sɔ̃ desine/ (Jp) /re, gja,a,ru, so,N, de,si,ne/ (9 morae)

5a. *l'otarie dans le puits* 'the sea lion in the well'

/lɔtaʀi dɑ̃ lə pɥi/* (Jp) /ro,ta,ri, da,N, ru, pju,i/ (8 morae)

5b. *l'eau tarit dans le puits* 'water in the well is drying up'

/lo taʀi dɑ̃ lə pɥi/* (Jp) /ro,o, ta,ri, da,N, ru, pju,i/ (9 morae)

6a. *le touret compliqué* 'the complicated travel plan'

/lə tuʀɛ kɔ̃plike/ (Jp) /ru, tu,(u,) re, ko,N,pu,ri,ke/ (8~9 morae)

6b. *le tour est compliqué* 'the trip is complicated.'

/lə tuʀ ɛ kɔ̃plike/ (Jp) /ru, tu,u,ru, e, ko,N,pu,ri,ke/ (10 morae)

[3] 7 syllable phrases

7a. *Ceux qui savent l'heure, souffleront.* 'Those who know when will tell quietly.'

/sø ki sav lœʀ suflərɔ̃/

(Jp) /su, ki, sa,a,bu, ru,u,ru, su, hu, ru, ro,N/ (13 morae)

7b. *Ceux qui savent, leur souffleront.* 'Those who know will tell quietly.'

/sø ki sav lœʀ sufləɔ̃/

(Jp) /su, ki, sa,a,bu, ru,u,ru, su,hu,ru,ro,N/ (13 morae)

[4] 8 syllable phrases

8a. *Cet homme est énormément bête.* 'This man is really stupid.'

/sɛt ɔm ɛ enɔʀmemɑ̃ bɛt/

(Jp) /se,t,to,mu, e, e,no,ru,me,mo,N, be,t,to/ (14 morae)

8b. *Cet homme est énorme et m'embête.* 'This man is large and bothersome.'

/sɛt ɔm ɛ enɔʀm e mɑ̃bet/

(Jp) /se,t,to,mu, e, e,no,ru,mu, e, mo,N,be,t,to/ (15 morae)

8c. *Cet homme et Ténor m'aiment en bête.* 'This man and Ténor love me crazily.'

/sɛt ɔm ɛ tenɔʀ mem ɑ̃ bet/

(Jp) /se,t,to,mu, e, te,no,o,ru, me,mu, o,N,be,t,to/ (16 morae)

* 5a and 5b can also be pronounced as 5 syllables. However, this does not alter the moraic interpretation, and therefore does not affect our conclusions.

Five native adult French speakers in Paris and six native Japanese speakers who speak fluent French took part in the experiment. Four of the native Japanese speakers were adult males from Tokyo, three of whom are university teachers of French. They have visited France regularly for short periods, and also lived in France for a total of 2-3 years. The other male speaker was a university student who had studied French for two years at the time of the recording. He had visited France a few times, for a short period each time,

and had passed the second grade certificate of the French proficiency test (*France-go Kentei Shiken*) after studying French for only one and a half years. His French was judged as very fluent by native French speakers. The other two Japanese speakers were adult females who had lived in Paris for more than ten years at the time of recording.

The test phrases were presented in the carrier sentence '*Je dis* ___*test phrase*___ *neuf fois.*' ('I say ___*test phrase*___ nine times'). The subjects were asked to pronounce the randomly presented test phrases three times. Five native adult French speakers (3 males and two females) in Paris also recorded the same phrases, and their data were analysed and used as a reference. The recorded data were digitised at a sampling rate of 48,000 Hz and analysed using Praat. The results were statistically analysed using SPSS statistical package.

4. RESULTS AND DISCUSSION

4.1. Phrase duration

Average durations of test phrases by the native French and Japanese speakers were calculated and analysed according to the number of syllables in the phrases. However, there were some problems in the experiment, especially phrases in (7) and (8). The Japanese subjects sometimes mixed up /l/s and /r/s in the phrases in (7)(a) *Ceux qui savent l'heure, souffleront*, and (b) *Ceux qui savent, leur souffleron.* They also had problems pronouncing the phrases in (8)(a) *Cet homme est énormément bête*, (b) *Cet homme est énorme et m'embête,* and (c) *Cet homme et Ténor m'aiment en bête.* They often mispronounced some of the words and repeated the same words two or three times. More importantly they often inserted a pause at the syntactic boundaries, i.e. at the comma, although they were instructed not to insert a pause in either phrase in (7). For the phrases in (8), they often inserted pauses randomly in all the phrases. This made measurements of phrasal durations invalid. Therefore phrases (7) and (8) were eliminated from the analyses.

The phrase durations of the utterances of the native French speakers were presented in Figures 1 and 2. Their phrase durations were proportional to the number of syllables in each phrase, and that the mora did not have any influence on phrase duration. **

T-test analyses (two-tailed) found no significant difference between any of the pair phrases in the native French speakers' utterances (Table 1). Since each pair consisted of the same number of syllables and differing number of morae, this result meant that the mora did not significantly affect duration for native French speakers. However, the durations of 5-syllable and 6-syllable phrases were significantly different [$t(89) = 8.60$, $p<.0001$] showing that the syllable plays a significant role in durational control by native French speakers.

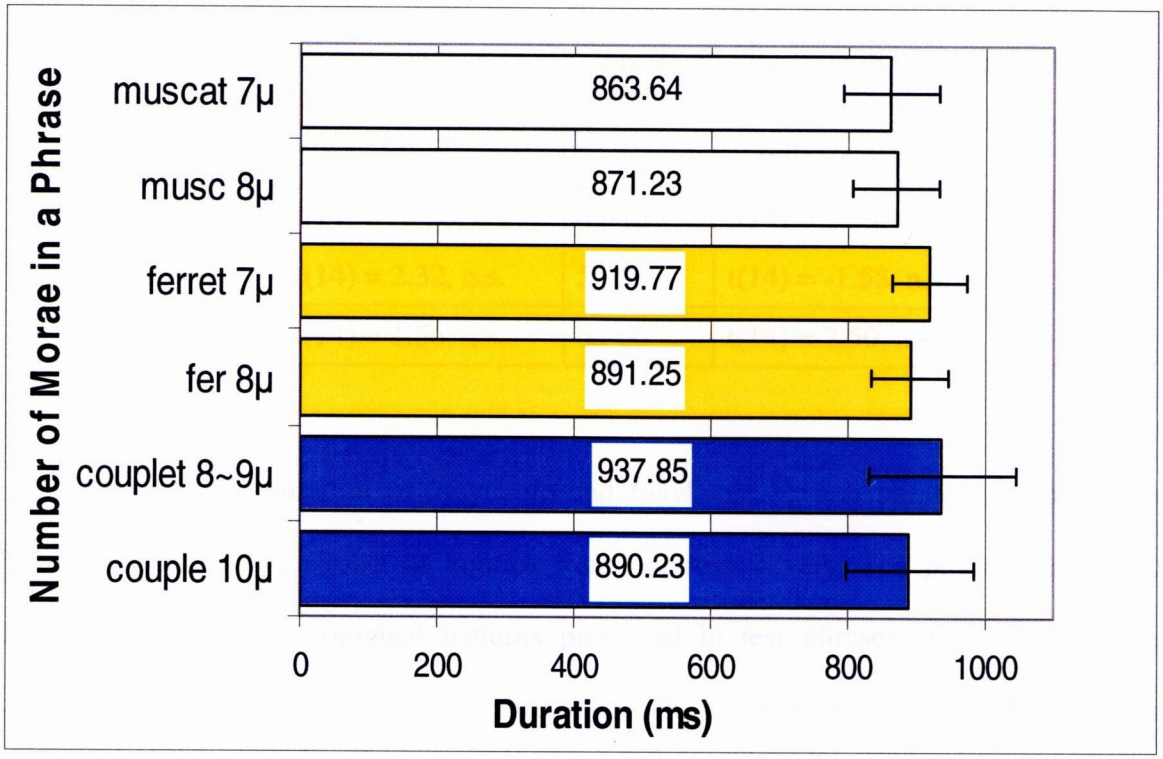

Figure 1: Average word duration of 5 syllable French phrases in (1) above pronounced by five native French speakers. | shows standard deviation at 95%.

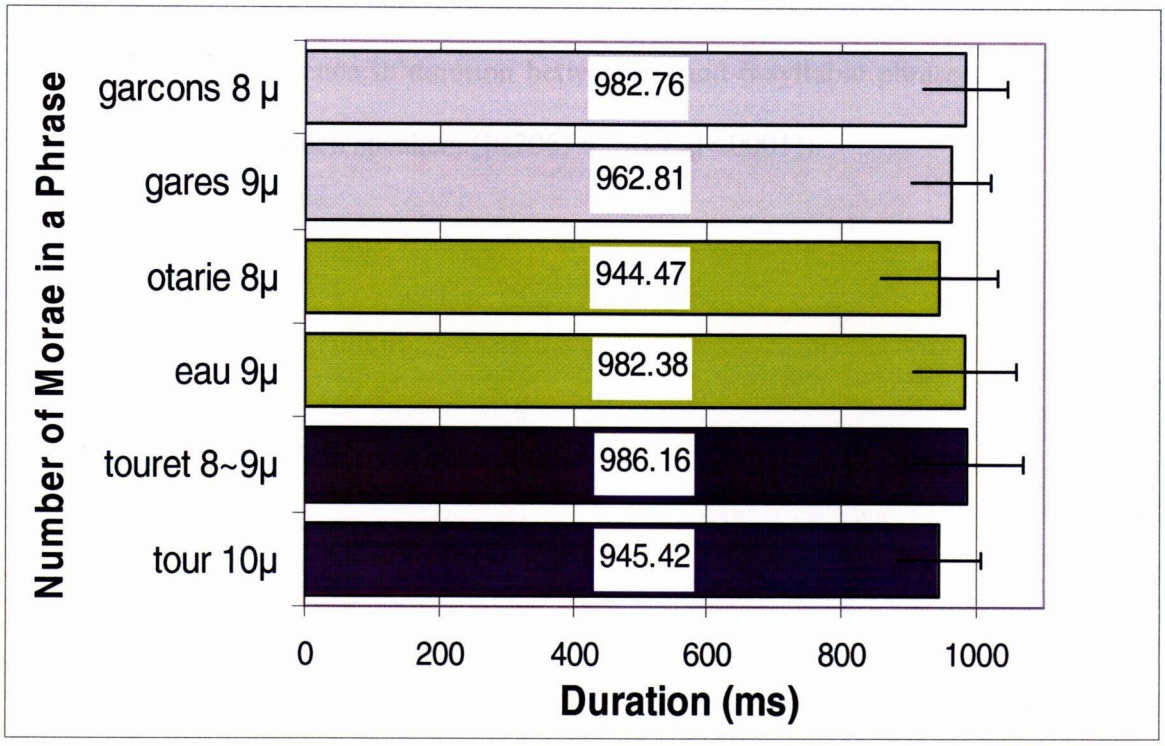

Figure 2: Average word duration of 6 syllable French phrases in (2) above pronounced by five native French speakers. | shows standard deviation at 95%.

Table 1: T-test (two-tailed) results comparing pairs of phrases with the same syllable count but differing mora count uttered by native French speakers.

	5-syllable phrases		6-syllable phrases
1a-1b	t(14) = -0.36, n.s.	4a-4b	t(14) = 1.19, n.s.
2a-2b	t(14) = 2.32, n.s.	5a-5b	t(14) = -1.58, n.s.
3a-3b	t(14) = 1.56, n.s.	6a-6b	t(14) = 2.50, n.s.

The average duration of 5-syllable and 6-syllable French phrases by the native Japanese speakers are shown in Figures 3 and 4, respectively. The pronunciation was different from the phonological patterns presented in test phrases above because the subjects did not necessarily parse the phrases into the expected moraic units. However, in contrast to the native French speakers, the phrase with the higher mora count was usually the longer utterance for the native Japanese speakers. The durational data of the native Japanese speakers were also analysed according to the number of syllables in phrase. There was a significant difference in duration between 5- and 6-syllable phrases, similar to the results of the native French speakers ([$t(206) = -5.19$, $p<.0001$]).

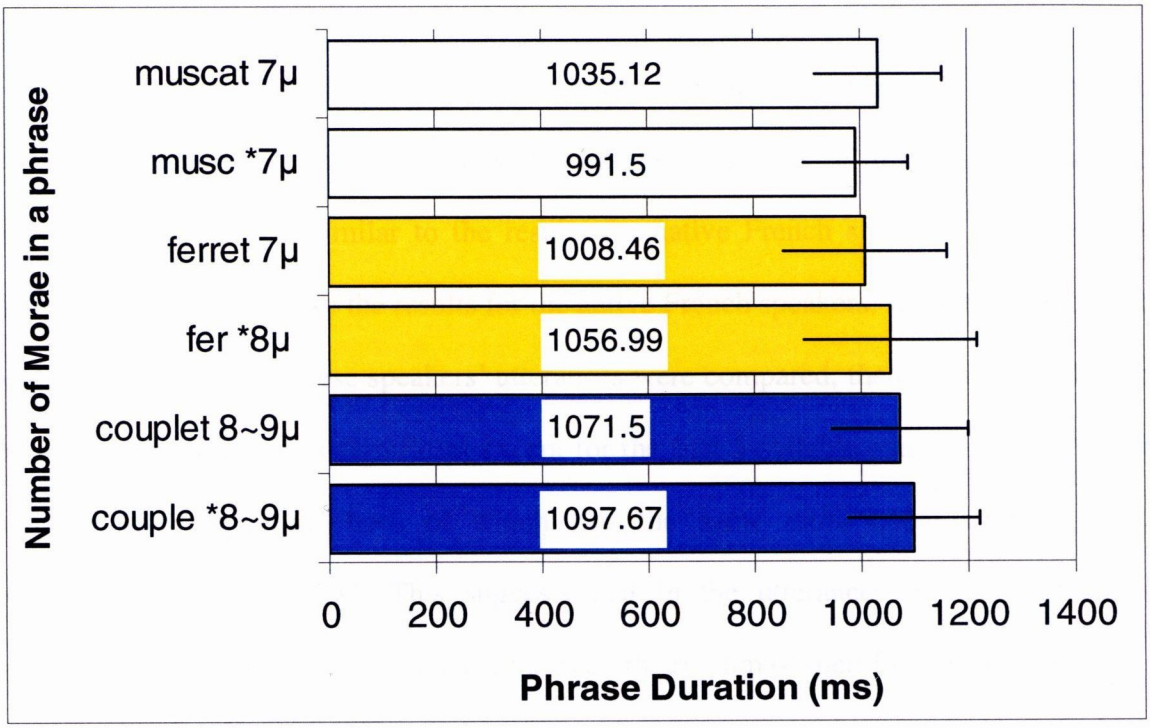

Figure 3: Average word duration of 5 syllable French phrases pronounced by six native Japanese speakers. The number of morae shown are the actual mora number in the utterances. | shows standard deviation at 95%.

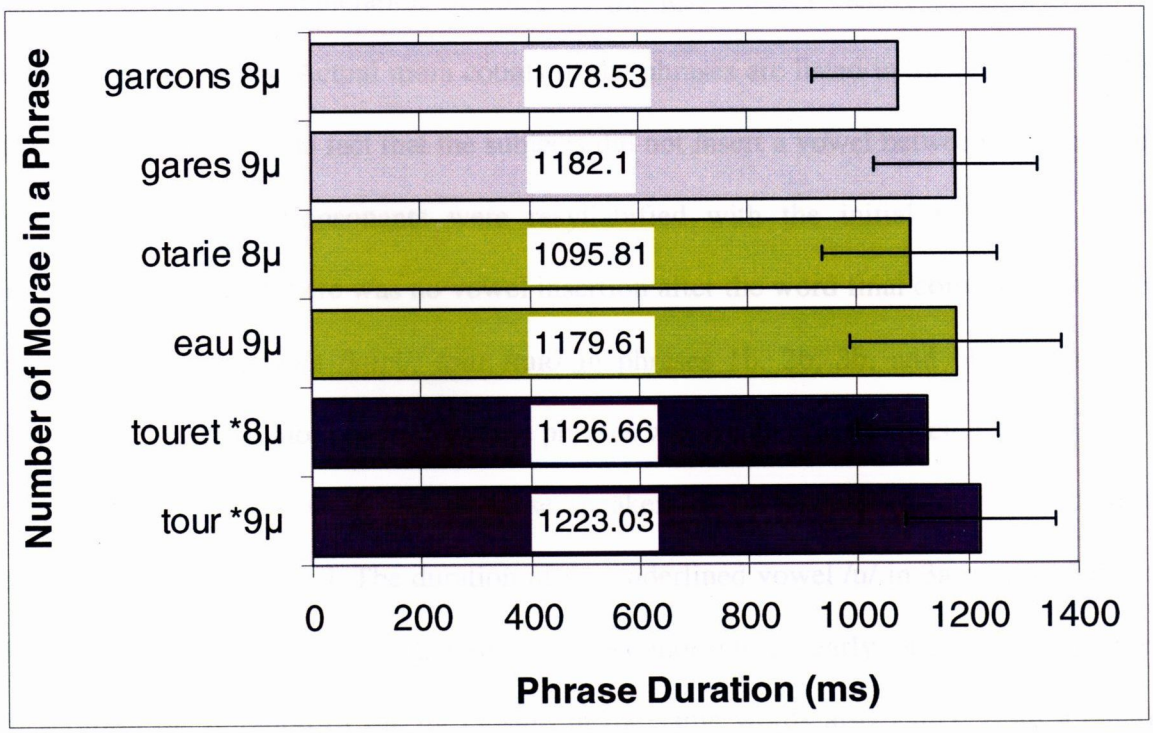

Figure 4: Average word duration of 6 syllable French phrases pronounced by six native Japanese speakers. The number of morae shown are actual mora number in the utterances. | shows standard deviation at 95%.

These durational data were also analysed by T-test according to the number of syllables in a phrase. The results showed a significant difference in duration between 5- and 6-syllable phrases, similar to the results for native French speakers [$t(53) = -8.70$, $p<.0001$]. However, unlike the results for the native French speakers, when the durations of each pair of native Japanese speakers' utterances were compared, the durational difference between pair phrases was significant except for the first 5-syllable pair: *'le muscat perdu'* and *'le musc a perdu'* both of which had the same mora count in their actual pronunciations (see below). This suggests that in the utterances by native Japanese speakers the mora count significantly influenced the rhythm of their French speech.

The phrase durations were re-analysed according to the number of morae in the phrases, based on the phonological prediction in [1] and [2] above. However, the native Japanese subjects' pronunciation of some of the test phrases clearly differed from the expected mora counts. Actual mora counts of the phrases are listed in Tables 2 and 3. The difference was due to the fact that the subjects did not insert a vowel between all consonant clusters. Word final consonants were resyllabified with the initial vowel /ɛ/ of the following words, and there was no vowel insertion after the word final consonants of *musc* /mysk/, *fer* /fɛʀ/, *couple* /kupl/, *tour* /tuʀ/ in phrases 1b, 2b, 3b, and 6b, respectively. Therefore, the actual mora count for these phrases was smaller than expected.

The pronunciation by the Japanese speakers of 3a *le couplet complet* and 3b *le couple est complet,* varied. The duration of the underlined vowel /u/ in 3a *couplet* /ku/ and 3b *couple* /ku/ varied from a clearly short [u] (one mora) to a clearly long [u:] (two morae). In addition the duration of the /p/ closure in the same words also varied from a clearly single [p] (one mora) to clear geminates [p:] (two morae). As a result, the actual mora numbers of these phrases varied from utterance to utterance, and it was difficult to

determine the mora number of the phrases 3a and 3b: potentially 8 or 9 morae for each phrase.

Table 2. Actual mora count of 5-syllable French phrases uttered by native Japanese speakers. The actual mora counts that differed from the predicted mora count (shown in brackets) are marked with *.

French phrases	Actual mora count
1a. *le muscat perdu*	7
1b. *le musc a perdu*	*7 (8)
2a. *le ferret français*	7
2b. *le fer est français*	*8 (9)
3a. *le couplet complet*	*8 (8~9)
3b. *le couple est complet*	*9 (10)

Table 3. Actual mora count of 6-syllable French phrases uttered by native Japanese speakers. The actual mora counts that differed from the predicted mora count (shown in brackets) are marked with *.

French phrases	Actual mora count
4a. *les garçons dessinés*	8
4b. *les gares sont dessinnées*	9
5a. *l'otarie dans le puits*	8
5b. *l'eau tarit dans le puits*	9
6a. *le touret compliqué*	8
6b. *le tour est compliqué*	*9 (10)

The pair phrases 1a and 1b did not differ in their actual mora counts and the T-test result did not find any significant difference in their durations [t(8) = -1.16, n.s.]. The other 5 pairs had different mora counts, and also significantly different phrase durations (Table 4).

Table 4. T-test (two-tailed) comparison of pairs of phrases with the same syllable count but different mora count uttered by Japanese speakers.

	5 syllable phrases		6 syllable phrases
1a-1b*	t(8) = -1.16, n.s.	4a-4b	t(8) = -2.78, p<.05
2a-2b	t(8) = -2.56, p<.05	5a-5b	t(8) = -3.20, p<.025
3a-3b	t(8) = -2.92, p<.025	6a-6b	t(8) = -2.00, p<.05

* 1a and 1b had the same mora count.

These durational data were also analysed by T-test according to the number of syllables in a phrase. The results showed a significant difference in duration between 5- and 6-syllable phrases, similar to the results for native French speakers [t(53) = -8.70, p<.0001]. However, unlike the results for the native French speakers, when the durations of each pair of native Japanese speakers' utterances were compared, the durational difference between pair phrases was significant except for the first 5-syllable pair: *'le muscat perdu'* and *'le musc a perdu'* both of which had the same mora count in their actual pronunciations (see below). The mora had a significant effect on the durations of the French phrases uttered by the native Japanese speakers; the durations of phrases were proportional to the number of phonologically predicted morae in each phrase. This suggests that in the utterances by native Japanese speakers the mora count significantly influenced the rhythm of their French speech.

Significant differences in durations between phrase pairs were only found for pairs 4a-4b (*les garçons dessinés* vs. *les gares sont dessinées*) and 6a-6b (*le touret compliqué* vs. *le tour est compliqué*): 4a-4b [t(34)=-2.02, p<0.05] and 6a-6b [t(34)=-2.17, p<0.05]. The durational differences of the other pairs were not significant. No significant difference had been expected for 1a-1b (*le muscat perdu* vs. *le musc a perdu*) and 3a-3b (*le couplet complet* vs. *le couple est complet*) because the mora count of the pairs did not differ.

However, the non-significant results for 2a-2b (*le ferret français* vs. *le fer est français*) and 5a-5b (*l'otarie dans le puits* vs. *l'eau tarit dans le puits*) were unexpected. Even so, the tendency of the effect of the mora count can be seen in the phrase durations in Figures 3, 4 and 5. The effect of the number of morae on phrase duration was examined eliminating the data of 3a *le couplet complet* and 3b *le couple est complet* because it was difficult to determine their mora numbers, as described above. The analysis found that there was a significant effect of the mora number in the French utterances of the native Japanese speakers. Phrase duration was significantly affected by the number of morae (7, 8 or 9 morae) in a phrase [$F(2, 176) = 21.24$, $p<0.0001$] (Figure 5). There was also a significant difference in phrase durations between 5 and 6 syllable phrases ([$t(166)=1.65$, $p<0.0001$]).

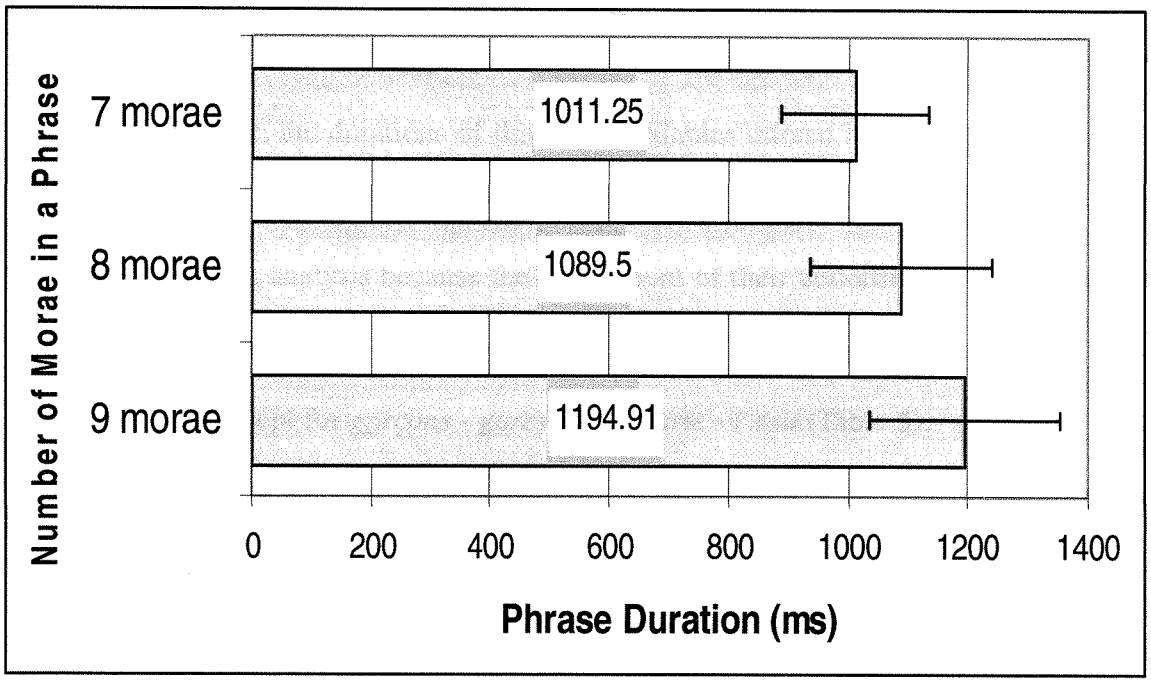

Figure 5: The average duration of French phrases pronounced by six native Japanese speakers. The mora number were based in actual utterances.
| shows standard deviation at 95%.

Figure 5 shows the average durations of the French phrases uttered by native Japanese speakers, arranged by the mora count in the phrase. The phrase durations of 7-, 8- and 9-mora phrases were significantly different ($p<.0001$). T-test analyses showed that there were significant differences between 7- and 8-syllable phrase durations ($p<.05$) and between 8- and 9-mora phrase durations ($p<.0005$). The results indicated that the durations of French phrases uttered by native Japanese speakers were influenced according to the phonologically expected mora count of the phrases. In other words, the mora plays a significant role in Japanese speakers' utterances.

4.2. CV syllable duration

The differences between the pairs of French phrases were related to the different CV syllables in each phrase. The Japanese speakers parsed one type of CV syllable into one mora and the other into two morae, and this probably caused the differences in phrase durations. Therefore, the durations of those CV syllables uttered by the native French and Japanese speakers were measured. The data of 3a *couplet* and 3b *couple* were once again eliminated from this analysis because the mora count of their underlined CV syllables was not consistent. There were no significant differences in CV syllable durations for the native French speakers except for *garçons* - *gares* and *l'otarie* - *l'eau* (Table 5).

However, there were significant difference in the CV syllable durations uttered by the native Japanese speakers (Table 6). There was no significant difference between *muscat* and *musc a* because there was no word-final /u/-insertion after *musc*, and therefore no added mora. The difference of the CV syllables of the other phrases were all found to be significant.

Table 5: The CV syllable duration (underlined) by native French speakers with the mora count and t-test results.

CV (underlined) (mora count)		Average Duration (ms)	t-test
*muscat**	(1)	139.94	t(25)= 0.82
*musc a**	(1)	135.74	n.s.
ferret	(1)	197.18	t(28)= -.087
fer	(2)	204.18	n.s.
garçons	(1)	145.24	t(28)= -2.20
gares	(2)	162.42	p<.05.
l'otarie	(1)	126.22	t(26)= -5.18
l'eau	(2)	163.37	p<.0001
touret	(1)	194.43	t(27)= 0.137
tour	(2)	192.95	n.s.

Table 6: The CV syllable duration (underlined) by native Japanese speakers with the mora count and t-test results.

CV (underlined) (mora count)		Average Duration (ms)	t-test
*muscat**	(1)	144.95	t(34)= -0.54
*musc a**	(1)	148.68	n.s.
ferret	(1)	202.45	t(31)= -3.98
fer	(2)	240.95	p<.0005
garçons	(1)	147.26	t(30)= -6.15
gares	(2)	210.71	p<.0001
l'otarie	(1)	157.54	t(28)= -2.41
l'eau	(2)	205.26	p<.005
touret	(1)	205.42	t(30)= -4.16
tour	(2)	249.68	p<.0005

* *muscat* and *musc a* had the same mora count.

These results, with data from the additional Japanese subjects, suggest that native Japanese speakers' phonological parsing of French sound sequences by the mora is reflected in CV syllable duration. In syllables where phonological analyses predicted two morae, their durations were longer. However, not all Japanese speakers consistently showed significant differences in paired phrase durations. The overall result showed that mora based phonological parsing is more obvious at the syllable level than at the phrase level. This result implies that for certain speakers phrase level timing control can be acquired separately from syllable level timing control, and at a later stage of phonological acquisition.

The native French speakers did not show significant durational differences in the CV syllables in question, since the mora does not have any significant role in French phonology. There were only significant CV syllable durational differences in two pairs, *garçons- gares* and *l'otarie* and *l'eau*. However, these durational differences disappeared at the phrase level and so the overall durations of the phrase pairs were not significantly different. Therefore these results support the theory that French speakers adjust phrase durations regardless of the differing duration of each syllable, as stated by Wenk and Wioland (1982).

5. CONCLUSIONS

The results suggest that Japanese speakers parse sound sequences by the mora, and also use the mora, rather than the syllable for durational control when they speak French. This tendency was typically clear in the experimental environments where the French vowels were analysed as potentially bimoraic. Since Japanese phrase duration is proportional to the number of morae, the durations of French phrases uttered by Japanese speakers depended on how phrases were analysed in terms of the mora. Only when there was difference in the mora count, did the phrase duration differ.

Interestingly, the (expected) additional mora in phrases only increased the phrase durations when it was introduced either by phonemic correspondence or by 'pre-final lengthening'. In cases where there was no vowel epenthesis in the production, the duration did not increase. It seems that vowel epenthesis could be eliminated by our subjects, who were proficient in French, but even so it is clear that rhythmic control in a second language is still different from that of native speakers. Our results suggest that this is due to moraic parsing of input by Japanese speakers. That is, once the mora is specified in the input, it is difficult to eliminate it from the process of production. Vowel epenthesis, on the other hand, is solely a phenomenon at the output level. We suggest that phrase durations only increase when vowel epenthesis occurs. Since epenthetic vowels are not present in input forms no morae will be specified, and thus stray consonants themselves will not necessarily influence the output phrase duration.

Previous studies have been unable to agree at which level in the prosodic hierarchy the timing compensation occurs for timing control in native French speech. In our study the phrase durations of native French speakers was proportional to the number of syllables in each phrase. Hence, phrase level compensation occurs according to the numbers of syllables present.

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Moraic specification and phrase duration: Evidence from Japanese speakers' French

Mariko Kondo

1. INTRODUCTION

The organisation of prosody, especially the timing of speech is important in terms of intelligibility of speech. It seems that listeners' tuning into timing organisation is a fine one. A study showed that native speakers' judgement on intelligibility of an utterance improved significantly, despite quite different acoustic features of the segments, by manipulating only its temporal features (Tajima et al., 1997).

However, temporal organisation of speech is difficult for L2 learners because it varies from language to language. In Japanese, the unit of speech rhythm is the mora; the durations of whole words are proportional to the number of morae, despite consisting of segments of different durations and also different numbers and structure of syllables (Port et al., 1987). This timing control is consistent even when vowels in a word are devoiced, despite the fact that morae with devoiced vowels are significantly shorter than the equivalent morae with fully voiced vowels (Kondo, 1995). A strong tendency to equalise the duration of morae was found in Japanese utterances. Durational compensation worked within CV sequences (a moraic unit) rather than V-C sequences (i.e. across a mora boundary) (Campbell and Sagisaka, 1991). In Japanese, durational adjustment in proportion to mora count appears to operate more significantly at the word level. In French, it used to be believed that each syllable takes approximately the same time, but there is tendency to equalize the phrase duration regardless of number of syllables that they contain (Wenk and Wioland, 1982).

It seems that Japanese adult listeners parse incoming speech strings into morae. Several psycholinguistic studies supported moraic segmentation in Japanese. The main hypothesis in the previous studies was that speech is prelexically segmented into rhythmic units specific to each language (Cutler and Norris, 1988; Mehler et al. 1981). Hence, French is segmented into syllables; English into trochaic stress feet. Following previous studies for French and English, Otake et al. (1993) and Cutler and Otake (1994) examined moraic segmentation by Japanese native listeners by using target detection tasks. They concluded

that Japanese listeners segment speech into morae whereas English listeners do not.

Moraic segmentation is not the only parsing found in Japanese. Rather, segmentation into the sub-unit of the syllable develops after syllabic segmentation. Meta-linguistic experimental results showed that Japanese speaking children's awareness for moraic segmentation developed after their awareness for syllabic segmentation, but before they had learned kana syllabary, which is a moraic writing system (Ito and Kagawa, 1991). Another study also reported Japanese new-born babies' insensitivity to moraic segmentation (Yamasaki, 1996).

It is, thus, interesting to test whether Japanese adult listeners employ moraic or syllabic segmentation when they attend to non-moraic languages like French or English. When durations of English vowels are altered by accent (cf. 'Interstress Interval'), Japanese listeners can only detect the change when it is large enough to shift from a long vowel (two morae) to a short vowel (one mora), or vice versa (Mochizuki-Sudo and Kiritani, 1991). This shows that there is an underlying phonemic adaptation process in English vowels where English vowel distinctions are encoded by moraic segmentation.

This study investigated the relationship between the mora and rhythm of speech, especially moraic specification and its influence on speech timing control. Speech timing was studied in Japanese and French utterances, which employ different phonological units for timing control. Japanese speakers' French utterances were analysed to determine the effect of the timing organisation of the first language (Japanese) on the production of the second language (French). Based on the phonological analysis of the loanword formation, the paper will discuss how Japanese speakers parse foreign sound sequences into a Japanese speech unit, i.e. the mora; and how in production, they use the mora rather than the syllable for durational control when they speak French.

2. PHONOLOGICAL PARSING OF LOANWORDS

Let us now explain the adaptation process underlying moraic count of foreign sound strings. Phonological study of Japanese adaptation of English words clearly indicates that some English vowel phonemes correspond to two morae and the others to one: *pita* |pɪtə| > /pita/ vs. *Peter* |pi:tə| > /piita/ (| | indicates foreign input forms; / / indicates Japanese adapted forms in phonemic representation) (Shinohara, 1997). There is another well-known moraic rendition in Japanese loanwords. Foreign words ending in a single

consonant are perceived (regardless of phonetic duration of the final C) and adapted with consonant gemination: *pit* |pɪt#| > /pit.to/ (Hirozane, 1992). The phonological interpretation that we adopt here for this phenomenon is that the prefinal lengthening is the result of alignment between the stem edge (#) and a syllable edge (.) (Tsuchida, m.s.) -- a cross-linguistically common process. A closer look at this phenomenon reveals that the same type of moraic lengthening is masked when a preceding vowel is already a long one: *Pete* |pi:t| > /pi:.to/. In both cases the prefinal syllables in adapted forms are heavy. We will call this 'prefinal lengthening' (see below).

Another factor adding extra morae (and for this matter, syllables) in Japanese rendition of foreign words is the syllabification of complex syllable structures. Since Japanese syllables allow only simple onsets and can be closed with the first half of a geminate or a nasal, the codas and clusters of foreign words are syllabified through vowel epenthesis: *extra* > /ekusutora/ (epenthesis underlined).

Phonemic correspondence and 'prefinal lengthening' create vowel or consonant gemination in Japanese adapted forms. Syllabification of stray consonants also creates morae. We suggest that when Japanese speakers process foreign words they do so using Japanese morae, and it should be possible to detect this process by analyzing foreign word utterances. We will test whether this durational compensation by mora is reflected in French phrases as spoken by Japanese learners. Our experimental materials exploit the differences introduced into pairs of phrases by these extra morae, when the phrases are parsed and produced by Japanese learners.

Let us explain more specifically the 'prefinal lengthening' in adaptations of French words. In Japanese, the following elements count as a mora: (C)(j)V; N (moraic nasal); first half of a geminate consonant; last half of a long vowel or of a diphthong. When a French word ends in a single consonant, in the adapted form the rime corresponding to this syllable is lengthened (a similar case is observed for word final obstruent-liquid clusters, while other word-final clusters do not trigger any lengthening). This prefinal syllable can be heavy in the following ways (lengthened rimes are underlined):

1. It ends in the first half of a geminate consonant: /arusjubekku/ < archevêque |aRʃəvɛk| 'archbishop'.
2. It contains a long vowel: /madureenu/ < madeleine |madlɛn| 'a type of cake'.

The type of lengthening obtained depends on two factors:

a) Nature of the consonant;

b) Whether the vowel is 'lengthening' or not (see below).

Below we give examples of consonant gemination, vowel lengthening and variation patterns.

(a) Voiceless obstruent:

When a French word ends in a voiceless obstruent, this obstruent is consistently geminated in the adapted output.

lac	|lak|	'lake'	/rakku/
mèche	|mɛʃ|	'lock'	/messju/

(a') Voiceless obstruent preceded by a lengthening vowel:

There are special cases to add to the preceding one: when the vowel in the final closed syllable is spelled with more than one letter (au, ou, etc.) or with a circumflex accent (ê, â, etc.), the vowel can optionally lengthen instead of the consonant. We will call these vowels 'lengthening vowels'.

haute	|ot|	'high'	/ooto/	or	/otto/
fête	|fɛt|	'party'	/ɸeeto/	or	/ɸetto/

The variation in this particular case is explained as follows. The choice depends on whether the vowel is recognised by the speaker as a lengthening vowel or not. If it is, then, the vowel is lengthened; otherwise, the regular consonant gemination in (a) above applies.

The lengthening vowels can be optionally adapted as a long vowel in any position. It is considered as a case of phonemic duration for some speakers apparently deviated by orthography.

(b) Voiced fricative:

When the final consonant is a voiced fricative, it is always the vowel that is lengthened.

rose	|Roz|	'rose'	/roozu/
terre	|tɛR|	'earth'	/teeru/

c) Voiced plosive or nasal stop, variation patterns:

robe	|Rɔb|	'dress'	/robbu/	or	/roobu/
aide	|ɛd|	'help	/eddo/	or	/eedo/
pomme	|pɔm|	'apple'	/pommu/	or	/poomu/
reine	|Rɛn|	'queen'	/rennu/	or	/reenu/

Along with Japanese syllabification of illegal French syllable types, the prefinal lengthening creates specific timing counts in Japanese speakers' French utterances.

3. EXPERIMENT

An experiment was carried out in order to examine how Japanese speakers parse French sound sequences into Japanese and the effect of this on their French utterances. If the mora plays a major role in the sound perception of Japanese speakers, they may also analyse French sound sequences according to the mora count and this will be apparent in the durations of their French utterances.

Six pairs of French phrases listed in (1) ~ (2) below were chosen for the experiment. The phrases in each pair consist of the same number of syllables. However, the phrases are potentially analysed into differing numbers of morae by Japanese speakers according to the rules explained in section 2 above. The typical phonological interpretation of each French phrase by Japanese speakers is presented below with the number of morae in brackets. If Japanese speakers parse L2 sound sequences by the mora, this difference in mora number will affect the French phrase duration, because Japanese phrase duration is proportional to the number of morae. Here the commas indicate mora boundaries.

(1) 5 syllable phrases

1a. *le muscat perdu*	'the lost muscat'	
/lə myska pɛʀdy/	(Jp) /ru, mju,su,ka, pe,ru,dju/	(7)
1b. *le musc a perdu*	'the musc is lost.'	
/lə mjusk a perdu/	(Jp) /ru, mju,su,ku, a, pe,ru,dju/	(8)
2a. *le ferret français*	'the French metal tag'	
/lə fɛʀe frʀɑ̃sɛ/	(Jp) /ru, fe,re, fu,ra,N,se/	(7)
2b. *le fer est français*	'that iron is French.'	
/lə fɛʀ ɛ frʀɑ̃sɛ/	(Jp) /ru, fe,e,ru, e, fu,ra,N,se/	(9)

3a. *le couplet complet* 'the complete verse'
/lə kuplɛ kɔ̃plɛ/ (Jp) /ru, ku,(p),pu,re, ko,N,pu,re/ (8~9)
3b. *le couple est complet* 'the couple is complete.'
/lə kupl ɛ kɔ̃plɛ/ (Jp) /ru, ku,p,pu,ru, e, ko,N,pu,re/ (10)

(2) 6 syllable phrases

4a. *les garçons dessinés* 'boys who were drawn'
/lɛ gaʀsɔ̃ desine/ (Jp) /re, gja,ru,so,N, de,si,ne/ (8)
4b. *les gares sont dessinées* 'the stations that are being drawn'
/lɛ gaʀ sɔ̃ desine/ (Jp) /re, gja,a,ru, so,N, de,si,ne/ (9)

5a. *l'otarie dans le puits* 'the sea lion in the well'
/lɔtaʀi dɑ̃ lə pɥi/ (Jp) /ro,ta,ri, da,N, ru, pju,i/ (8)
5b. *l'eau tarit dans le puits* 'water in the well is drying up'
/lo taʀi dɑ̃ lə pɥi/ (Jp) /ro,o, ta,ri, da,N, ru, pju,i/ (9)

6a. *le touret compliqué* 'the complicated travel plan'
/lə tuʀɛ kɔ̃plike/ (Jp) /ru, tu,(u), re, ko,N,pu,ri,ke/ (8~9)
6b. *le tour est compliqué* 'the trip is complicated.'
/lə tuʀ ɛ kɔ̃plike/ (Jp) /ru, tu,u,ru, e, ko,N,pu,ri,ke/ (10)

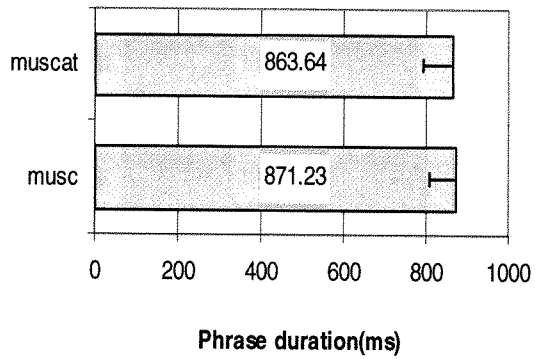
The experiment was carried out in Paris and Tokyo. Five native speakers of French living in Paris and seven native speakers of Japanese who speak fluent French took part in the experiment. The French speakers' recordings were made in an anechoic room of Laboratoire de Psychologie Expérimentale in Paris and Japanese speakers' recordings were done in an anechoic room of Waseda University in Tokyo. Only the data of 3 out of 7 Japanese speakers were analysed for this study, because the other four speakers often inserted pauses between a test phrase and the carrier sentence. Therefore, the data of these four Japanese subjects were excluded from the results of this study. The test phrases were presented in the carrier sentence '*Je dis* ___*test phrase*___ *neuf fois.*' ('I say ___test word___ nine times'). The durations of the test phrases were measured from the periodic waveform of the vowel /i/ of *dis* /di/ to the end of the last vowel of a test word, immediately prior to the beginning of the nasal /n/ of *neuf* /nœf/ of the carrier sentence. Subjects were asked to pronounce the phrases three times, each presented randomly. The recorded data were digitised at the sampling rate of 48,000 Hz and analysed using Waves+ on linux. The results were statistically analysed using SPSS statistical package.

4. RESULTS

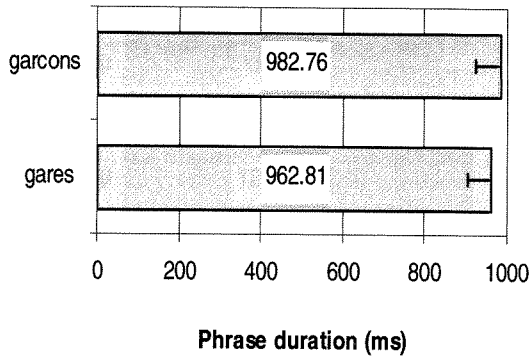
Average durations of test phrases by five native French speakers and three Japanese speakers were calculated and analysed according to the number of syllables in the phrases. Figures 1a ~ 1c show average durations of paired 5-syllable French phrases uttered by French speakers, and Figures 2a ~ 2c shows the results of paired 6-syllable phrases.

The data was statistically analysed to compare the whole durations of the phrases in each pair. T-test (2-tailed) analyses showed no significant difference between any of the pairs in the French speakers' utterances (Table 1). Since each pair consisted of the same number of syllables and differing number of morae, this result meant that the mora did not significantly affect duration for French speakers. Interestingly, in a pair of phrases the one with the higher mora count often had a shorter duration, although the difference was not statistically significant. The durations of 5-syllable and 6-syllable phrases were significantly different [$t(89) = 8.60$, $p<.0001$] showing that the syllable plays a significant role in durational control of French speakers.

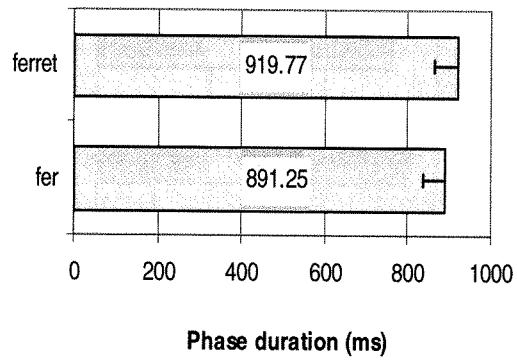
(1a)



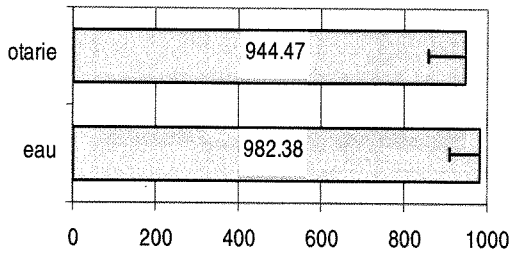
(2a)



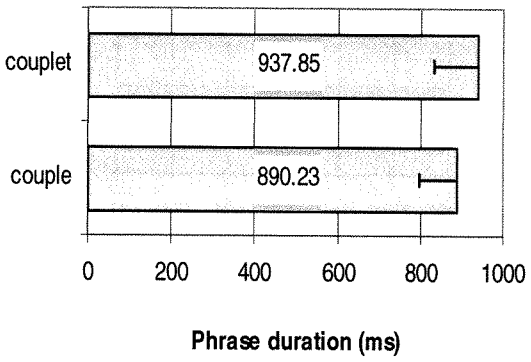
(1b)



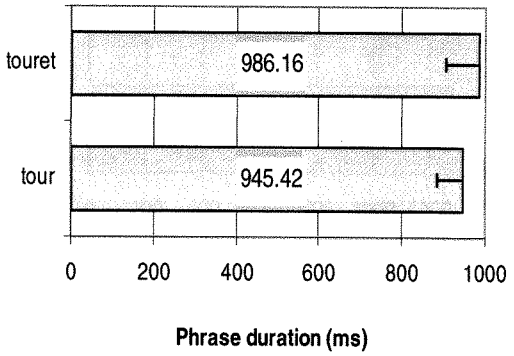
(2b)



(1c)



(2c)



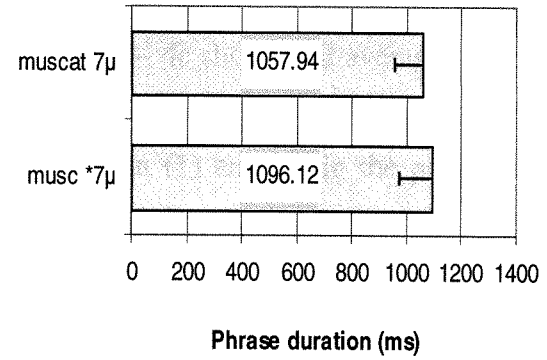
Figures 1a ~ 1c Average word duration of 5 syllable French phrases in (1) above pronounced by five French speakers. The number of morae shown are actual mora number in the utterances. | shows standard deviation at 95%.

Figure 2a ~ 2c Average word duration of 6 syllable French phrases in (2) above pronounced by five French speakers. The number of morae shown are actual mora number in the utterances. | shows standard deviation at 95%.

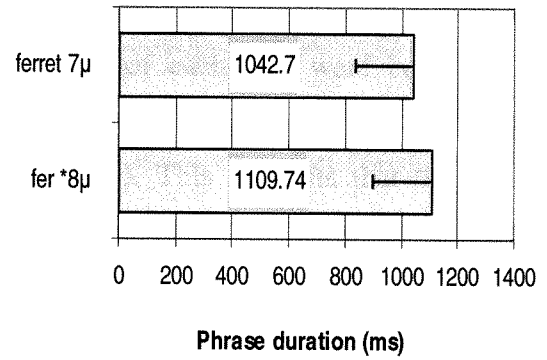
Table1. T-test (two-tailed) results comparing pairs of phrases of the same syllable count but differing mora count by French speakers

	5 syllable phrases		6 syllable phrases
1a-1b	t(14) = -0.36, n.s.	4a-4b	t(14) = 1.19, n.s.
2a-2b	t(14) = 2.32, n.s.	5a-5b	t(14) = -1.58, n.s.
3a-3b	t(14) = 1.56, n.s.	6a-6b	t(14) = 2.50, n.s.

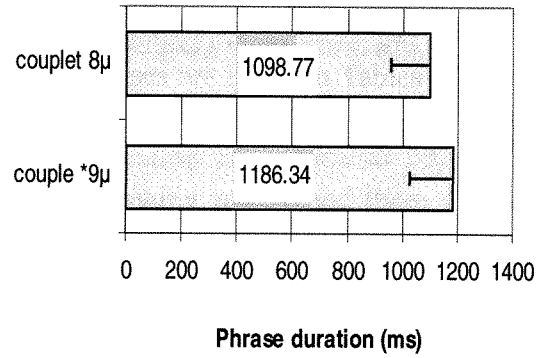
(3a)



(3b)

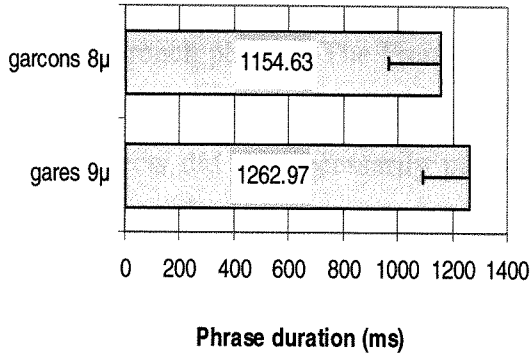


(3c)

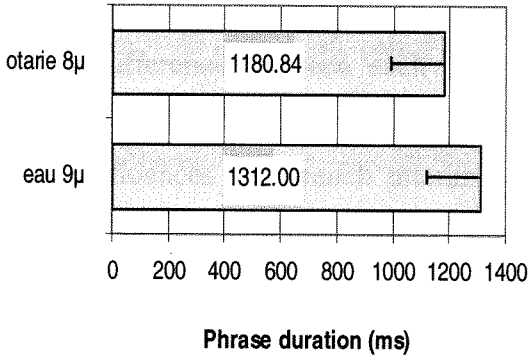


Figures 3a ~ 3c Average word duration of 5 syllable French phrases in (1) above pronounced by three Japanese speakers The number of morae shown are actual mora number in the utterances. | shows standard deviation at 95%.

(4a)



(4b)



(4c)

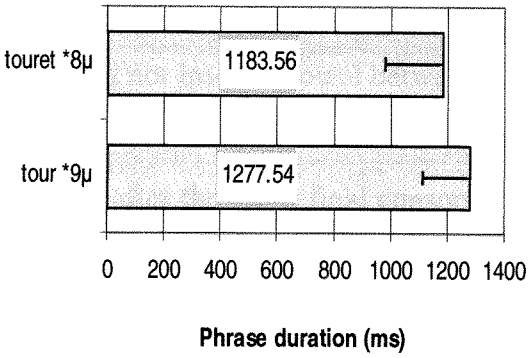


Figure 4a ~ 4c Average word duration of 6 syllable French phrases in (2) above pronounced by three Japanese speakers The number of morae shown are actual mora number in the utterances. | shows standard deviation at 95%.

Table2. T-test (two-tailed) results comparing pairs of phrases of the same syllable count but differing mora count by Japanese speakers

	5 syllable phrases		6 syllable phrases
1a-1b*	t(8) = -1.16, n.s.	4a-4b	t(8) = -2.78, p<.05
2a-2b	t(8) = -2.56, p<.05	5a-5b	t(8) = -3.20, p<.025
3a-3b	t(8) = -2.92, p<.025	6a-6b	t(8) = -2.00, p<.05

* 1a and 1b had the same mora count (see below).

Figures 3a ~ 3c show Japanese speakers' average duration of 5-syllable French phrases, and Figures 4a ~ 4c show their average durations of 6-syllable French phrases. The French phrase pronunciation was not exactly as would have been expected from the phonological patterns presented in (1) and (2) in the previous section. Our subjects did not necessarily parse the phrases into the expected moraic units. However, in contrast to the French speakers' results, the Japanese speakers the phrase with the higher mora count was usually the longer utterance. Japanese speakers' durational data were also analysed according to the number of syllables in phrase by T-test. The results found a significant difference in duration between 5- and 6-syllable phrases similar to the results of French speakers [$t(53) = -8.70$, $p<.0001$]. When the durations of each pair were compared, the durational difference between each pair was significant except for the first 5-syllable pair: *'le muscat perdu'* and *'le musc a perdu'* (see the discussion). This suggests that the mora significantly influences the French utterances of Japanese speakers, despite their native-like pronunciation.

The durations were reanalysed according to the number of morae in the words based on the phonological prediction in (1) and (2) above. However, our Japanese subjects' pronunciation of some of the test words clearly differed from the expected mora counts. Actual mora counts of the phrases are listed in Tables 3 and 4. Our subjects did not insert a vowel between every single consonant clusters. Word final consonants were resyllabified with the initial vowel /ɛ/ of the following words, and there was no vowel insertion after the word final consonants of *musc* /mjusk/, *fer* /fɛʀ/, *couple* /kupl/, *tour* / tuʀ/ in phrases 1b, 2b, 3b, and 6b respectively. Therefore there was no vowel insertion after the word-final consonant, and the actual mora count for these phrases was smaller than expected.

Table 3. Actual mora count of 5 syllable French phrases by Japanese speakers utterances . The actual mora counts differing from the predicted mora count are marked with *.

	French phrases	Phonological mora count	Actual mora count
1a	*le muscat perdu*	7	7
1b	*le musc a perdu*	8	*7
2a	*le ferret français*	7	7
2b	*le fer est français*	9	*8
3a	*le couplet complet*	8~9	*8
3b	*le couple est complet*	10	*9

* The actual mora counts differing from the phonological mora count.

Table 4. Actual mora count of 6 syllable French phrases by Japanese speakers utterances. The actual mora counts differing from the predicted mora count are marked with *.

	French phrases	Phonological mora count	Actual mora count
4a	*les garçons dessinés*	8	8
4b	*les gares sont dessinnées*	9	9
5a	*l'otarie dans le puits*	8	8
5b	*l'eau tarit dans le puits*	9	9
6a	*le touret compliqué*	8~9	8
6b	*le tour est compliqué*	10	*9

* The actual mora counts differing from the phonological mora count.

The pair phrases 1a and 1b did not differ in their actual mora counts and the T-test result did not find their durations significantly different [t(8) = -1.16, n.s.] (Table 2). The other 5 pairs did have different mora counts, and their phrase durations were also significantly different. In the 5-syllable phrase, *le couplet complet* (3b), gemination of /p/ in *couplet* was absent, and the final /l/ of *couplet* was resyllabified with the following vowel /ɛ/ of *est* as /ku,pu,re/ (in French /kuplɛ/). Therefore the moraic interpretation of the phrase was /ru, ku,pu,re, ko,N,pu,re/ (8 morae). On the other hand, gemination of the /p/ in *couple* /kupl/ as /ku,p,pu,ru/ increased the mora count of the phrase despite the resyllabification of the final /l/ and the following /ɛ/. Hence the 3b phrase is 9 morae. In the 6-syllable phrase *le touret compliqué,* the vowel /u/ in *touret* /tuʀɛ/ did not seem to be long enough to be counted as 2 morae. Therefore, the moraic interpretation of the phrase was considered as /ru, tu, re, ko,N,pu,ri,ke/ (8 morae). In the phrases 2b and 6b, however, the vowels in the respective words *fer* and *tour* came before the word-final /r/ and were interpreted as 2 morae. With regard to phrase 6a, all the Japanese speakers pronounced *touret* /tuʀɛ/ with two morae as /tu,re/ rather than with three morae as /tu,u,re/.

Figures 5 and 6 show the durations analysed by the mora count of phrases and the results were compared by one-factor ANOVA. The results showed that Japanese speakers' French durations were influenced by the phonologically expected word mora count [F(2, 105) = 10.31, p<. 0001]. The differences between 7-, 8- and 9-mora phrases were also significant: 7 vs 8 morae [t(70) = -1.92, p<.05] and 8 vs 9 morae [t(79) = -2.85, p<.0005]. Then the durations of 5- and 6-syllable phrases were compared after grouping the phrases into the phonologically expected mora counts. For groups with 8 or 9 morae, the durations of

6-syllable phrases were longer than the durations of 5- syllable phrases. However, the difference was not statistically significant. In other words, the syllable count did not affect phrase durations, but the mora played a significant role in Japanese speakers' utterances.

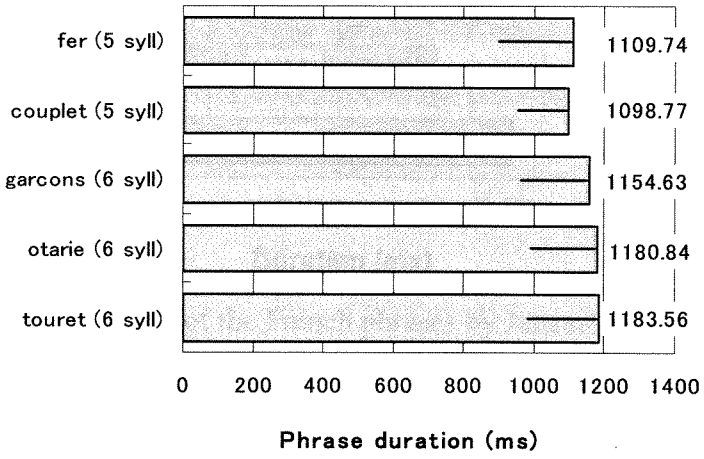


Figure 5. Durational comparison between 5 syllable 8 mora and 6 syllable 8 mora. The mora number is determined based on the actual pronunciation of the subjects. | shows standard deviation at 95%.

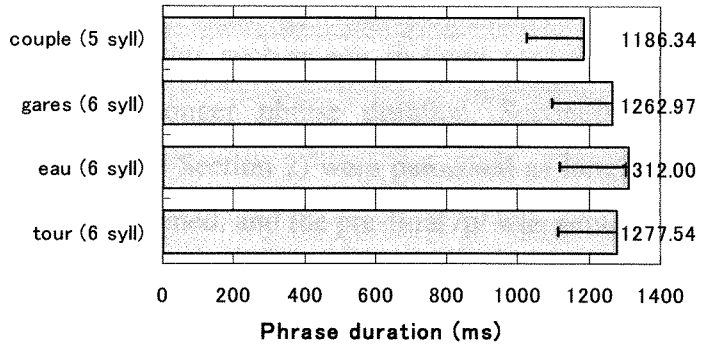


Figure 6. Durational comparison between 5 syllable 9 mora and 6 syllable 9 mora. The mora number is determined based on the actual pronunciation of the subjects. | shows standard deviation at 95%.

Figure 7 shows the results were arranged by the mora count in the phrases. The French phrase durations were clearly affected by the number of moras in phrases in Japanese speakers' utterances.

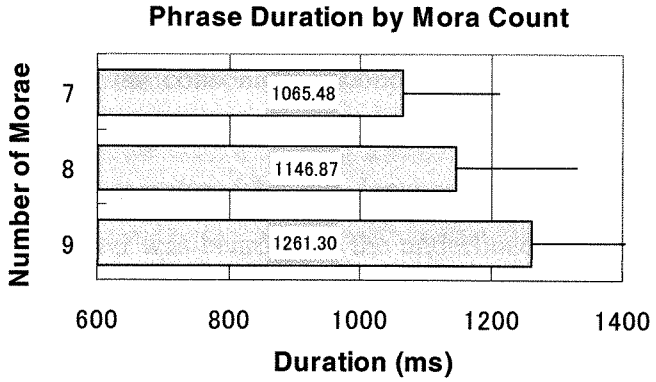


Figure 7 Durations of the French phrases by Japanese speakers according to the number of morae in a phrase. | shows standard deviation at 95%.

6. DISCUSSION

When the Japanese speakers' utterances were analysed, the French sound sequences were different from the patterns expected from phonological predictions, as explained earlier. There were three patterns of moraic parsing of French phrases: (i) vowel lengthening, (ii) pre-final lengthening, and (iii) no vowel epenthesis. The first two patterns (i) and (ii) were phonologically predicted patterns, but (iii) was different from that predicted. Firstly, vowels spelled with more than one letter, such as *eau* in *l'eau tarit dans le puits*, were counted as 2 moras and this caused a longer phrase duration. Secondly, sounds in the 'pre-final lengthening' environment (see Section 2) were perceived as long. For example, all vowels in *gare*, *fer* and *tour* were lengthened, and the pre-final /p/ was geminated in *couple*. The process increased the mora number of the relevant vowels and the /p/; hence producing a longer phrase duration.

The third pattern was not as predicted. Japanese speakers were expected to insert vowels in certain places in order to maintain the Japanese /(C)V/ syllable structure. However, our subjects did not insert vowels in all places where it was phonologically possible. In particular when a word ended with a consonant such as *musk* /mjusuk#/, the vowel /u/ was expected to be inserted after the /k/ to form a /CV/ structure /mju,su,ku/. The Japanese subjects also did not insert any vowel, when the next word started with a vowel, and the sequences were realised as /mju,su,ka/. Similarly, the final /ʀ/ of *fer* was syllabified with /ɛ/ of *est* to become

/fe,re/, the /l/ of *couple* syllabified with /ɛ/ of *est* to become /ku,pu,re/, and the /ʀ/ of *tour* syllabified with /ɛ/ of *est* to become /tu,re/. One possible reason for this was because the Japanese subjects were fluent French speakers and therefore may have been capable of using the syllable in French utterances to a certain extent.

In addition to word final consonants, phonologically predicted vowels were absent in some other positions. Actual pronunciations of *muscat*, *musc*, *perdu, couplet, couple*, *complet, garçons*, *touret*, and *compliqué* by our Japanese subjects were very similar to the French speakers' and no vowel was heard after the underlined consonants in the following words in (3).

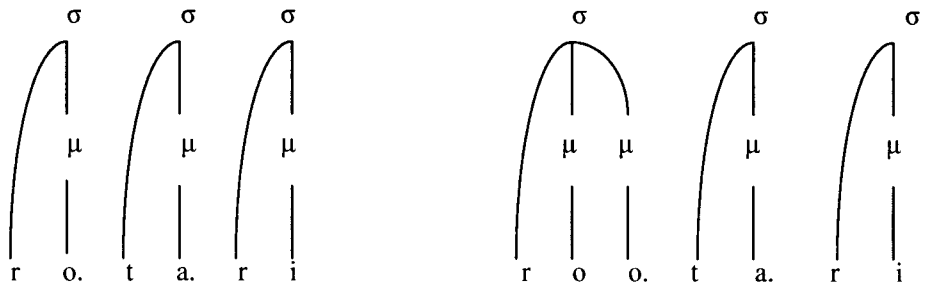
(3)

muscat	/myska/	*musc*	/myska/
perdu	/pɛʀdy/	*couplet*	/kuplɛ/
couple	/kupl/	*complet*	/kɔ̃plɛ/
garçons	/gaʀsɔ̃/	*compliqué*	/kɔ̃plike/

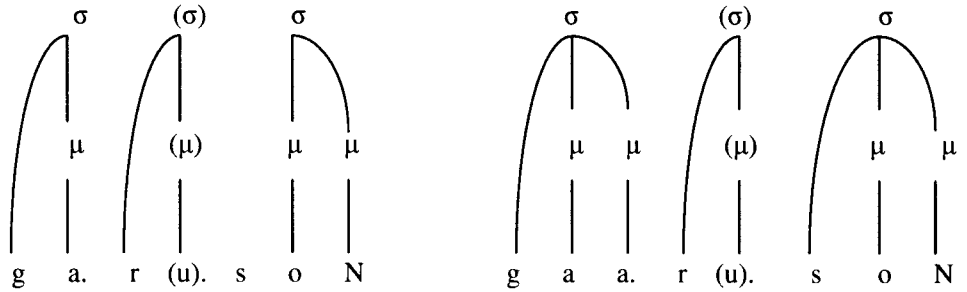
This means that the Japanese subjects might have used the syllable rather than the mora to control French speech timing, just as the French speakers did. In that case, the syllable count of each pair of phrases uttered by the Japanese speakers would be the same, and consequently the phrase durations of each pair should also have been the same, just as with the French speakers' durational results. However, the Japanese speakers' phrase durations were dependent on the mora count of the phrases. This implied that Japanese speakers were actually using the mora despite their French native-like pronunciation.

For Japanese speakers the variation in durations of French language phrases with the same syllable count can be explained in relation to the assignment of the mora as shown in (4) ~ (6).

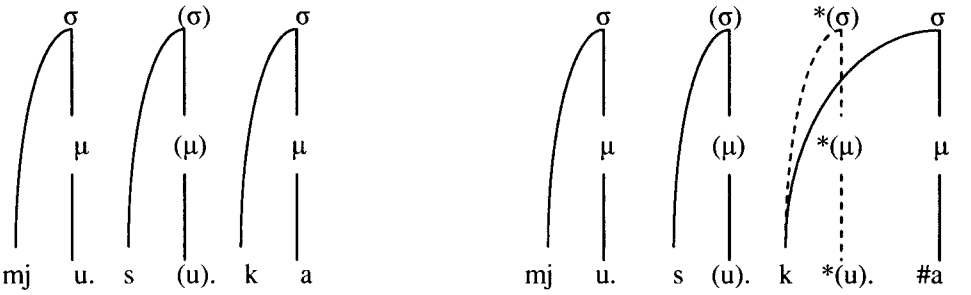
(4)



(5)



(6)



As explained earlier, Japanese language phrase duration is proportional to the number of morae. That means the duration of the adapted French phrases depends on whether the segments of the output phrases were assigned to the mora. In the cases of 'phonemic lengthening' [as in /ro̲otati/ (4)] and 'pre-final lengthening' of word-final consonants [as in /gaa̲rusoN/ (5)], the underlined lengthened vowel portions are moraic. Even when there is acoustically no vowel insertion after the underlined consonants in (3), vowels are phonologically present and each vowel is specified to a mora. Therefore, the preceding consonants can not be syllabified to the preceding syllable, and consequently retain the duration.

On the other hand, in the case of epenthetic vowels [e.g. the underlined /u/ in /mjusuku̲#a/ (6)], even if the vowel /u/ is inserted after the end of the first vowel, it does not have moraic specification. In contrast, the /u/ between /s/ and /k/ in /mjusu̲ku#a/ (6) is not normally realised as it is devoiced in the vowel devoicing environment, but has moraic specification and retains the duration.

The results suggest that:

1) Japanese speakers parse foreign sound sequences into a Japanese speech unit, i.e. the mora. This was similar to the results by Mochizuki-Sudo and Kiritani (1991), which demonstrated sensitivity to moraic length difference in English by Japanese adults.

2) Japanese speakers use the mora rather than the syllable for durational control of French.

3) Not all three moraic renditions used in phonological adaptation appeared in Japanese speakers' French. When the difference between the pair of phrases consisted of expected vowel epenthesis, the durational difference was not observed. The difference was interpreted as follows. Moraic specification introduced by phonemic vowel length and 'prefinal-lengthening' in the input are dominant in production. Vowel epenthesis does not affect the duration because stray consonants do not incur moraic specification in the input form.

4) The study also showed that French speakers' phrase duration was proportional to the number of syllables in a phrase, hence, phrase level compensation for the numbers of syllables present.

Since Japanese phrase duration is proportional to the number of morae, the French phrase duration of the adapted output form depends on how the phrases were analysed in terms of the mora. Only when there is a change in moraic status and consequently a change of the mora count, will the phrase duration differ.

7. CONCLUSIONS

The results suggest that Japanese speakers parse foreign sound sequences by the mora, and also use the mora, rather than the syllable for durational control when they speak French. This tendency was typically clear in the experimental environments where the French vowels were analysed as potentially bimoraic. Interestingly, the additional mora in phrases only increased the durations when it was introduced either by phonemic correspondence or 'pre-final lengthening', but not by syllabification of a stray consonant. It seems that vowel epenthesis could be eliminated by our subjects, who were proficient in French, but even so it is clear that rhythmic control in a second language timing unit is difficult to acquire.

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Phonological parsing of foreign sound sequences and the effect on speech rhythm

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1. INTRODUCTION

Temporal organisation of speech varies from language to language. This study compares timing compensation phenomena in Japanese and French. In Japanese, the unit of speech rhythm is the mora. A strong tendency to equalise the duration of morae was found in Japanese utterances: durational compensation worked within CV sequences (a moraic unit) rather than V-C sequences (i.e. across a mora boundary) (Campbell and Sagisaka 1991). Durational adjustment in proportion to mora count appears to operate more significantly at the word level. The durations of whole words are proportional to the number of morae, despite consisting of segments of different durations, and also different numbers and structures of syllables (Port et al. 1987). This timing control works even when a vowel in a word is devoiced. The short duration of a devoiced mora was compensated to a certain extent at the word level as long as it did not occur consecutively (Kondo 2003). This occurred despite the fact that morae with devoiced vowels are significantly shorter than the equivalent morae with fully voiced vowels. Moreover, the duration of a pause in an utterance is proportional to the duration of a mora in the utterance (Kaiki and Sagisaka 1992). Thus, phonological structure with underlying vowels was reflected in the durational control. However, in a language like French, it was previously believed that the duration of each syllable was similar, but Wenk and Wioland (1982) claimed that there is a tendency to equalize phrase durations regardless of number of syllables that they contain. This current study will present results that conflict with the theory of equalized phrase durations.

With regard to perception, several psycholinguistic studies have shown that Japanese adult listeners parse incoming speech strings into morae. The main hypothesis in these studies was that speech is prelexically segmented into rhythmic units specific to each language (Cutler and Norris 1988; Mehler et al. 1981). Hence, French is segmented into syllables; English into trochaic stress feet. Following previous studies for French and English, Otake et al. (1993) and Cutler and Otake (1994) examined moraic segmentation by Japanese native listeners by using target detection tasks. They concluded that Japanese listeners segment speech into morae whereas English listeners do not. However, moraic

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segmentation is not the only parsing found in Japanese. Rather, segmentation into the sub-unit of a syllable develops after syllabic segmentation. Meta-linguistic experimental results showed that Japanese speaking children's awareness for moraic segmentation developed after their awareness for syllabic segmentation, but before they had learned *kana* syllabary, which is a moraic writing system (Ito and Kagawa 1991). Another study reported new-born babies' insensitivity to moraic segmentation (Yamasaki 1996), which suggests that the syllable is the only default rhythmic unit for segmentation (Bertoncini et al. 1995). It is, thus, interesting to test whether Japanese adults employ moraic or syllabic segmentation when they hear non-moraic languages like French.

The aim of this study is to explore further how Japanese speakers parse foreign sound strings into rhythmic units and to clarify the relationship between phonological parsing and timing control in production. French utterances made by Japanese speakers were analysed to determine these effects. The paper will discuss if there are any differences in phrase duration among different types of moraic renditions predicted by phonological analysis of foreign word adaptation.

2. PHONOLOGICAL PARSING OF LOANWORDS

This section explains the adaptation process underlying moraic counts of foreign sound strings. Mochizuki-Sudo and Kiritani (1991) showed that when durations of English vowels are altered by accent (cf. 'Interstress Interval'), Japanese listeners can only detect the change when it is large enough to shift from a long vowel (two morae) to a short vowel (one mora), or vice versa. This clearly indicates that there is an underlying phonemic adaptation process in English vowels where English vowel distinctions are encoded by moraic segmentation.

We shall explain three types of moraic renditions of foreign sound sequences which would create an extra mora compared to the vowel count in the original words based on Shinohara (1997). The Japanese syllable structure is the following: $(C_1)(j)V_1(V_2)(C_2)$. $(C_1)(j)V_1$ typically consists of a mora, and exceptionally, both V_2 and C_2 can constitute a mora on their own, but only when V_2 is either the second half of a long vowel or of a diphthong, and C_2 is either N (moraic nasal) or the first half of a geminate consonant.

1) In Japanese adaptations of English words, some English vowel phonemes correspond to two morae and the others to one: *pita* |pɪt| > /pita/ vs. *Peter* |pi:t| > /piita/ (| | indicates

foreign input forms; / / indicates Japanese adapted forms in phonemic representation). In adaptations of French words, this mapping process is deviated by orthography. Certain vowels, either spelt with more than one letter or written with an accent-circumflex, are optionally rendered as long vowels by Japanese speakers: *au, eau* > /oo/, *ou* > /uu/, *ê* > /ee/ etc.

2) There is another well-known moraic rendition in Japanese loanwords. Foreign words ending in a single consonant are perceived (regardless of phonetic duration of the final C) and adapted with consonant gemination: *pit* |pɪt#| > /pit.to/ (Hirozane 1992). A closer look at this phenomenon reveals that the same type of moraic lengthening is masked when a preceding vowel is already a long one: *Pete* |pi:t| > /pi:.to/. In both cases the prefinal syllables in adapted forms are heavy. We will call this 'prefinal lengthening' (a similar case is observed for word final obstruent-liquid clusters, while other word-final clusters do not trigger any lengthening)

3) Another factor adding extra morae (and for this matter, syllables) in Japanese renditions of foreign words is the syllabification of complex syllable structures. Since Japanese syllables allow only simple onsets and can be closed with the first half of a geminate or a nasal, the codas and clusters of foreign words are syllabified through vowel epenthesis: *extra* > /ek*u*st*o*ra/ (epenthesis italicised).

There is a phonological difference in terms of moraic specification in the input among these three types. In the first case, phonemic length difference must be encoded in the input. Thus, long vowels require moraic specification, and this is straightforward.

In the second case, the mora is acquired as a result of alignment between the word boundary and the syllable boundary. The 'prefinal lengthening' itself is explained by an alignment between the right word boundary of the input form and the right syllable boundary of the output (Tsuchida 1996) - a cross-linguistically common process. This explains why the first syllable of words such as *picnic* does not lengthen in the Japanese adapted form.

(1) Pre-final lengthening

pit |pɪt#| > /pit.to/ . # alignment

picnic > /pikunikku/ */pikkunikku/

When phonotactic constraints make it impossible to geminate the final consonant of the input, e.g. in the case of the liquid /r/, then the mora on the final consonant re-associates to the preceding vowel to maintain the weight of the prefinal syllable.

(2) Compensatory lengthening

gare |gaʀ#| > */gar.ru/ by *[rr] > [gaaru]

This compensatory lengthening indicates that the final consonant acquires moraic specification and hands it over to the preceding vowel before it reaches the output level. This allows the vowel-lengthened form such as /gaaru/ to resemble a form with C-gemination, which more clearly indicates the alignment effect.

However, the third case, namely the syllabification process, does not require any moraic specification in the input level. In phonological analysis, syllable structure is assumed to be absent in the input because of its fully predictable nature. Constraints on the surface forms such as *CC and No Deletion are sufficient to derive the output with epenthesis. Consequently morae on the epenthetic vowels are acquired only on the output level.

To sum up, phonemic correspondence, 'prefinal lengthening' and syllabification of stray consonants all create extra morae in Japanese renditions of foreign words. However, only the first two types require mora specification in the input form. We shall compare our experimental results in relation to these three moraic renditions and assess the consequences of different phonological properties in the input form.

3. EXPERIMENT

An experiment was carried out to examine how Japanese speakers parse French sound sequences into Japanese and the effect of this on their French utterances. Six pairs of French phrases were used in the experiment and are listed in [1] and [2] below. The phrases in each pair consisted of the same number of syllables, but the phrases could be potentially perceived by Japanese speakers as having differing numbers of morae, according to the parsing rules explained in Section 2 above. The typical phonological interpretation of each French phrase by Japanese speakers is presented below with the number of morae in brackets. If Japanese speakers parse L2 sound sequences by the mora, this difference in

mora number will affect the French phrase duration, because Japanese phrase duration is proportional to the number of morae. In the examples below the commas indicate mora boundaries.

[1] 5 syllable phrases

1a.	*le muscat perdu*	'the lost muscat'	
	/lə myska pɛʀdy/	(Jp) /ru, mju,su,ka, pe,ru,dju/	(7)
1b.	*le musc a perdu*	'the musc is lost.'	
	/lə mysk a pɛʀdy /	(Jp) /ru, mju,su,ku, a, pe,ru,dju/	(8)
2a.	*le ferret français*	'the French metal tag'	
	/lə fɛʀɛ fʀɑ̃sɛ/	(Jp) /ru, fe,re, fu,ra,N,se/	(7)
2b.	*le fer est français*	'that iron is French.'	
	/lə fɛʀ ɛ fʀɑ̃sɛ/	(Jp) /ru, fe,e,ru, e, fu,ra,N,se/	(9)
3a.	*le couplet complet*	'the complete verse'	
	/lə kuplɛ kɔ̃plɛ/	(Jp) /ru, ku,(p,)pu,re, ko,N,pu,re/	(8~9)
3b.	*le couple est complet*	'the couple is complete.'	
	/lə kupl ɛ kɔ̃plɛ/	(Jp) /ru, ku,p,pu,ru, e, ko,N,pu,re/	(10)

[2] 6 syllable phrases

4a.	*les garçons dessinés*	'boys who were drawn'	
	/le gaʀsɔ̃ desine/	(Jp) /re, gja,ru,so,N, de,si,ne/	(8)
4b.	*les gares sont dessinées*	'the stations that are being drawn'	
	/le gaʀ sɔ̃ desine/	(Jp) /re, gja,a,ru, so,N, de,si,ne/	(9)
5a.	*l'otarie dans le puits*	'the sea lion in the well'	
	/lɔtaʀi dɑ̃ lə pɥi/*	(Jp) /ro,ta,ri, da,N, ru, pju,i/	(8)
5b.	*l'eau tarit dans le puits*	'water in the well is drying up'	
	/lo taʀi dɑ̃ lə pɥi/*	(Jp) /ro,o, ta,ri, da,N, ru, pju,i/	(9)
6a.	*le touret compliqué*	'the complicated travel plan'	
	/lə tuʀɛ kɔ̃plike/	(Jp) /ru, tu,(u,) re, ko,N,pu,ri,ke/	(8~9)
6b.	*le tour est compliqué*	'the trip is complicated.'	
	/lə tuʀ ɛ kɔ̃plike/	(Jp) /ru, tu,u,ru, e, ko,N,pu,ri,ke/	(10)

* 5a and 5b can also be pronounced as 5 syllables. However, this does not alter the moraic interpretation, and therefore does not affect our conclusions.

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Five native French speakers in Paris and three native Japanese speakers in Tokyo, who speak fluent French, took part in the experiment. The test phrases were presented in the carrier sentence '*Je dis* ___*test phrase*___ *neuf fois.*' ('I say ___test phrase___ nine times'). The subjects were asked to pronounce the randomly presented test phrases three times. The recorded data were digitised at a sampling rate of 48,000 Hz and analysed using Waves+ on linux. The results were statistically analysed using SPSS statistical package.

4. RESULTS AND DISCUSSION

Average durations of test phrases by the native French and Japanese speakers were calculated and analysed according to the number of syllables in the phrases. The durations of 5- and 6-syllable phrases by the native French speakers are listed in Tables 1 and 2. The durations of 5-syllable and 6-syllable phrases were significantly different [$t(89) = 8.60$, $p<.0001$] showing that the syllable plays a significant role in durational control by native French speakers. However, T-test (2-tailed) analyses found no significant differences between any of the phrase pairs in the French speakers' utterances (Table 3). Since each pair consisted of the same number of syllables and differing numbers of morae, this result meant that the mora count did not affect duration for native French speakers.

Table 1. Average duration of 5-syllable French phrases pronounced by 5 French speakers.

French phrases	Mora count	Phrase duration
1a. *le muscat perdu*	7	863.64 ms
1b. *le musc a perdu*	8	871.23 ms
2a. *le ferret français*	7	919.77 ms
2b. *le fer est français*	9	891.25 ms
3a. *le couplet complet*	8~9	937.85 ms
3b. *le couple est complet*	10	890.23 ms

Table 2. Average duration of 6-syllable French phrases pronounced by 5 French speakers.

French phrases	Mora count	Phrase duration
4a. *les garçons dessinés*	8	982.76 ms
4b. *les gares sont dessinnées*	9	962.81 ms
5a. *l'otarie dans le puits*	8	944.47 ms
5b. *l'eau tarit dans le puits*	9	982.38 ms
6a. *le touret compliqué*	8~9	986.16 ms
6b. *le tour est compliqué*	10	945.42 ms

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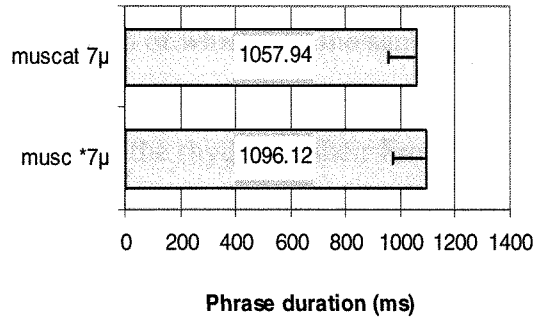
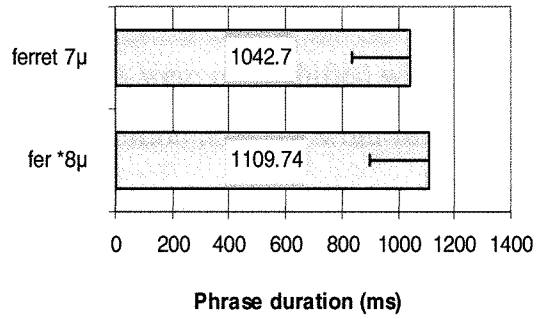
Table 3. T-test (two-tailed) results comparing pairs of phrases with the same syllable count but differing mora count uttered by native French speakers.

	5-syllable phrases		6-syllable phrases
1a-1b	t(14) = -0.36, n.s.	4a-4b	t(14) = 1.19, n.s.
2a-2b	t(14) = 2.32, n.s.	5a-5b	t(14) = -1.58, n.s.
3a-3b	t(14) = 1.56, n.s.	6a-6b	t(14) = 2.50, n.s.

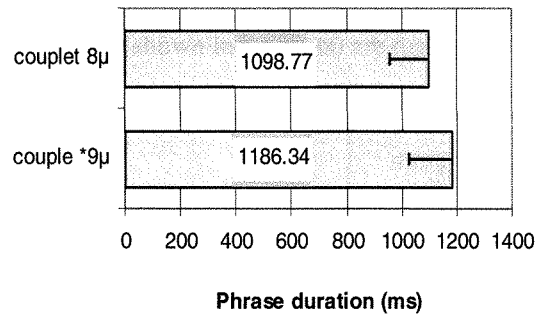
(1a)



(1b)

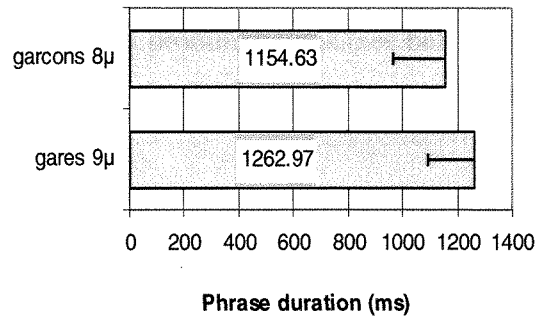


(1c)

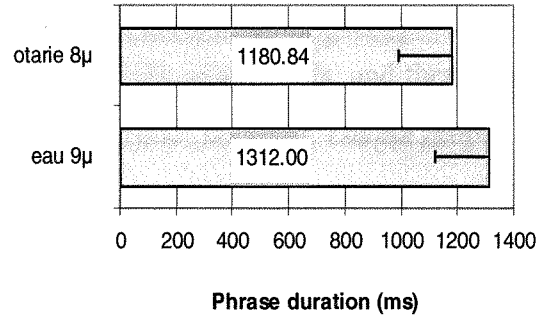


Figures 1a ~ 1c. Average word duration of the 5-syllable French phrases pronounced by three native Japanese speakers. The numbers of morae shown are the actual mora number in the utterances. | shows standard deviation at 95%.

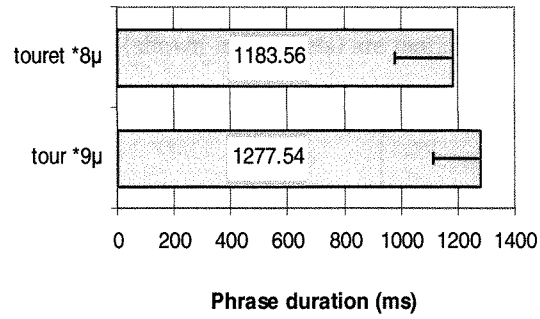
(2a)



(2b)



(2c)



Figures 2a ~ 2c. Average word duration of the 6-syllable French phrases pronounced by three native Japanese speakers. The number of morae shown are the actual mora number in the utterances. | shows standard deviation at 95%.

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Figures 1a ~ 1c show the average durations of 5-syllable French phrases uttered by native Japanese speakers, and Figures 2a ~ 2c show the equivalent average durations for 6-syllable phrases. These durational data were also analysed by T-test according to the number of syllables in a phrase. The results showed a significant difference in duration between 5- and 6-syllable phrases, similar to the results for native French speakers [$t(53) = -8.70$, $p<.0001$]. However, unlike the results for the native French speakers, when the durations of each pair of native Japanese speakers' utterances were compared, the durational difference between pair phrases was significant except for the first 5-syllable pair: *'le muscat perdu'* and *'le musc a perdu'* both of which had the same mora count in their actual pronunciations (see below). This suggests that in the utterances by native Japanese speakers the mora count significantly influenced the rhythm of their French speech.

The phrase durations were re-analysed according to the number of morae in the phrases, based on the phonological prediction in [1] and [2] above. However, the native Japanese subjects' pronunciation of some of the test phrases clearly differed from the expected mora counts. Actual mora counts of the phrases are listed in Tables 4 and 5. The difference was due to the fact that the subjects did not insert a vowel between all consonant clusters. Word final consonants were resyllabified with the initial vowel of the following words, and there was no vowel insertion after the word final consonants of *musc* /mysk/, *fer* /fɛʀ/, *couple* /kupl/, *tour* /tuʀ/ in phrases 1b, 2b, 3b, and 6b, respectively. Therefore, the actual mora count for these phrases was smaller than expected.

Table 4. Actual mora count of 5-syllable French phrases uttered by native Japanese speakers . The actual mora counts that differed from the predicted mora count (shown in brackets) are marked with *.

French phrases	Actual mora count
1a. *le muscat perdu*	7
1b. *le musc a perdu*	*7 (8)
2a. *le ferret français*	7
2b. *le fer est français*	*8 (9)
3a. *le couplet complet*	*8 (8~9)
3b. *le couple est complet*	*9 (10)

Table 5. Actual mora count of 6-syllable French phrases uttered by native Japanese speakers. The actual mora counts that differed from the predicted mora count (shown in brackets) are marked with *.

French phrases	Actual mora count
4a. *les garçons dessinés*	8
4b. *les gares sont dessinnées*	9
5a. *l'otarie dans le puits*	8
5b. *l'eau tarit dans le puits*	9
6a. *le touret compliqué*	8
6b. *le tour est compliqué*	*9 (10)

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The pair phrases 1a and 1b did not differ in their actual mora counts and the T-test result did not find any significant difference in their durations [t(8) = -1.16, n.s.]. The other 5 pairs had different mora counts, and also significantly different phrase durations (Table 6).

Table 6. T-test (two-tailed) comparison of pairs of phrases with the same syllable count but different mora count uttered by Japanese speakers.

	5 syllable phrases		6 syllable phrases
1a-1b*	t(8) = -1.16, n.s.	4a-4b	t(8) = -2.78, p<.05
2a-2b	t(8) = -2.56, p<.05	5a-5b	t(8) = -3.20, p<.025
3a-3b	t(8) = -2.92, p<.025	6a-6b	t(8) = -2.00, p<.05

* 1a and 1b had the same mora count.

Figure 3 shows the average durations of the French phrases uttered by native Japanese speakers, arranged by the mora count in the phrase. The phrase durations of 7-, 8- and 9-mora phrases were significantly different (p<. 0001). T-test analyses showed that there were significant differences between 7- and 8-syllable phrase durations (p<.05) and between 8- and 9-mora phrase durations (p<.0005). The results indicated that the durations of French phrases uttered by native Japanese speakers were influenced according to the phonologically expected mora count of the phrases. In other words, the mora plays a significant role in Japanese speakers' utterances.

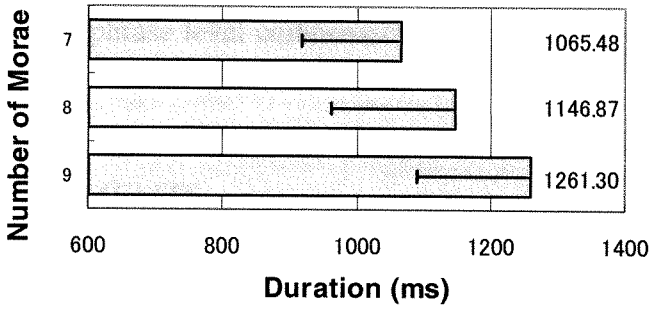

Figure 3. Durations of the French phrases uttered by native Japanese speakers according to the number of morae in each phrase. | shows standard deviation at 95%.

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5. CONCLUSIONS

The results suggest that Japanese speakers parse sound sequences by the mora, and also use the mora, rather than the syllable for durational control when they speak French. This tendency was typically clear in the experimental environments where the French vowels were analysed as potentially bimoraic. Since Japanese phrase duration is proportional to the number of morae, the durations of French phrases uttered by Japanese speakers depended on how phrases were analysed in terms of the mora. Only when there was difference in the mora count, did the phrase duration differ.

Interestingly, the (expected) additional mora in phrases only increased the phrase durations when it was introduced either by phonemic correspondence or by 'pre-final lengthening'. In cases where there was no vowel epenthesis in the production, the duration did not increase. It seems that vowel epenthesis could be eliminated by our subjects, who were proficient in French, but even so it is clear that rhythmic control in a second language is still different from that of native speakers. Our results suggest that this is due to moraic parsing of input by Japanese speakers. That is, once the mora is specified in the input, it is difficult to eliminate it from the process of production. Vowel epenthesis, on the other hand, is solely a phenomenon at the output level. We suggest that phrase durations only increase when vowel epenthesis occurs. Since epenthetic vowels are not present in input forms no morae will be specified, and thus stray consonants themselves will not necessarily influence the output phrase duration.

Previous studies have been unable to agree at which level in the prosodic hierarchy the timing compensation occurs for timing control in native French speech. In our study the phrase durations of native French speakers was proportional to the number of syllables in each phrase. Hence, phrase level compensation occurs according to the numbers of syllables present.

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Strategies for Acquiring Japanese Prosody by English Speakers

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1 Introduction

This study investigates acquisition processes of Japanese speech rhythm and its timing control by English speakers. Prosodic organisations of the two languages differ. Japanese is a pitch accent language and its speech rhythm is based on the mora. Word duration is proportional to the number of morae (Port et al. 1987) and durational adjustment between neighbouring segments seems to work within a mora rather than a unit across a mora boundary (Campbell and Sagisaka 1991; Han 1994, etc.). Lexical and phrase accents are manifested as a sharp fall of the fundamental frequency (F0) from the accented mora to the following mora, and the presence or absence of accent does not change duration or vowel quality. On the other hand, English is a stress accent language and the unit of speech rhythm is the foot. There is a tendency for each foot to be equal, and the mora does not play any significant role in English phonology. Stressed syllables are typically longer, with higher F0s, larger intensities, and the vowels keep their full quality. In contrast, unstressed vowels are shorter, weaker and are reduced to a schwa–like quality (Beckman 1986; Fujisaki et al., 1986).

Kondo (1999) showed that English speakers of fluent Japanese were able to control word duration according to the mora number similar to native Japanese speakers, but they had difficulty in placing the accent on the right syllable. Therefore it is important to assess how English speakers manipulate acoustic features of English stress and speech rhythm in order to achieve Japanese prosody, and also which Japanese prosodic features are easier for English speakers to acquire. This study investigates acoustic manifestations of Japanese lexical accent

by native English speakers. It examines how English speakers transfer acoustic features of English stress to realise Japanese lexical accent and how they manipulate these acoustic features to achieve Japanese speech rhythm.

2 The Experiment

Four English speakers, who speak fluent Japanese, pronounced seven sets of Japanese words, which consisted of the same sound sequences but differing lexical accent positions, as listed in (1) and (2) below. Each pair of test words showed contrast either by (1) the position of lexical accent, or (2) the presence or absence of lexical accent. The test words were marked as (a) 1st mora accented, (b) 2nd mora accented, or (c) no accent word[1].

The test words were presented in the carrier sentence 'korewa *test word* no desu' (This belongs to '*test word*'.), written in Japanese orthography, with the lexical accent position marked on the text, and were presented in a random order. Measurements taken were: (i) mora duration, (ii) average intensity of vowels, and (iii) the peak and lowest F0 of vowels. Four Japanese speakers made the same recordings as a control.

(1)					(2)				
(a) *'kami*	'god'	–	(b) *ka'mi*	'paper'	(a) *'kasi*	'lyrics'	–	(c) *kasi*	'fish market'
(a) *'kame*	'turtle'	–	(c) *kame*	'jug'	(a) *'kasa*	'umbrella'	–	(b) *ka'sa*	'volume'
(a) *'kama*	'sickle'	–	(c) *kama*	'kiln'	(a) *'kasu*	'scum'	–	(c) *kasu*	'to rent'
(a) *'kamu*	'to bite'	–	(c) *kamu*	'to blow nose'					

[1] No accent word means that there is no sharp fall of pitch in a word, in contrast to the type (b) words where pitch drops after the vowel in the second mora when another words immediately follows the word. In Standard Japanese, it is the syllable that carries the lexical accent not the mora. However, the syllable and the mora match in all test words used in this experiment. Therefore, in this paper, I use the term 'mora' to indicate the accent carrying unit in order to simplify the discussion.

There were very few type (c) utterances in the data because the English speakers failed to produce the non-accented type (c) words correctly, even though the reading text indicated that the words were non-accented. In most cases they placed the lexical accent on the second mora and pronounced type (c) words as if they were type (b) words. Therefore, in the analysis, when type (c) words were pronounced as type (b) words, with the second mora accented, they were treated as type (b) words, and the data from the few correctly pronounced type (c) words were eliminated from the analysis. The samples were digitised at a sampling rate of 48 KHz, and analyzed using Praat. The statistical analysis was performed by the SPSS statistical package.

3 The Results

The data from each language were analysed separately. The data from English speakers (A~D) were analysed individually because the ability to control Japanese prosody may differ between speakers. The data from Japanese speakers was averaged and used as a control. The intensity results will not be discussed in this paper because there was no significant difference in the average intensity of accented and non-accented vowels.

3.1 Mora Duration

The durations of the first mora /ka/ and the second mora /C2V2/ (where /C2/ is either /m/ or /s/ followed by a vowel) were compared, with or without the lexical accent.

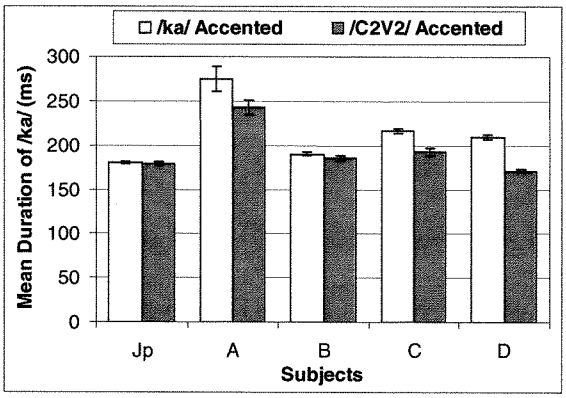

Figure 1. Effect of accent position on mean durations of the first mora /ka/. Jp; mean of all words for all Japanese. A~D; mean of all words for each English speaker (A~D). Error bars = 1 SEM.

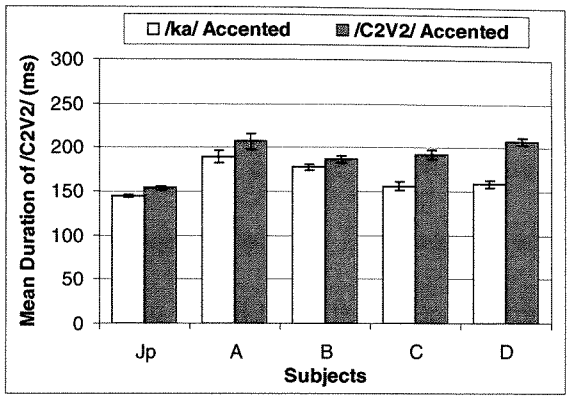

Figure 2. Effect of accent position on mean durations of the second mora /C2V2/. JP; mean of all words for all Japanese. A~D; mean of all words for each English speaker (A~D). Error bars = 1 SEM.

In Japanese speakers' utterances, the presence or absence of accent on the mora did not significantly alter the average duration of the first mora /ka/ (Fig. 1). The duration of /C2V2/ increased when it was accented in Japanese speakers' utterances ($p<0.0001$), though the increase was much smaller than with the English speakers (Fig. 2). English speakers A and B controlled the mora durations well and there was no effect of lexical accent on mora durations in their utterances for /ka/ and /C2V2/. However, in the utterances of speakers C and D, there was a significant effect of lexical accent on the durations of both /ka/ and /C2V2/ ($p<0.0001$) (Figs. 1 & 2).

3.2 The fundamental frequency

Figure 3 shows mean F0 ratios of the first and the second vowels of all words for all Japanese speakers and the mean of all words for each English speaker (A~D). The peak F0 of accented vowels and the lowest F0 of unaccented vowels were measured, and the ratio of V1/V2 was obtained in order to minimise differences between the English speakers. With the Japanese speakers, when the first mora was accented, the peak F0 of the first vowel was on average

126.1% higher than the lowest F0 of the unaccented second vowel. When the second vowel was accented, the lowest F0 of the unaccented first vowel was on average 72.0% of the highest F0 of the second vowel. It should be noted that F0 change for High-Low pitch patterns and Low-High pitch patterns is not a mirror image. When the first mora is accented (e.g. pattern (a) in (1) and (2): High-Low), there is a sharp fall of pitch from the accented first mora to the unaccented second mora. However, when the second mora is accented (e.g. pattern (b) in (1) and (2): Low-High), the peak F0 of the accented second mora is not as high as that of the accented first mora. Therefore, when the first mora /ka/ is accented, a higher V1/V2 ratio means a greater F0 increase for the accented V1 (/ka/), and a lower ratio means less F0 increase for V1. In contrast when the second mora /C2V2/ is accented, a higher ratio means there is little F0 increase for the accented /C2V2/, and a lower ratio means more F0 increase for /C2V2/.

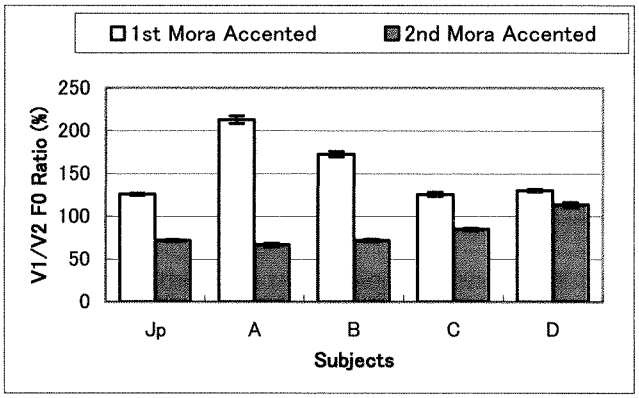

Figure 3. Mean F0 Ratios of V1/V2 by all Japanese (Jp) and individual English speakers (A~D). Error bars = 1 SEM.

English speakers A and B showed a much greater increase of F0 for accented vowels compared with the F0 ratios of the Japanese speakers, both when the first mora /ka/ was accented and when the second mora /C2V2/ was accented (Fig. 3). The F0 ratios for speakers C and D were similar to those of the Japanese speakers. When the second mora was accented,

the F0 increase for the accented second mora in the utterances of speakers C and D was much less than the average for the Japanese speakers. In particular speaker D's results indicated a higher F0 for the unaccented first mora /ka/ than for the accented second mora /C2V2/.

The F0 results showed that speakers A and B, who controlled speech rhythm better, showed more F0 increase for accented vowels, whereas speakers C and D, who increased accented mora durations, showed less F0 increase for accented vowels. In particular, speakers A and B greatly raised the F0 of the first mora when it was accented, whereas the F0 contours of speakers C and D were much flatter. The fundamental frequencies of the first and second morae were quite similar in the words where the second mora was supposedly accented and was judged as accented. The F0 measurements also indicated that speakers C and D did not use the F0 to indicate the lexical accent in Japanese. In fact, the pitch contours of the whole utterances of speakers C and D were much flatter compared with typical utterances by Japanese speakers, especially for type (b) words. However, in the utterances of speakers C and D the second mora was judged by Japanese speakers to have a higher pitch than the first mora. Possible reasons for the second mora sounding higher are: (i) the F0 did not fall sharply after the first mora, implying that the first mora was not accented, and (ii) the duration of the second mora tended to be longer than the first mora.

4. **Conclusions**

Two English speakers, who showed good mora timing control in Japanese, greatly increased the F0 for accented morae, but did not increase mora durations. This result implies that these two speakers were able to manipulate acoustic features of stress in English, i.e. vowel duration and F0 increase independently, and could control these features separately in Japanese. However, the other two speakers, who showed less mora timing control, did not increase F0 for accented morae. Instead, they either manipulated the lexical accent by

increasing mora duration or suppressed their pitch range. This was possibly because for most English speakers it is not possible to separate the acoustic features of F0 and vowel duration with manifestation of lexical stress. Therefore, the speakers who were less able to control mora duration were probably still trying to achieve mora rhythm, and as a result reduced the pitch range in order not to lengthen the duration of accented morae. Probably they knew subconsciously that increasing the F0 also meant increasing the duration.

Acknowledgement

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