Temporal Variation Due to Tense *vs.* Lax Consonants in Korean*

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ABSTRACT

Many languages show reverse durational variation between preceding vowel and following voiced/voiceless (lax/tense) consonants. This study investigated the likely effects of phoneme type (tense *vs.* lax) on the timing structure (duration of syllable, word, phrase and sentence) of Korean. Three rates of speech (fast, normal, slow) applied to stimuli with the target word /a-Ca/ where /C/ is one of /p, p', p^h/. The type (tense/lax) of /C/ caused marked inverse durational variations in the two syllables /a/ and /Ca/ and highly different durational ratios between them. Words with /p', p^h/ were significantly longer than that with /p/, which contrasts with many other languages where such pairs of words have a similar duration. The differentials between words remained up to the phrase and sentence level, but in general the higher linguistic units did not statistically differ within each level. Thus, the phrase is suggested as a compensatory unit of phoneme type effects in Korean. Different rates did not affect the general tendency. Distribution of time variations (from normal to fast and slow) to each syllable (/a/ and /Ca/) was also observed.

Keywords: Tense *vs.* Lax, Timing Structure, Speech Rate, Compensation, Phrase

1. Introduction

A great number of studies have reported that voiceless (tense) consonants are longer than their voiced (lax) cognates whereas the duration of a vowel preceding voiceless (tense) consonants is shorter than that of a vowel followed by voiced (lax) consonants. In consequence, the sum of the preceding vowel and the following consonant tend to maintain a relatively constant duration at a higher level of phonological unit (i.e. syllable or word) due to the compensatory durational movements at the neighbouring segments.

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Although the reverse durational changes between the preceding vowel and the following consonant seem to be almost language universal, the extent of variation is known as different from language to language (Chen, 1970; Mack, 1982). In particular, many authors insist that English is greatest in the durational changes among many languages investigated (e.g., Chen, 1970). However, such claim should be restricted to when the phoneme type effects (the reverse durational variation between the preceding vowel and the following consonant) occur within a syllable. This is supported by the fact that most of the English data in the literature concerning the phenomenon were obtained within a syllable (e.g. hu*peep*-hu*beeb*, House & Fairbank, 1953; *neat-need* and *seat-seed*, Zimmerman & Sapon, 1958; *heat-heed* and *back-bag-bang*, Peterson & Lehiste, 1960; *cat-cad* and *cease-seize*, Catford, 1977; *deeb-deep*, Port, 1981). On the other hand, Korean does not have such monosyllabic word pairs as the above English items. It is because the three-way distinction of consonants (phonologically unaspirated lax *vs.* unaspirated tense *vs.* aspirated tense) disappear in coda position – neutralisation (Martin, 1951; Kim, 1979; Kim & Jongman, 1996). Interestingly, the preconsonantal vowel shortening is considerably greater in Korean than in English as far as we observe them across a syllable boundary (Kim, 1987). Furthermore, when it comes to the following consonant duration, Korean shows much greater differences between tense and lax counterparts than English (Chen, 1970; Kim, 1987). Altogether, the phoneme type effects (the reverse durational variation between the preceding vowel and the following consonant) are greater in Korean than in English, if the consonant is intervocalic. With regard to speech timing, it is very important whether the reverse durational variation occurs within a syllable or across a syllable boundary. When the shortening and compensation occur within the same syllable, the syllable duration will remain relatively constant and thus the durational ratio between neighbouring syllables will not be influenced greatly. But when they occur across two adjacent syllables, the durational ratio will undergo a drastic change. Hence, the timing structure of English, despite marked reverse durational variation in monosyllabic words would be influenced to a relatively small extent at the level of syllable or word, whereas Korean will show greater durational variation between syllables.

Inter-language differential may also be observed in the whole duration of the neighbouring syllables, between which compensation occurs as a function of the feature of the following consonant. Port, et al. (1980, 1987) suggested two contrastive terms *temporal microstructure* of speech, which indicates the level of phoneme, and *temporal macrostructure* of speech, which is larger units than a phoneme (e.g., syllable, word). With special regard to the temporal macro-structure, Port, et al. claimed that the durational compensation within two-syllable words has some linguistic significance for mora-timing in Japanese, while the tendency for a constant duration in English is probably not linguistically critical. On the other hand, Sato (1993) observed that Korean word pairs with tense/lax stops differed in duration while English and Japanese did not. These indicate that the language specific compensatory phenomena associated with the distinctive feature (voicing or tenseness) of the following consonants can be linguistically significant (phonological) with reference to timing. Therefore, it is worthwhile to examine whether the compensatory phenomenon is crucial to the temporal microstructure and/or macrostructure in a given language. The present study will expand our concern to the phrase and sentence level as well as the phoneme or word level in order to identify the relationship between the phoneme type effects and the length of context. Furthermore, we will examine how much the effects are influenced by tempo variation (fast, normal and slow rate).

2. Method

2.1 Subjects

Participants were eight (two male and six female) native speakers of Korean, ranging in age from their twenties to thirties. All of them had the Seoul accent, which is the standard for Korean. No one exhibited speaking or hearing problems.

2.2 Materials and procedure

Three phonemes /p/, /p'/, /p^h/ which have the same place of articulation (bilabial plosives) but different manners of articulation (/p/: phonologically lax unaspirated, /p'/: tense unaspirated, /p^h/: tense aspirated) were adopted as speech items. They were embedded twice in a sentence frame with the target word /aCa/, "aCa-do sakwarul aCa-cherem coahanda" (= aCa likes an apple like aCa, too). The three target words had their meanings – "apa" (= the Swedish vocal group, ABBA), "ap'a" (= daddy) and "ap^{h}a" (= painful). The speech materials are shown in Table I. In this experiment we use the term 'item' (i.e. items 1, 2 and 3) to indicate the three phonemes, and words or sentences embedding them.

Five lists of the three sentences with a different order were prepared. The informants practised the materials once or twice before recording. They delivered the five lists at their normal rate first and at slow and fast rates, producing a total of 720 tokens (3 phonemes × 2 positions (1st and 3rd phrase) x 3 rates x 5 repetitions x 8 subjects). They were asked to be cautious not to put a special emphasis on a particular phrase. Recording was made using a recorder and a microphone in a sound treated recording room. The recording was digitised onto a Sun Sparcstation at a sampling rate of 16 kHz with 16 bit resolution and saved as files to be processed by the software package WAVES+/ESPS. From the waveforms and spectrograms generated, measurements were made of the durations of each syllable of the target words /aCa/. And the words, phrases and sentences were measured. In particular, the penultimate level (the whole sentence – the final phrase) was also measured to get rid of durational variation due to the likely irregular final lengthening of the final phrase. The *phrase* here is syntactic; it could be composed of one word (noun, verb, adverb, adjective, or conjunction) or one noun plus a postposition (particle), etc. On the other hand, there are terms to indicate a rhythmic unit in Korean: *malt^{h}omak* (Lee, 1982) or *rhythm unit* (Lee, 1990), and other terms which seem suitable for representing a rhythmic unit: *phonological word* or *accentual phrase* (Jun, 1995). Although the size of a rhythmic unit (the number of syllables in it) can vary according to the rate and style of speech, its most frequent form would correspond syntactically to a phrase. For consistency our observation will focus on the syntactic phrase in all three rates. For the initial syllable (vowel) /a/ of the target word /aCa/, the duration was the interval from the onset of the regular pulse of voicing to the offset which indicates the onset of the following consonants /p, p', p^h/. The duration of the second syllable /Ca/ was the sum of stop closure, aspiration and the following vowel /a/ (regular pulse of voicing). The final phrases also were measured in duration. But they can be inconsistently influenced by final lengthening effects, and especially it is controversial how to decide the ending point of the final syllable '-da'. The endpoint of the vowel /a/ was taken to be the point where either F1 or F2 became invisible on the spectrogram whichever came later. Some speakers put a pause between phrases when they read at their slow rate. For the balance between speakers, the pause intervals were excluded from the durations of phrases and sentences.

3. Results and Discussion

3.1 Normal rate

3.1.1 Syllable and word level

As seen in Figure 1, the changes of phoneme type give crucial effects on the durations of the two syllables (i.e. the initial syllable /a/ and the second syllable /Ca/) of the target word

/a-Ca/. In the first phrase, the mean durations of /Ca/ with the tense unaspirated stop /p'/ and tense aspirated stop /p^h/ were longer by 54 ms (32.4%) and 58 ms (35%) respectively than that with the lax stop /p/. As opposed to this, the mean durational ratio of the vowel /a/'s before /p/, /p'/ and /p^h/ was 1 (85 ms) : 0.69 (59 ms) : 0.72 (61 ms). Taking into account the two reverse variations together, the mean durational ratio between /a/ and /Ca/ markedly varied according to the type (lax/tense) of phoneme (stop) (i.e. /a/ : /pa/ = 1 : 1.96; /a/ : /p'a/ = 1 : 3.76; /a/ : /p^{h}a/ = 1 : 3.69).

The same tendency was maintained in the third phrase as well. The mean durational ratio of the vowel /a/'s followed by /p/, /p'/ and /p^h/ was 1 (107 ms) : 0.8 (85 ms) : 0.89 (91 ms), whereas the mean durations of /p'a/ and /p^{h}a/ were respectively increased by 48 ms (35%) compared with that of /pa/. Therefore, the mean durational ratio between /a/ and /Ca/ was still markedly different according to the type of phoneme – /a/ : /pa/ = 1 : 1.3; /a/ : /p'a/ = 1 : 2.19; /a/ : /p^{h}a/ = 1 : 2.1.

Durational variations in one syllable of the target words considerably compensate for those in the other. As a result, only the differences between the reverse variations in the two syllables remain the increase of the word duration, which looks relatively small, considering the extent of active variations in the two syllables. However, the durational differences between the target words are statistically significant irrespective of their position (1st and 3rd phrase).

In the first phrase, the word /ap'a/ and /ap^{h}a/ are longer by 28 ms (11%) and 34 ms (14%) respectively than the word /apa/, and in the third phrase, by 26 ms (11%) and 32 ms (13%).

A three-way ANOVA with Subject, Phoneme Type and Phrase as factors revealed that every factor had significant effects on word duration: [F (7, 208) = 229.12, p=0.000; F (2, 208) = 179.22, p=0.000; F (1, 208) = 7.52, p=0.007]. There was a significant interaction effect for Subject × Phrase [F (1, 208) = 19.57, p = 0.000] (i.e. different phrases had different effects on word duration for each subject), but not for Subject × Phoneme Type [F (14, 208) = 1.60, p=0.081]. Post-hoc Tukey's HSD tests (p=0.05) revealed that the word /apa/ was significantly shorter than /ap'a/ and /ap^{h}a/, while /ap'a/ was similar to /ap^{h}a/ in duration, irrespective of phrase (1st and 3rd phrase).

3.1.2 Higher level than word

Figure 2 explicitly illustrates that the durational differentials between words with tense/lax intervocalic consonants (/p/ *vs.* /p'/; /p/ *vs.* /p^h/) are maintained up to sentence level through phrase and penultimate level. On the other hand, the differentials between the four units with tense consonants /p', p^h/ seem to be negligible.

In the first phrases, the durations of /ap'a-do/ and /ap^{h}a-do/ are longer by 30 ms and 39 ms respectively than /apa-do/. In the third phrases also, /ap'a-cherem/ and /ap^{h}a-cherem/ increase by 29 ms and 32 ms compared to /apa-cherem/. The durations of penultimate level with tense phonemes /p', p^h/ were longer by 54 ms and 73 ms than that with lax stop /p/. At sentence level as well, items 2 and 3 with tense phonemes /p', p^h/ were longer by 55 ms and 81 ms than item 1.

Two-way ANOVAs with Speaker and Phoneme Type as factors were carried out for each phrase (1st and 3rd phrase), penultimate and sentence level. The results showed that Phoneme Type has significant main effects on the duration of each unit (First Phrase: F (2, 96) = 73.51, p = 0.000; Third Phrase: F (2, 96) = 34.75, p = 0.000; Penultimate: F (2, 96) = 43.81, p = 0.000; Sentence: F (2, 96) = 31.63, p = 0.000). Despite the significant main effects of Phoneme Type, post-hoc comparisons in each unit (family error rate, p = 0.05) revealed that except in the first phrase, the individual 95% confidence intervals were partially overlapped between the units embedding tense/lax phonemes (i.e. they were similar in duration). This appears partly because the durational differentials at word level become relatively smaller, as the unit becomes longer. In contrast, standard deviations grow larger in a longer unit. These can be regarded as compensatory responses. Another Factor Speaker also has significant main effects on the duration of each unit (First Phrase: F (7, 96) = 217.10, p = 0.000; Third Phrase: F (7, 96) = 159.32, p =0.000; Penultimate: F (7, 96) = 312.39, p = 0.000; Sentence: F (7, 96) = 309.94, p = 0.000). There were no significant interaction effects for Speaker x Phoneme Type.

To summarise, the durational ratio between /a/ and /Ca/ markedly varied according to the type (tense/lax) of consonant /C/, and the durational differences at word level were significant. In addition, the durational increments at word level were significantly and consistently maintained at larger levels (i.e. phrase, penultimate and sentence), irrespective of speaker. Phoneme type had a significant main effect on the durations of phrase, penultimate and sentence level. However, the increments in the units longer than word were not generally long enough to distinguish the units from the statistical point of view (post-hoc pairwise comparisons, p=0.05).

3.2 Fast and slow rate

3.2.1 Syllable and word level

Despite the application of different rates, the basic results regarding syllable level were similar to those in normal rate (compare Figures 1, 3 and 4) – durational ratios of the first syllable /a/ to the second syllable /Ca/ in the target words are noticeably different according to the type (tense *vs.* lax) of the intervocalic /C/.

However, some interesting temporal variations were observed with regard to the durational ratios between the first and the second syllables of the target word /aCa/. Table II summarises the ratios at the three speech rates.

In general, the faster the rate, the higher the ratio of the first syllable to the second syllable in the target word with lax phoneme /p/, and vice versa with tense phonemes /p', p^h/. Due to these inverse variations, the differentials in durational ratios tend to be reduced as tempo increases. This is because the pattern of distribution of time variation differs depending on the types of phoneme inserted into the target word /a-Ca/. So as to produce intervocalic tense stops, closure phase tends to begin earlier than in lax stops. Though enough time was given (i.e., slow rate), the speaker might try unconsciously to keep the start of closure phase early rather than increasing the duration of the initial syllable /a/ followed by tense stops. Therefore, most of the time increased is allotted to the second syllable /Ca/. By contrast, the increased time is distributed relatively evenly across the two syllables in the word with lax stop /p/ which seems freer at the beginning of its closure phase. As a result, the slower the rate, the bigger the inverse durational variations between the two syllables /a/ and /Ca/ caused by the tense/lax distinction of /C/.

As seen in Table III, when tempo becomes slow, the initial /a/ in /apa/ yields a higher increase (1.68) than those in /ap'a/ (1.38) and /ap^ha/ (1.44) in the first phrase, and it is also higher in /apa/ (1.54) than in /ap'a/ (1.26) and /ap^ha/ (1.26) in the third phrase. In contrast, at fast tempo there are no noticeable differences between them in both phrases. On the other hand, it is unlikely that the second syllables show marked differences in the increase/decrease ratios with regard to the tense/lax distinction. Yet, the comparison between the increase ratios of the first syllable /a/ and those of the second syllable /Ca/ reveals marked differences. Especially when the speech rate changes from normal to slow, the increase ratios of /Ca/ are smaller than those of /a/ in word /apa/ in each of the two phrases (i.e. 1.68 (/a/) : 1.43 (/pa/) in the first phrase; 1.54 (/a/) : 1.35 (/pa/) in the third phrase), whereas they are bigger than those of /a/ in words /ap'a/ and /ap^ha/ (i.e. 1.38 (/a/) : 1.49 (/p'a/) in the first phrase; 1.26 (/a/) : 1.38 (/p'a/) in the third phrase; 1.44 (/a/) : 1.45 (/p^ha/) in the first phrase; 1.26 (/a/) : 1.39 (/p^ha/) in the third phrase). Accordingly, in the words with lax stop /p/, a change in speech rate (especially from normal to slow) is more likely to be absorbed into the first syllable /a/. As opposed to that, in the words with tense stops /p', p^h/, time variation is more likely to be reflected in the second syllable /Ca/.

The overall results at word level did not differ from those in normal rate – words with lax /p/ are longer than those with its cognates. But some statistical differences were found especially in slow rate.

At fast tempo, the three factors (Subject, Phoneme Type and Phrase) all have significant main effects on word duration respectively: [F (7, 206) = 109.61, p = 0.000; F (2, 206) = 72.72, p = 0.000; F (1, 206) = 9.16, p = 0.003]. There were significant interaction effects for Subject × Phoneme Type [F (14, 206) = 2.73, p = 0.001], Subject × Phrase [F (7, 206) = 7.39, p = 0.000] and Phoneme Type × Phrase [F (2, 206) = 4.63, p = 0.011] (i.e. different types of phoneme and phrases had different effects on word duration for each subject, and different types of phoneme had different effects on word duration for each phrase). At slow tempo also, the three factors (Subject, Phoneme Type and Phrase) have significant effects on word duration respectively: [F (7, 206) = 249.50, p = 0.000; F (2, 206) = 33.15, p = 0.000; F (1, 206) = 180.59, p = 0.000]. However, significant interaction effect was observed only for Subject × Phrase [F (7, 206)=14.68, p=0.000]. Post-hoc Tukey's pairwise comparisons (p = 0.05) revealed that in fast tempo, word durations were distinguished as a function of tense/lax distinction of the intervocalic consonant while they were not in slow tempo. The mean durations and (standard deviations) of the words in slow tempo were 382 ms (72), 412 ms (70) and 417 ms (65) in the first phrase and 351 ms (69), 365 ms (73) and 374 ms (63) in the third phrase respectively. The mean word durations are likely to be distinguished according to the feature tenseness of the intervocalic phonemes (i.e. /ap'a/ and /ap^{h}a/ are similar in mean duration but they are rather different from /apa/ in each phrase). Nevertheless, the large standard deviations do not allow them statistically to be different. This result could be attributed partly to irregular speech rates and different reading styles (i.e., with or without a pause during speech) between and within speakers. A stronger compensation at slow tempo (durational difference due to phoneme type becomes smaller in terms of the ratio relative to the whole word durations, when enough time is given) will be another reason. However, it is intriguing that in contrast with the loss of significancy in durational differences, the words with the tense/lax stops – /apa/ *vs.* /ap'a/ and /ap^{h}a/ – show a stronger contrast in the inner temporal structure at slow speech rate (see Table II).

3.2.2 Higher level than word

Overall, phoneme type effects remained significant when the tempo changes from normal to fast while they became weaker when from normal to slow.

In fast rate, Phoneme Type has a main effect on the duration of each unit (First Phrase: F (2, 96) = 32.46, p = 0.000; Third Phrase: F (2, 96) = 18.73, p = 0.000; Penultimate: F (2, 96) = 18.88, p = 0.000; Sentence: F (2, 96) = 10.67, p = 0.000). In slow tempo, however, main effects of Phoneme

Type on each unit were not consistent (First Phrase: F (2, 96) = 14.88, p = 0.000; Third Phrase: F (2, 96) = 2.73, p = 0.070; Penultimate: F (2, 96) = 3.11, p = 0.049; Sentence: F (2, 96) = 2.20, p = 0.116).

In spite of the main effects of Phoneme Type in fast or slow tempo, post-hoc comparisons in each unit (p = 0.05) revealed that each of the four units was not distinguished as a function of phoneme type. That is, the individual 95 % confidence intervals for mean based on pooled standard deviations were partially overlapped between the same units embedding tense/lax phonemes. This tendency is stronger at slow tempo, considering the weak or non-significant effects of Phoneme Type on the durations of the units. As in the normal tempo, this seems to be because the durational differentials at word level become relatively smaller, as the unit becomes longer. In addition to that, larger standard deviations in a longer unit must be crucial to the results. These, of course, can be interpreted as a compensatory movement.

4. Summary and Conclusion

Our Korean data showed noticeable inverse durational variations in each syllable of the target words /a-Ca/ associated with the type (tense *vs.* lax) of /C/. The two reverse variations caused the durational ratio between /a/ and /Ca/ to markedly vary. The word duration also significantly varied depending on the consonant feature, with words embedding tense consonants being longer. This means that Korean differs from many languages in which word duration remains constant irrespective of the type (voiced/voiceless or tense/lax) of inserted consonants. The invariability of word duration is not limited to any particular type of rhythm, i.e., English (stress-timed), Spanish (syllable-timed) and Japanese (mora-timed) all show the tendency for a constant duration (Otake, 1989). It supports the idea that the variability of word duration in Korean can be language specific. The durational differentials between words with tense/lax consonants were maintained up to the sentence level through the phrase level, but they were not long enough to distinguish the higher units. That is, the durational differentials caused by phoneme type were compensated for at the phrase level comprising three or four syllables. This may suggest that the syntactic phrase is worthy of attention with reference to Korean speech rhythm. However, the phrase is not an isochronic unit but the shortest unit to offset the durational differences. More research is required for a conclusion. On the other hand, the results in fast and slow speech rates were generally similar to those in normal rate. But it is notable that time variation especially from normal to slow was more likely reflected in the first syllable /a/ for /apa/, but in the second syllable /Ca/ for /ap'a/ and /ap^{h}a/. The slower the rate was, the smaller the durational ratio between /a/ and /pa/, while the bigger the ratio between /a/ and /p'a/ or between /a/ and /ap^{h}a/.

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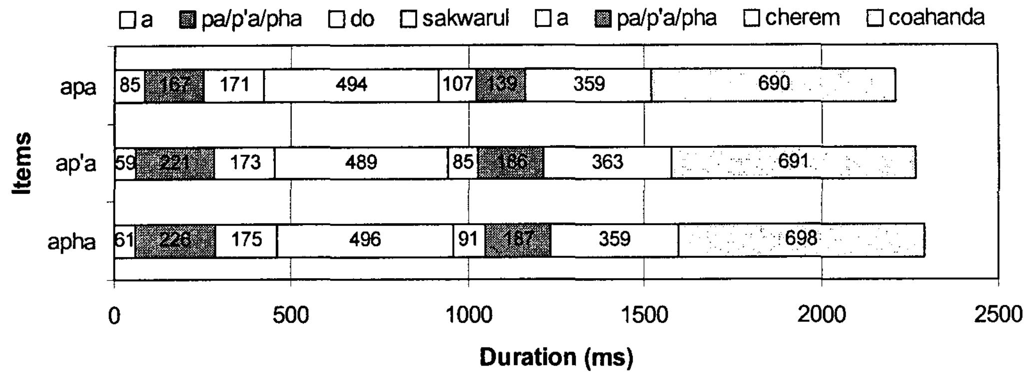

Figure 1. Mean durations of each component in the three items (normal rate, ms, 8 speakers, n = 40)

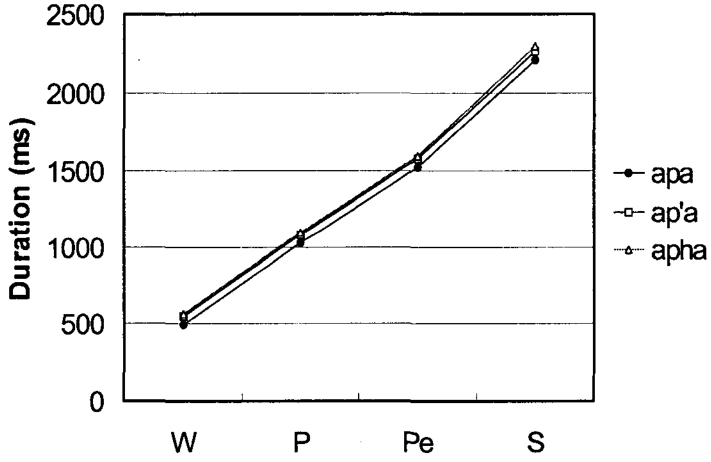

Figure 2. Durational differences due to the tense vs. lax distinction at each level of **Word** (1st phrase + 3rd phrase), **Phrase** (1st phrase + 3rd phrase), **Penultimate** (sentence - 4th phrase) and **Sentence** (8 subjects, n = 40, ms)

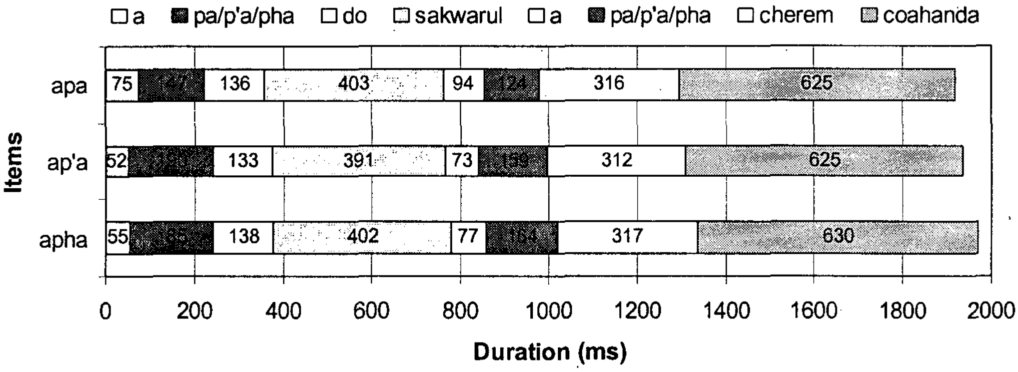

Figure 3. Mean durations of each component in the three items (fast rate, ms, 8 speakers, n = 40)

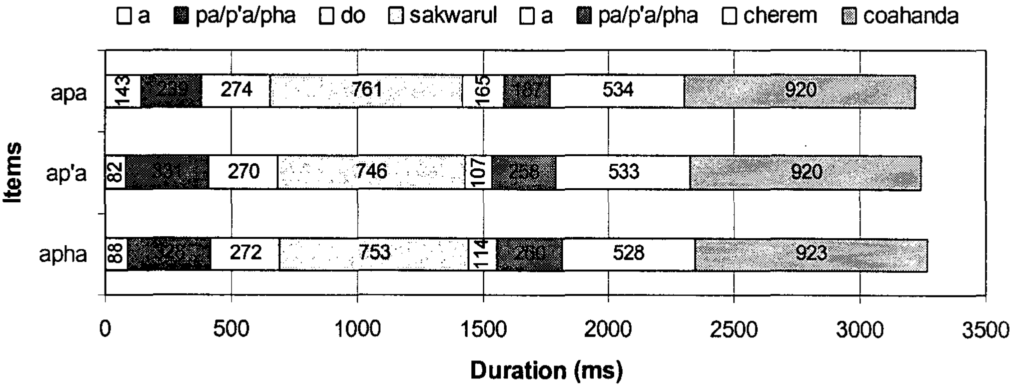

Figure 4. Mean durations of each component in the three items (slow rate, ms, 8 speakers, n = 40)

Table I. Speech materials

item 1	apa-do sakwarul apa-cherem coahanda (= apa likes an apple like apa, too).
item 2	ap'a-do sakwarul ap'a-cherem coahanda.
item 3	ap^{h}a-do sakwarul ap^{h}a-cherem coahanda.

Table II. Durational ratios of the first syllable /a/ to the second syllable /Ca/ in the target words /aCa/ at slow, normal and fast rate (C = /p, p', p^h/)

Phrase	Rate	/a/ : /pa/	/a/ : /p'a/	/a/ : /p^{h}a/
1st	Slow	1:1.66	1:4.05	1:3.73
	Normal	1:1.96	1:3.76	1:3.69
	Fast	1:1.97	1:3.67	1:3.40
3rd	Slow	1:1.13	1:2.41	1:2.27
	Normal	1:1.30	1:2.19	1:2.07
	Fast	1:1.32	1:1.96	1:1.94

Table III. Durational ratios between the initial syllable /a/'s and between the second syllable /Ca/'s of the target word /aCa/ at slow, normal and fast rate (C = /p, p', p^h/)

		/apa/		/ap'a/		/ap^{h}a/	
Phrase	Rate	/a/	/pa/	/a/	/p'a/	/a/	/p^{h}a/
1st	Slow	1.68	1.43	1.38	1.49	1.44	1.45
	Normal	1	1	1	1	1	1
	Fast	0.88	0.88	0.88	0.86	0.89	0.82
3rd	Slow	1.54	1.35	1.26	1.38	1.26	1.39
	Normal	1	1	1	1	1	1
	Fast	0.88	0.89	0.86	0.85	0.85	0.88