The intrinsic pitch and intrinsic length of high and low vowels in Mon-Khmer language*

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Abstract

High vowels tend to have higher F0 (pitch) and shorter duration (length) than low vowels (Neweklowsky, 1975; Fischer-Jørgensen, 1990). To test whether this Compensation Theory is applicable to SEA languages, the F0 and duration values of high and low vowels in Waic languages of the Mon-Khmer language family were studied.

Lavue', Wa, and Plang were selected to represent non-tonal, register, and tonal languages, respectively. In each language, six informants of the same sex were used. They were divided into two age groups: over-sixty and under-twenty. The Praat program was used for acoustic analysis. The findings showed that high vowels tend to have higher F0 and longer duration than low vowels. This means that the results of the acoustical measurements of the F0 values confirmed the Compensation Theory but those of the duration values rejected.

1. Introduction

Based on analysis of more than 30 languages, Whalen and Levitt (1995), Connell (2002), Whalen *et al.* (2004) have demonstrated a universal relationship between vowel height and fundamental frequency (F0). For example, the high vowels [i] and [u] have a higher relative pitch than the lower vowels [ɛ] and [a]. Building on this theory, Mohr (1971), Neweklowsky (1975), Fischer-Jørgensen (1990) have likewise proposed the universality of relations between vowel height and vowel length that Lehiste (1970), Neweklowsky (1975), Fischer-Jørgensen (1990), Laver (1994), and Hajek and Maeda (2004) call "intrinsic vowel length", based on observations that suggest high vowels tend to have shorter durations than low vowels. Some researchers now believe intrinsic length is connected with intrinsic pitch, that is, high vowels tend to have higher pitch than low vowels to compensate for their shorter length and, thereby, enhance the perceptibility of vowel quality. Neweklowsky (1975) and Fischer-Jørgensen (1990) have established this hypothesis as "compensation theory".

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In order to test this compensation theory, the intrinsic pitch and intrinsic length of vowels were analyzed using measurements of the fundamental frequency and duration value of vowels in three Waic languages of the Mon-Khmer language family, Lavue', Wa, and Plang, representing non-tonal, register, and tonal languages, respectively.

2. Preliminary background: intrinsic pitch

Intrinsic pitch first began to be recognized in 1896-1897, when Meyer (cited in Whalen and Levitt, 1995) observed that high vowels in German tended to be pitched higher than low vowels. In the ensuing years, there have been a number of studies of this phenomenon. Whalen and Levitt (1995) have synthesized more than 30 languages of 11 world language families to show intrinsic pitch. From this research, they conclude that intrinsic pitch is universal. However, an attempt to compare studies on intrinsic pitch phenomenon in European languages with similar studies on Southeast Asia languages has revealed that there are fewer research reports dealing with the latter group.

In Southeast Asian languages, high vowels have higher pitch than low vowels in non-tonal languages such as Malagasy (Rakotofiringa, 1968, 1982, cited in Whalen and Levitt, 1995), an Austronesian language; in register languages such as Paroak (Svantesson, 1993; Watkins, 2002), a Mon-Khmer language; and in tonal languages (Han, 1969; Zee, 1980; Mohr, 1971; Boonphan et al., 1982; Shi and Zhang, 1987; Svantesson, 1988; Rose, 1997). Through the application of different methodologies, generally using both sexes as informants, the fundamental frequency values were measured at different points of the syllables, e.g., the onset (Mohr, 1971), the first half of the syllable (Rose, 1997), and the whole syllable (Boonphan et al., 1982). All of the findings showed that, as in European languages, the fundamental frequency values of high vowels are higher than those of low vowels.

3. Preliminary background: intrinsic length

Some linguists, such as Lehiste (1970) and Laver (1994) support the intrinsic-length hypothesis: "the lower the vowels, the longer the duration". And research has confirmed this claim for some languages, e.g., English (Malmberg, 1963), Chinese, Russian and German (Mohr, 1971), and Paroak (Watkins, 2002). However, as with intrinsic pitch, fewer studies have been conducted on intrinsic vowel length in Southeast Asian Languages than in European languages.

In German, Neweklowsky (1975) found high vowels had shorter duration than low vowels. He concluded that the intrinsic length of high vowels was shorter than that of low vowels. He finally hypothesized that longer intrinsic length is a compensation mechanism for a lower intrinsic pitch. Thus "compensation theory" was established. He established the hypothesis that, "intrinsic duration and intrinsic pitch of vowels are a matter of

compensation conditioned by different resonance factors of the vocal tract when high and low vowels are produced" (p. 38).

However, in Farsi, Norwegian, and Herve French (Cochrane, 1970; Detry, 1985, cited in Hajek and Maeda, 2004; Lindau-Webb, 1985) compensatory lengthening has not been detected because the high vowel [iː] has a longer duration than the low vowel [aː].

4. Language data

The language data used as the test tokens were drawn from Lavue', Wa, and Plang, three Waic languages belonging to the Palaungic sub-branch of the Mon-Khmer or Austroasiatic language family.

Lavue', is a non-tonal language spoken in Umphai Village, Papae Subdistrict, Mae Sariang District, Mae Hong Son Province.

Wa is a register language spoken in Maisamakkhi-Nongkhiaw Village, Muangna Subdistrict, Chiangdao District, Chiangmai Province.

Plang is a tonal language spoken in Huaynamkhun Village, Mae Fah Luang Sub-district, Mae Fah Luang District, Chiangrai Province.

All three languages have a repertoire of 9 monopthongal vowels /i, ɨ, u, e, ə, o, ɛ, a, ɔ/ with no length distinction.

For each language, six informants were chosen from a single sex, male for Lavue', and female for Wa and Plang. As language variation can be affected by age, these informants were then divided into two groups: under 20 years old and over 60 years old. The age of the informants is supposed to help confirm of the universality claim of the Compensation Hypothesis.

The three pairs of high and low vowels used in this study consisted of the front vowels i-ɛ, the central vowels ɨ-a, and the back vowels u-ɔ. Four test tokens were selected for each vowel of each language as follows:

Wordlist A (Lavue')

(-i- -ɛ-)		(-ɨ- -a-)		(-u- -ɔ-)	
thiʔ 'one'	tɛp 'dog flea'	chɨk 'field'	kaʔ 'fish'	phuʔ 'sister'	kɔt 'to feel cold'
ciʔ 'index finger'	ʔɛp 'to split'	phɨs 'to carry'	cak 'deer'	chut 'to call'	kɔk 'headache'
chis 'salt'	cɛh 'to tear'	tɨk 'the most'	kap 'chin'	phuk 'to tie'	sɔʔ 'dog'
rəphiʔ 'shirt'	kɛt 'to doubt'	tɨt 'to block'	pas 'to sweep'	thuk 'poor'	hɔk 'to dry in the sun'

Wordlist B (Wa)

(-i- -ɛ-)		(-ɨ- -a-)		(-u- -ɔ-)	
pih 'to sweep'	hɛh 'to pour'	tɨt 'to gore'	pah 'to kill'	sahtuh 'thunder'	pɔk 'to answer'
tih 'mushroom'	tɛʔ 'earth'	tɨh 'breast'	taʔ 'grandfather'	kuh 'to cook rice'	kɔʔkɔʔ 'yesterday'
kih 'salt'	hlɛʔ 'rain'	ʔɨp 'rice'	ʔah 'to scold'	ʔuc 'all'	kɔc 'hot'
ʔit 'to sleep'	sɛh 'to sterilize'	hɨc 'to sting'	kah 'to untie'	sut 'to pick up thing'	chɔk 'to ask'

Wordlist C (Plang)[1]

(-i- -ɛ-)		(-ɨ- -a-)		(-u- -ɔ-)	
kətiʔ 'earth'	tɛʔ 'here'	cɨʔ 'to visit'	ʔelkat 'duck'	suʔ 'dog'	masaŋpɔʔ 'papaya'
hliʔ 'rain'	chɛp 'shoes'	chɨʔ 'to fight'	kaʔ 'fish'	kuʔ 'to wait'	tɔʔ 'there'
səciʔ 'stool'	ʔɛt 'tiny'	ʔɨc 'all'	ʔak 'bow'	kuh 'to get up'	pəsɔh 'coal'
piʔ 'to win'	tɛh 'over there'	hɨc 'fresh meat'	hak 'skin'	ʔup 'narrow'	kɔt 'cold'

5. Methodology

A number of words were selected from related dictionaries, research reports and other related documents. Before recording the data, every word in the list was carefully checked with an informant of each language. Four test tokens were selected for each vowel (i, ɛ, ɨ, a, u, ɔ). The informants were then asked to pronounce each test word in isolation 5 times. The first 3 of these were selected in order to prevent intonation effect. The number of total test tokens was 1,296 (3 languages x 3 informants x 2 age groups x 6 vowels x 4 tokens x 3 times). In addition, all test tokens had voiceless initials and finals to avoid context effects. The recordings were made using AIWA TP VS535. The program Cooledit Pro was then used when each sound was segmented. The Praat program version 4.2.05 was used to analyze the fundamental frequency and duration of isolated words.

[1]Plang is a tonal language which has two tones, high and low. Wordlist of Plang is all in high tone.

To get rid of the perturbation from initial and final consonants, the fundamental frequency values in Hertz were measured at the mid point of each vowel. The duration values in milliseconds were measured in real time. Line graphs were drawn using Microsoft Excel. The different mean values of each pair of high vowels and low vowels, i.e., i *vs.* ɛ, ɨ *vs.* a, and u *vs.* ɔ were analyzed statistically using Anova with a 95% level of confidence.

6. Results

6.1 Intrinsic pitch of vowels

In Lavue'(see table 1[2] and figure 1), the findings show that, in every pair of high-low vowels (i-ɛ, ɨ-a, u-ɔ), the pitch of the high vowel was significantly higher than the low vowel for both age groups ($p<.05$)-except that the pair of central vowels (ɨ-a) in the young-speaker group showed no significant difference.

Table 1. Fundamental frequency (Hz) of high and low vowels in Lavue'

High-Low vowel / Age group	Front vowel			Central vowel			Back vowel		
	i	**ɛ**	**sig**	**ɨ**	**a**	**sig**	**u**	**ɔ**	**sig**
Over 60	152.86	130.28	*	155.09	128.21	*	151.69	136.28	*
Under 20	162.16	154.04	*	160.87	159.44	-	156.99	152.04	*

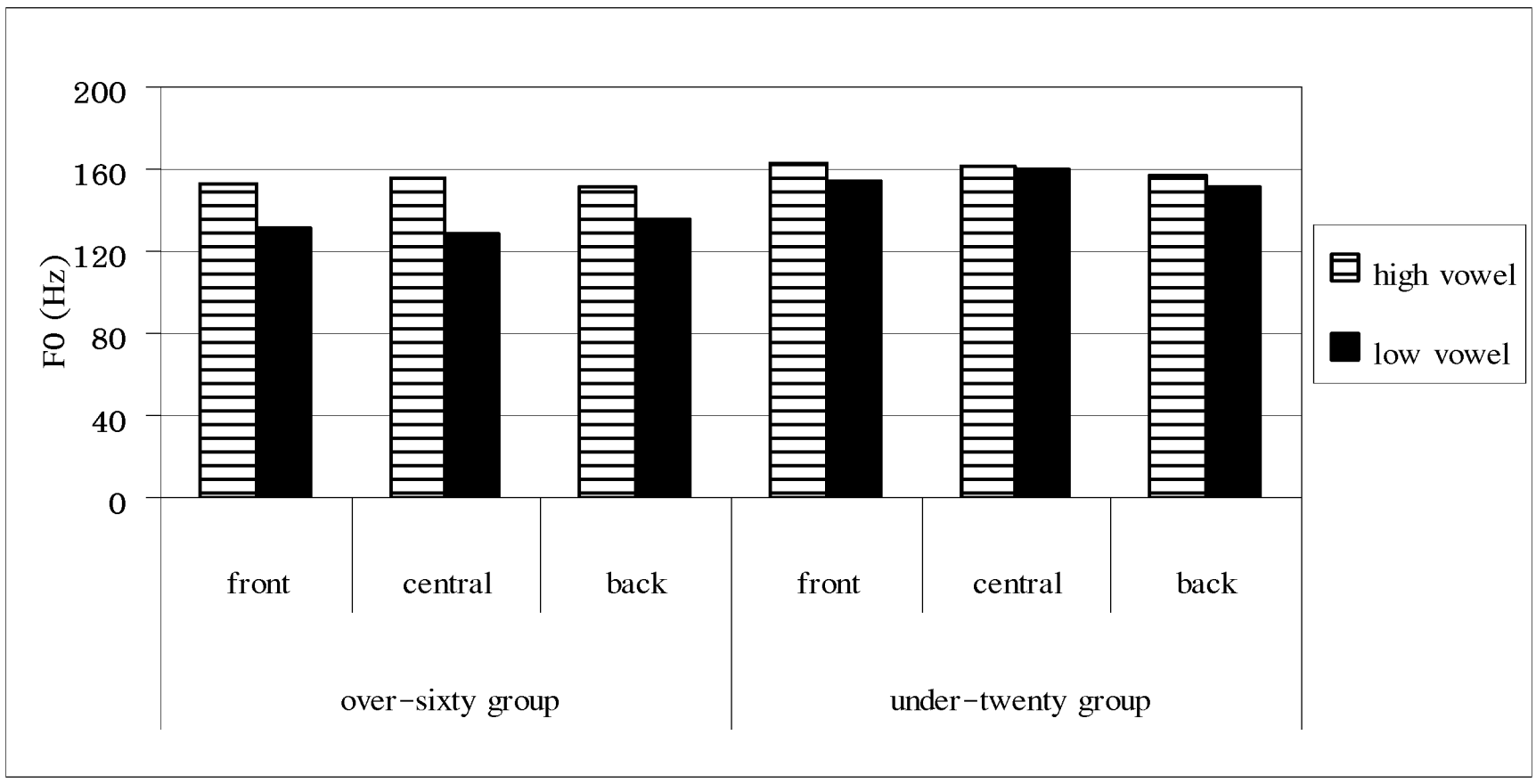

Figure 1. Fundamental frequency (Hz) of high and low vowels in Lavue'

[2]*means significantly different
-means insignificantly different

In Wa (see table 2 and figure 2), the findings show that, in every pair of vowels (i-ɛ, ɨ-a, u-ɔ) the pitch of the high vowel was significantly higher than the low vowel for both age groups ($p<.05$).

Table 2. Fundamental frequency (Hz) of high and low vowels in Wa

High-Low vowel / Age group	Front vowel			Central vowel			Back vowel		
	i	**ɛ**	**sig**	**ɨ**	**a**	**sig**	**u**	**ɔ**	**sig**
Over 60	216.94	205.75	*	217.16	194.14	*	213.51	202.27	*
Under 20	228.01	217.87	*	223.22	220.35	*	218.55	210.06	*

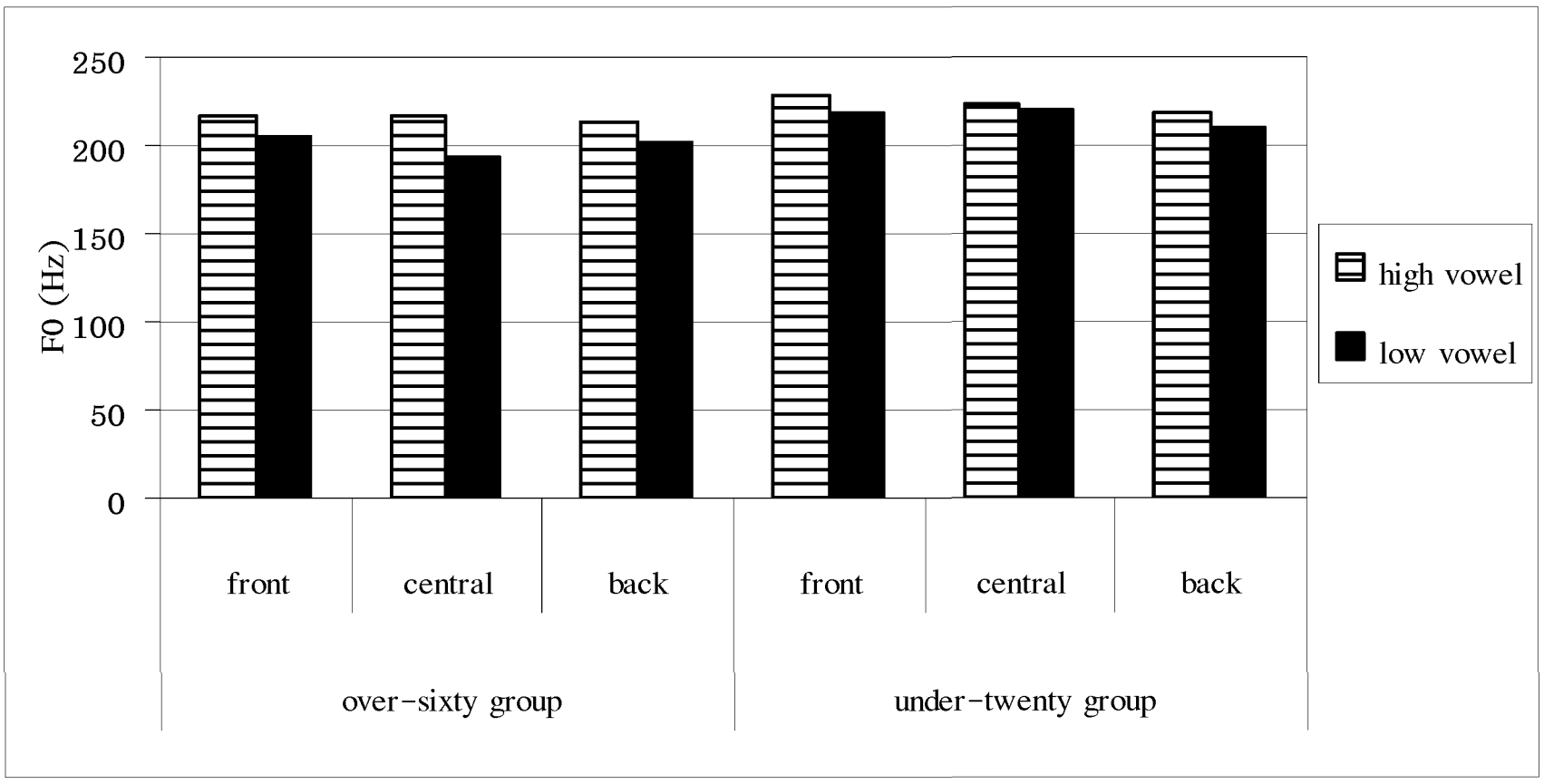

Figure 2. Fundamental frequency (Hz) of high and low vowels in Wa

In Plang (see table 3 and figure 3), the findings show that, in every pair of vowels (i-ɛ, ɨ-a, u-ɔ), the pitch of the high vowel was higher than the low vowel. It is significantly different ($p<.05$) for every age group, except for the pair of front vowels (i-ɛ) of the over-sixty group and the pair of central vowels (ɨ-a) of both age groups.

Table 3. Fundamental frequency (Hz) of high and low vowels in Plang

High-Low vowel / Age group	Front vowel			Central vowel			Back vowel		
	i	**ɛ**	**sig**	**ɨ**	**a**	**sig**	**u**	**ɔ**	**sig**
Over 60	183.23	181.53	-	177.79	177.38	-	199.45	181.91	*
Under 20	247.96	234.91	*	247.41	245.83	-	250.21	230.47	*

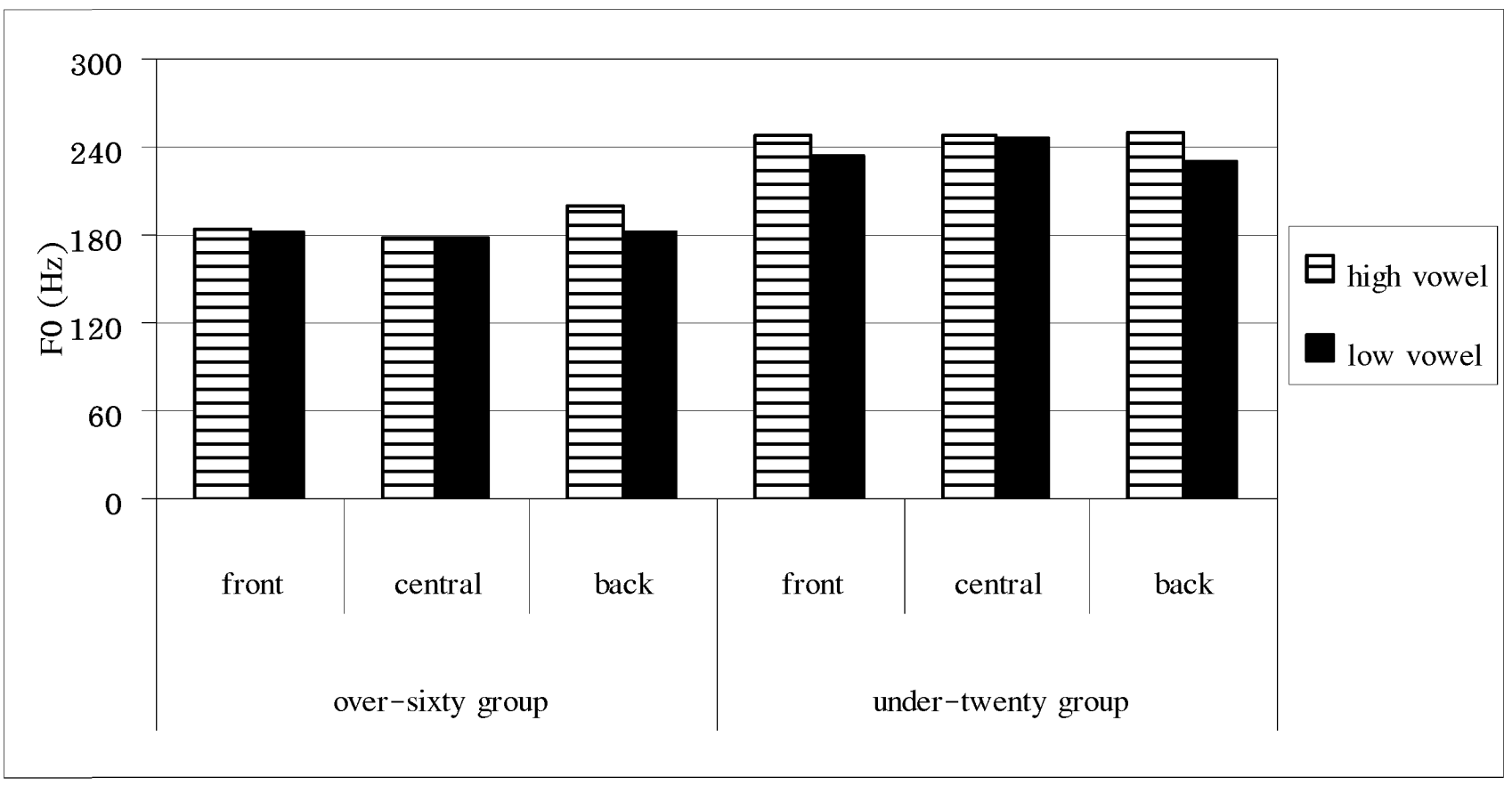

Figure 3. Fundamental frequency (Hz) of high and low vowels in Plang

From the findings above, in every age group, the pitch of the high vowels was higher than the low vowels, though there were some exceptions for the statistical test.

Statistical results also show that age ($F(1, 648)=2.012$; $p<.05$) and language type ($F(2, 432)=1.333$; $p<.05$) are not significant factors affecting the intrinsic pitch.

6.2 Intrinsic length of vowels

In the over-sixty group for Lavue' (see table 4 and figure 4), the findings show that high vowels tend not to have shorter duration than low vowels (i-ɛ, ɨ-a, u-ɔ). The pair of front (i-ɛ) and back (u-ɔ) vowels show that the high vowels were of longer duration than the low vowels, but only insignificantly. In the under-twenty group, the high vowels were of significantly shorter duration than low vowels ($p<.05$) for every pair of vowels (i-ɛ, ɨ-a, u-ɔ).

Table 4. Duration (msec) of high and low vowels in Lavue'

High-Low vowel / Age group	Front vowel			Central vowel			Back vowel		
	i	**ɛ**	**sig**	**ɨ**	**a**	**sig**	**u**	**ɔ**	**sig**
Over 60	118.58	117.49	-	107.26	121.67	*	110.07	105.59	-
Under 20	123.60	152.20	*	108.09	128.18	*	123.37	132.16	*

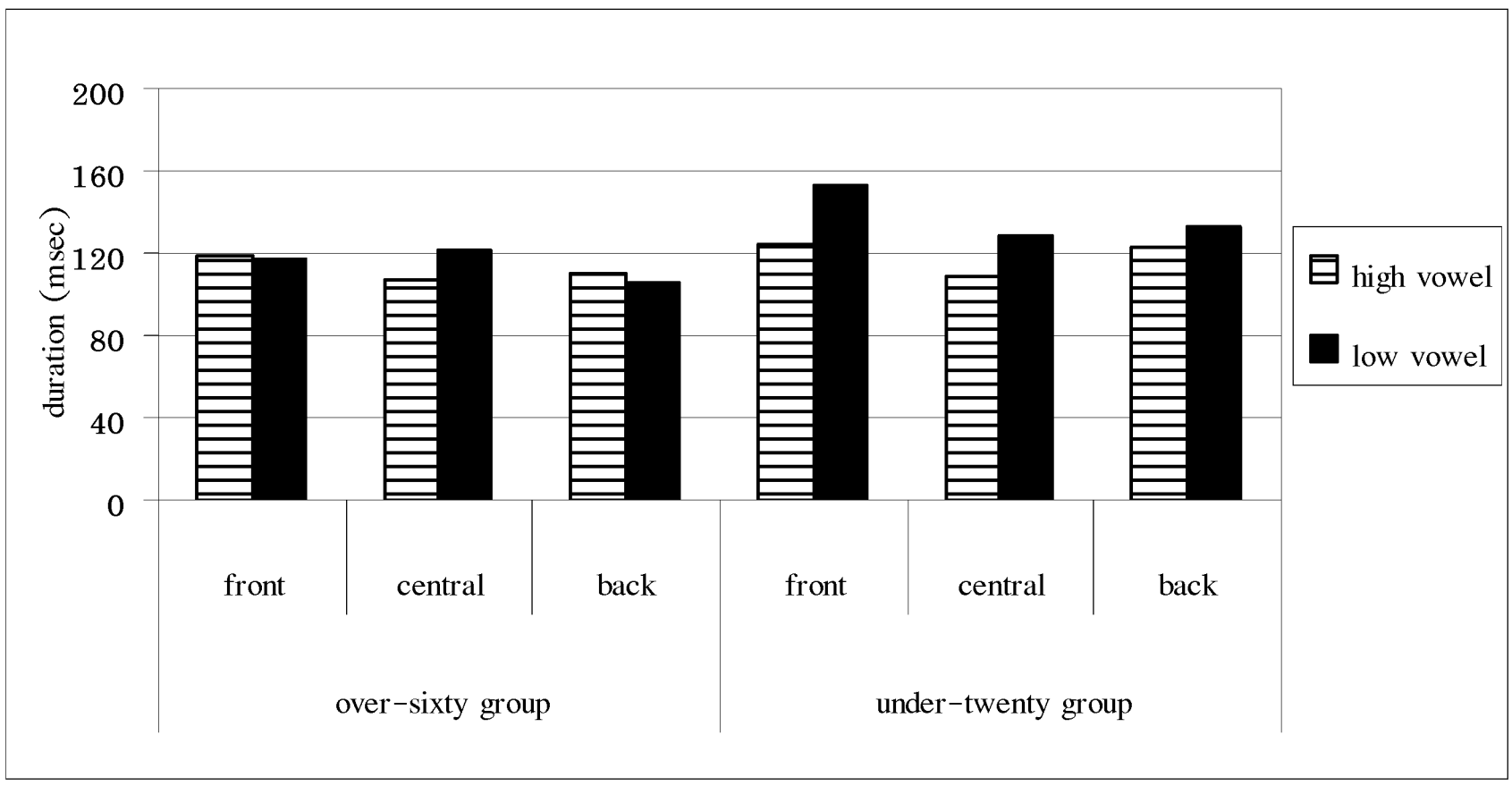

Figure 4. Duration (msec) of high vowel and low vowels in Lavue'

In Wa (table 5 and figure 5), the results show that, for every pair of vowels (i-ɛ, ɨ-a, u-ɔ), the high vowel was of significantly shorter duration than the low vowel ($p<.05$). But the pair of front vowels (i-ɛ) of the under-twenty group revealed high vowels with significantly longer durations than the low vowels ($p<.05$).

Table 5. Duration (msec) of high and low vowels in Wa

High-Low vowel / Age group	Front vowel			Central vowel			Back vowel		
	i	**ɛ**	**sig**	**ɨ**	**a**	**sig**	**u**	**ɔ**	**sig**
Over 60	142.89	162.71	*	126.73	169.71	*	109.23	135.21	*
Under 20	230.52	211.94	-	189.75	233.84	*	147.27	183.42	*

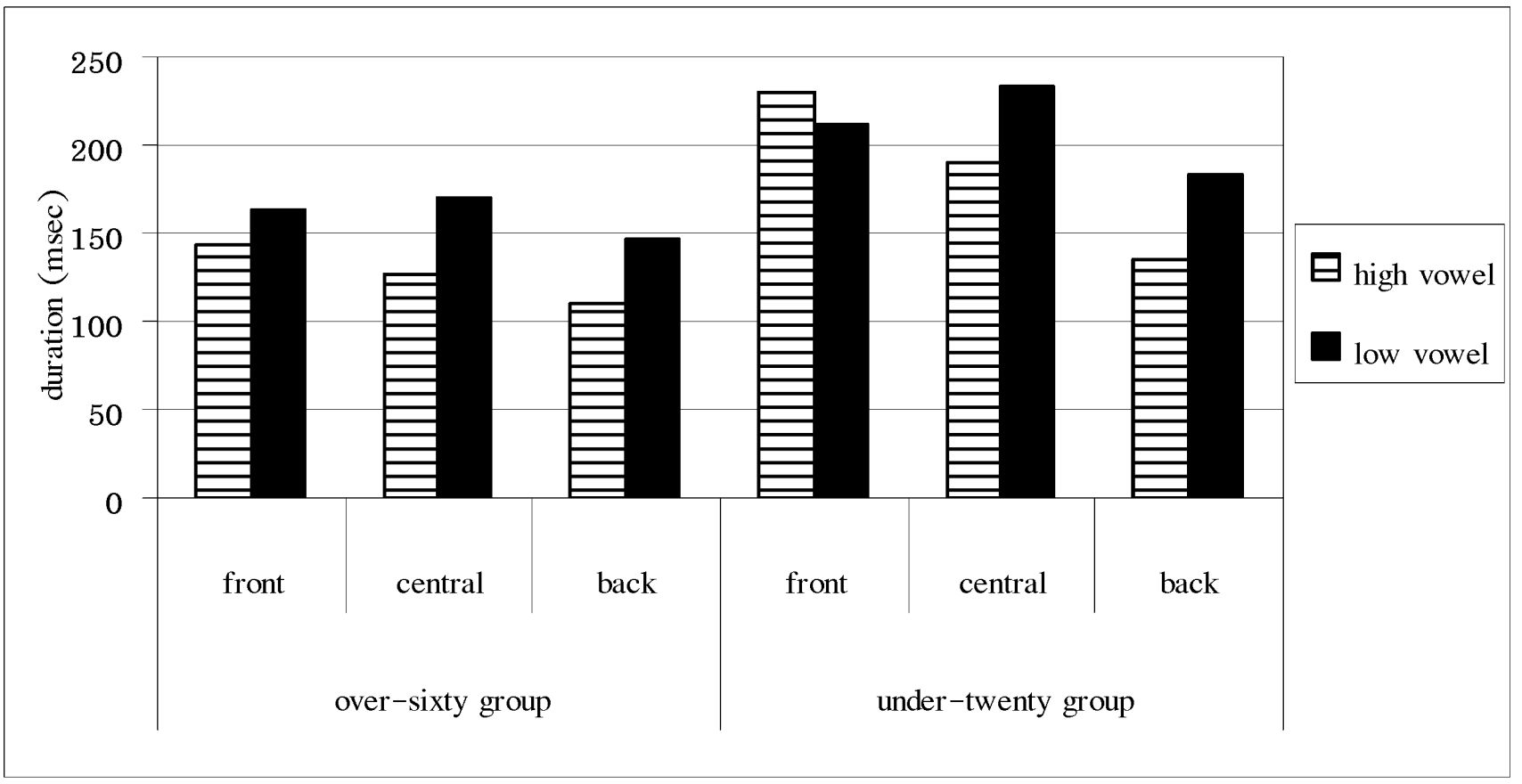

Figure 5. Duration (msec) of high and low vowels in Wa

The findings for Plang (table 6 and figure 6) were similar to those for Wa, i.e., for every pair of vowels (i-ɛ, ɨ-a, u-ɔ), the high vowels were of significantly shorter duration than the low vowel ($p<.05$), except for the pair of front vowels (i-ɛ) of the under-twenty group.

Table 6. Duration (mesc) of high and low vowels in Plang

High-Low vowel / Age group	Front vowel			Central vowel			Back vowel		
	i	**ɛ**	**sig**	**ɨ**	**a**	**sig**	**u**	**ɔ**	**sig**
Over 60	233.11	235.50	-	181.75	219.07	*	225.20	228.48	-
Under 20	287.09	219.05	*	167.69	215.76	*	239.27	250.44	*

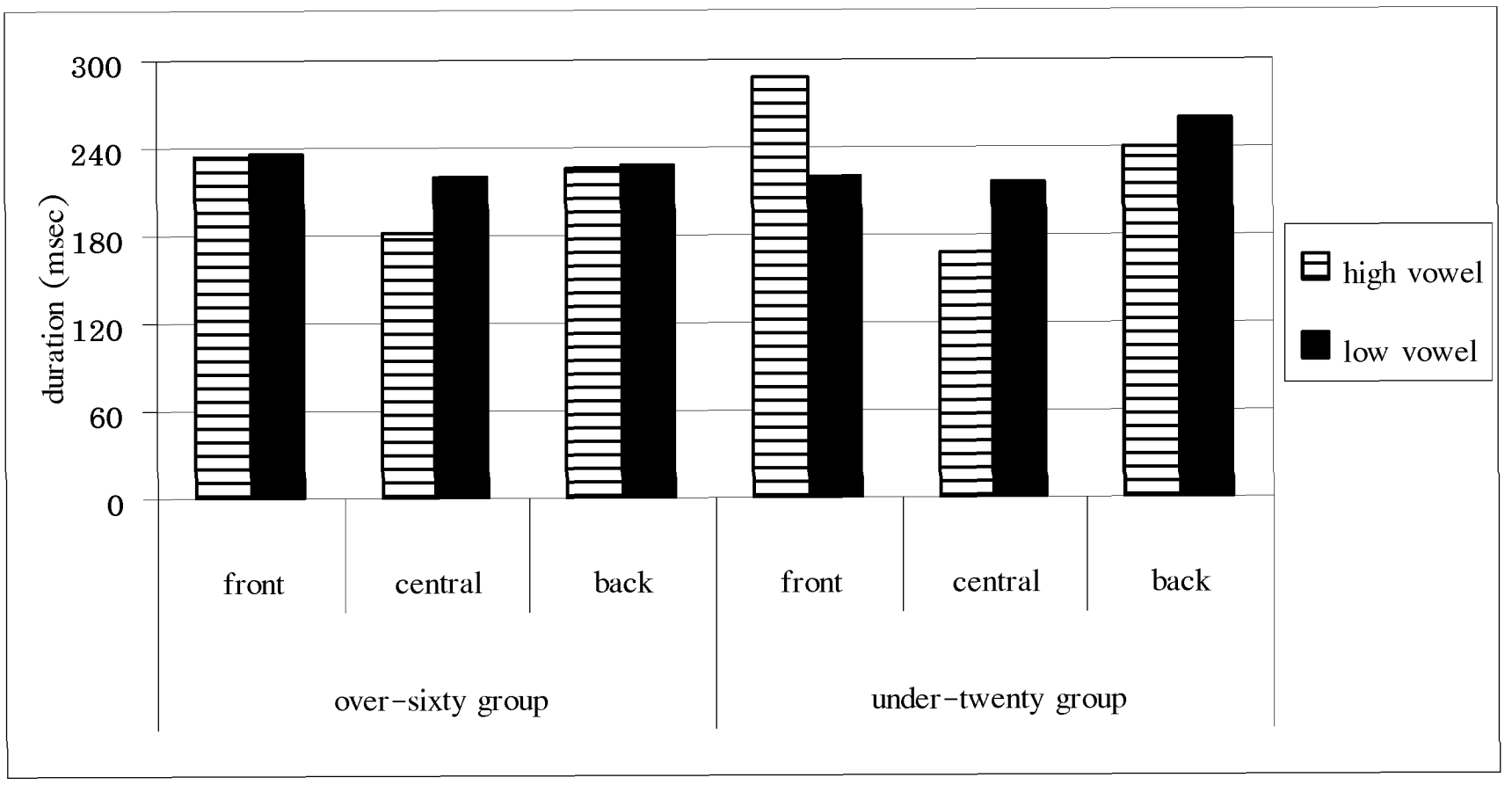

Figure 6. Duration (msec) of high and low vowels in Plang

The findings show that high vowels are not always of shorter duration than low vowels in Waic languages, which does not support the hypothesis of the universality of intrinsic vowel length. Statistical results also show that age ($F(1, 648)=0.824$; $p<.05$) and language type ($F(2, 432)=2.808$; $p<.05$) are not significant factors affecting intrinsic length.

6.3 The relationship between the intrinsic pitch and the intrinsic length of vowels

The findings in 6.1 and 6.2 demonstrate the higher pitch of the high vowels has not been compensated for by their shorter duration. One obvious example occurs in the over-sixty group in Lavue'. A comparison of the pair of front vowels (i-ɛ) reveals that the high vowel (i) had higher pitch than the low vowel (ɛ), yet the duration of high vowel (i) was conversely longer than that of the low vowel (ɛ).

When comparing the pair of front vowels (i-ɛ) in the under-twenty group in Wa, the high vowel (i) had a higher pitch than the low vowel (ɛ), but the duration of the high vowel (i) was longer than that of the low vowel (ɛ).

In Plang, a comparison of the fundamental-frequency values of the under-twenty group reveals that the high vowel (i) had a higher pitch than the low vowel (ɛ). However, the high vowel (i) had a longer duration than the low vowel (ɛ).

While the over-sixty group shows some compensation effect between F0 and duration in most pair of vowels, the under-twenty group shows no corresponding relationship between intrinsic pitch and intrinsic length in front vowels (i-ɛ). It can be inferred that age group is one of the plausible conditioning factors to confirm the universality claim of the Compensation Hypothesis.

To confirm that there is no corresponding relationship between intrinsic pitch and intrinsic length of vowels, the effect of vowel height on the intrinsic pitch and the intrinsic length was statistically analyzed. The results demonstrated that vowel height significantly affected the intrinsic pitch ($F= 34.92\ (1, 648)$, $p<.05$) but not the intrinsic length.

7. Discussion and conclusion

The intrinsic pitch of vowels appears in every type of Waic language: in a non-tonal language (Lavue'), a register language (Wa), and a tonal language (Plang). In both age groups, the over-sixty group and the under-twenty group, the intrinsic pitch phenomenon can be found. These findings confirm the universality of the intrinsic vowel pitch (Whalen and Levitt, 1995; Connell, 2002; Whalen et al., 2004).

Statistical analysis clearly shows that language type (non-tonal language, register language and tonal language) and age group of the informant do not limit the appearance of intrinsic pitch. This is an additional finding from Whalen and Levitt (1995). Whalen and Levitt (1995) have found that factors such as tongue advancement, sex, number of vowels, tonal languages, etc. do not limit the intrinsic pitch phenomenon. They concluded that the intrinsic pitch of vowels is an automatic mechanism. Their findings contradicted the Enhancement Theory (Diehl and Kluender, 1989a, 1989b; Diehl, 1991; Di Benenetto, 1994), which emphasized the intention of speakers to produce the intrinsic pitch difference, to make the vowel quality clearer.

The intrinsic length of vowels is not as universal as intrinsic pitch. It is a specific characteristic which differs from language to language. It is also reported not to appear in Farsi, Norwegian (Cochrane, 1970) and Herve French (Detry, 1985).

The findings show no correspondence between the intrinsic pitch and the intrinsic length of vowels as mentioned in the Compensation Theory. The high vowels have not compensated for their intrinsic pitch with their intrinsic length. This supports the findings of Hajek and Maeda (2004) which showed that the correlation between intrinsic pitch and intrinsic length was widespread cross-linguistically but not universal.

As phonetic correlates comprise pitch, length and loudness, it is plausible that loudness also plays an important role in compensation. The intrinsic pitch may not be compensated for by the intrinsic length alone but also intrinsic loudness (Fant, 1960). This suggests the need for further study of the way in which intrinsic pitch, length, and loudness interact.

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