Stress and tone Sandhi in Vietnamese reduplications

Anh-Thư T. NGUYỄN
School of English, Media studies,
and Art history, Australia

John C. L. INGRAM
School of English, Media studies,
and Art history, Australia

Abstract

In this paper we take advantage of the segmental control afforded by full and partial Vietnamese reduplications on a constant carrier phrase to obtain acoustic evidence of asymmetrical prominence relations (van der Hulst 2005), in support of a hypothesis that Vietnamese reduplications are phonetically right headed. Acoustic parameters of syllable duration (onset, nucleus and coda), F0 range, F0 contour, vowel intensity, spectral tilt and vowel formant structure are analyzed to determine: (1) which syllable of the two (base or reduplicated) is more prominent and (2) how the tone sandhi forms differ from their full reduplicated counterparts. A comparison of full and partial reduplicated syllables in tone sandhi forms provide additional support for this analysis.

1. Introduction

Vietnamese is a contour tone language, which is strongly syllabic in its phonological organization and morphology. However, reduplication is also a highly productive word formation process, with disyllabic word forms predominating, raising the question of whether there exists a distinctive level of phonological structure identifiable with the phonological word. In traditional accounts of Vietnamese phonology, the existence of stress at the word level has been a matter of unresolved controversy (Thompson 1987; Nguyễn 1970, among others).

In this paper, acoustic parameters including syllable duration (onset, nucleus and coda), F0 range, F0 contour, vowel intensity, spectral tilt and vowel formant structure are analyzed to determine: (1) which syllable of the two (base or reduplicated) is more acoustically prominent and (2) how the tone sandhi forms differ from their full reduplicated counterparts, in forms such as:

1a. *Pha trà cho* ***đậm đậm*** [fa^{33} ʈʂa^{21} cɔ^{33} **ɗʌm^{212} ɗʌm^{212}**]
fully reduplicated

1b. *Pha trà cho* ***đầm đậm*** [fa^{33} ʈʂa^{21} cɔ^{33} **ɗʌm^{21}** ɗʌm^{212}]
partially reduplicated
(tone sandhi)

reduplicated base

1.1. Tone and tone sandhi in Vietnamese

Vietnamese has 6 tones divided into two groups on the basis of register; high tones: level (*ngang*), rising (*sắc*), broken (*ngã*) and low tones: falling (*huyền*), dropping (*nặng*), and curve (*hỏi*) (Đoàn 1977; Vương and Hoàng 1996; Vũ, 1981, 1982). The number of tones, as well as their realisation, varies according to dialect: Northern dialect has 6 tones while Central and Southern dialects have 1 tone less due to the historical merging of the curve (hỏi) and broken (ngã) tones. Table 1 presents the five Southern Vietnamese tones adapted from Vũ (1981, 1982). Tone height, tone direction and voice quality (creaky and breathy…) are important distinctive features of tones in Vietnamese, while other phonetic features such as duration and intensity have been mentioned but not considered as distinctive (Đỗ, Trần and Boulakia 1998; Phạm 2003; Vũ 1982).

Table 1. Southern Vietnamese tones.

Tones	**Diacritics**	**Chao letter**	**F0 Contour**
Ngang Level	a (unmarked)	33	Level F0 contour, slight declination toward the end
Sac Rising	á (acute accent)	35	Rising F0 contour, starting at about the same F0 as the Level tone, and reaching top F0 range at the end. *In checked syllables:* similar to the non-checked tone in many respects, only the F0 onset is higher and the duration shorter.
Huyen Fallin g	à (grave accent)	21	Falling F0 contour, begins on a low pitch and falls gradually, sometimes breathy voice
Nang Drop	ạ (subscript dot)	212	Concave contour, starting at low F0, falling in the first third then rising gently at the last one half or one third back to onset level, sometimes breathy or creaky. *In checked syllables:* similar to the non-checked tone in many respects, but F0 onset a little higher, the rising end negligible and shorter duration
Hoi Curve	ả (question mark)	214	Concave F0 contour, starting at low level, reaching lowest F0 at about one third, then rising sharply but not reaching the same height as the rising tone.

Note: checked syllables are syllable ending in stops

There is a segmental constraint on Vietnamese tonal distribution. This segmental constraint is confined mainly to the kinds of syllable codas. Vietnamese syllables are closed by only two kinds of consonants: obstruents: voiceless stops (/p/, /t/, and /k/) and sonorants: nasals (/m/, /n/, and /ŋ/) or glides (/w/ and /j/). One constraint of segmental pattern on tones in Vietnamese is that only two tones, the rising (sắc) and dropping (nặng) tones, can appear in syllables ending in voiceless stops (/p/, / t/, and /k/), while any tone can occur in syllables ending in sonorants (vowels, nasals and glides) (Thompson 1987).

It is generally claimed that there is no tonal neutralisation due to "sandhi" in Vietnamese, a phenomenon that occurs in other tone languages like Chinese and Thai. Tonal variation due to the influence of neighbouring tones can, however, be observed and is described as a type of tonal assimilation or coarticulation. Tonal coarticulation in Vietnamese introduces considerable variation in both slope and height of fundamental frequency and its perseveratory or progressive effects are greater than its anticipatory or regressive effects, (Han and Kim 1974; Seitz 1986). Đỗ (1986) underlines the importance of progressive assimilation according to the height reached by the tone which precedes it. After a rising tone such as rising (sắc) or curve (hỏi), any immediately following tone will start one or two quarter tones higher than its normal target value, and after dropping (nặng) and falling (huyền) tones it will start one or two quarter tones lower. Apart from this, a relative difference in register and contour is generally preserved. However, in spite of the claimed absence of tone sandhi in Vietnamese by most linguists, it cannot be denied that tone sandhi occurs in a subset of Vietnamese reduplication words (Thompson 1987; Trần 1969).

Vietnamese has no system of culminative word stress; nevertheless, it is widely accepted that there is stress in the sense of accentual prominence at the phrasal level (Thompson 1987; Nguyễn 1970). It is shown by Đỗ (1986) that duration and intensity are important parameters for describing stress in Vietnamese. Chaudhary (1983) remarks that intensity is one stable acoustic correlate of Vietnamese stress. Some other authors, such as Hoàng and Hoàng (1975), or Gsell (1980) consider that full tonal realization of accented syllables is one of the positive marks of accent. Jones and Huỳnh (1960) remark that normally stresses in a Vietnamese utterance are conditioned by junctures. Generally, these studies examined stress in the sense of phrasal- level accentual prominence but do not address the question of stress at the word level, which is the aim of this study.

1.2 Reduplication

Reduplication is a productive process in Vietnamese. Almost every adjective and adverb has its reduplication forms. There are 5000 entries in the recently published dictionary of Vietnamese reduplicants (Viện Ngôn Ngữ 1995), which, compared to a regular dictionary of 50,000 entries, is a significant amount (approximately about 10%) (Alves 1999).

Phonologically, there are four main types of reduplication: full reduplications: copying of full segmental composition and tone, and partial reduplications with three main sub categories: (1) same rhyme and tone but with alternate onset consonant, (2) same segmental composition but with alternate tones, and (3) same onset consonant but alternate tones and rhymes. There is a constraint on tone harmony in reduplication forms that the tone of the copying (reduplicated) syllable must be in the same register as that of the base form: a phonological patterning of high tones: level (*ngang*: high level), rising (*sắc*: high rising), curve (*hỏi*: gradual fall-rise) and that of three low tones: falling(*huyền*: gradual falling), dropping (*nặng:* low dropping), and broken (*ngã*: fall glottalised and abrupt rise). In addition, many full reduplications undergo tone sandhi, which is also constrained by the within-register tone harmony. For example, the full reduplication *đỏ đỏ* [ɗɔ^{214} ɗɔ^{214}] (red red = rather red) with the same curve (fall-rise) tone has an alternative form with a tone sandhi: đo đỏ [ɗɔ^{33} ɗɔ^{214}] with a combination of two high-register tones: a level tone and a curve tone. In reduplications with syllables ending in stop consonants, when the first syllable of the word undergoes tone sandhi, its final stop consonant is replaced by its corresponding homorganic nasal (e.g., p-m: *đẹp đẹp* [ɗɛp^{212} ɗɛp^{212}] vs. *đèm đẹp* [ɗɛm^{21} ɗɛp^{212}], t-n: tốt tốt [tot^{35} tot^{35}] vs. *tôn tốt* [ton^{33} tot^{35}]). A summary of patterns of reduplication on a phonological basis and tone sandhi rules is presented in Table 2 below.

Table 2. Types of reduplication.

Types of reduplication	**Full reduplication**	**Partial reduplications**		
		Tone sandhi	**Onset change, same rime**	**Same onset, rime change**
Examples	sáng sáng [ʂ̥aŋ̟^{35} ʂ̥aŋ̟^{35}] (rather bright) sột sột [ʂ̥ot^{212}ʂ̥ot^{212}] (rustle: paper or cloth)	sang sáng [ʂ̥aŋ̟^{33} ʂ̥aŋ̟^{35}] (rather bright) sồn sột [ʂ̥on^{21} ʂ̥ot^{212}] (rustle: paper or cloth)	sáng láng [ʂ̥aŋ̟^{35} laŋ̟^{35}] (bright&clear) lột sột [lot^{212} ʂ̥ot^{212}] (rustle: paper or cloth)	sáng suốt [ʂ̥aŋ̟^{35} ʂ̥uɜt^{35}] (clear-minded) sột sạt, sột soạt [ʂ̥ot^{212} ʂ̥at^{212}] [ʂ̥ot^{212} ʂ̥wat^{212}] (rustle: paper or cloth)

It is widely agreed among Vietnamese linguists that in these bisyllabic words, the right-edged component is the base or the stem, thus carries the semantic weight and is therefore more auditorily prominent (Hồ 2002, among others). There are reduplications with a reverse direction of tone sandhi (e.g., *héo héo* [hɛw^{35} hɛw^{35}] (Rising-Rising tones: tree leaves becoming dry)->*héo* ***hẹo*** [hɛw^{35} hɛw^{212}] (Rising-Drop tones: becoming very dry) as opposed to ***heo*** *héo* [hɛw^{33} hɛw^{35}] (Level-Rising: rather dry)). This study investigates only the right-to-left sandhi forms of the full reduplications. Apart from a few reduplications that have only one form (e.g., *nòng nọc* [nɔŋ͡m^{21} nɔk͡p^{212}], *lông lốc* [loŋ͡m^{33} lok͡p^{35}] which have no full form counterparts *nọc nọc* [nɔk͡p^{212} nɔk͡p^{212}] or *lốc lốc* [lok͡p^{35} lok͡p^{35}]), most full reduplications and their right-to-left sandhi forms are in free variation and both indicate the same meaning (Thompson 1987; Nguyễn 1981).

1.3 Phonological constraint on tone sandhi in reduplication

There are several phonological constraints on the right-to-left tone sandhi forms of the full reduplications. First, tone sandhi reduplication only applies to forms with dynamic (or 'uneven') tone contour such as rising-rising, dropping-dropping, curve-curve and broken-broken but not to forms with "even" tone such as level-level (e.g., *xanh xanh* [sɐɲ^{33} sɐɲ^{33}]: bluish) or falling-falling (e.g., *vàng vàng* [vaŋ^{21} vaŋ^{21}]: yellowish).

Second, the sandhi forms undergo the within-register tonal harmony. The tone sandhi rules in Table 3 show a regressive tone sandhi (i.e., from right-to-left: the first syllable undergoes tone sandhi) which is well-documented.

Table 3. Within - register tone harmony rules.

High register: Rising/Curve -> Level	**Low register:Drop/Broken->Falling**
Rising-Rising->Level-Rising *sáng* sáng->*sang* sáng (rather bright) [ʂa̰ŋ^{35} ʂa̰ŋ^{35}]->[ʂa̰ŋ^{33} ʂa̰ŋ^{35}]	Drop-Drop->Falling-Dropping *nhẹ* nhẹ-*nhè* nhẹ (rather light) [ɲɛ^{212} ɲɛ^{212}]->[ɲɛ ^{21} ɲɛ^{212}]
Curve-Curve->Level-Curve *nhỏ* nhỏ->*nho* nhỏ (rather small) [ɲɔ^{214} ɲɔ^{214}]->[ɲɔ^{33} ɲɔ^{214}]	Broken-Broken->Falling-Broken *cũ* cũ->*cù* cũ/ *cu* cũ (rather old) [ku^{214} ku^{214}]->[ku^{21} ku^{214}/[ku^{33} ku^{214}](*)

(*):*cũ* is spoken as curve tone (hỏi: 214) by Southerners but produced as broken tone (ngã: 325) by Northerners.

However, it is worth noting the mismatch between phonological patterning and the phonetic realisation of tones in reduplication. That is, tones are traditionally classified into two registers on the phonetic basis of tonal shape and height: high tones (level-rising-broken: *ngang-sắc-ngã*) and low tones (falling-drop-curve: *huyền-nặng-hỏi*) (Đoàn 1977; Vương and Hoàng 1996), by contrast, on the basis of phonological patterning of tone in reduplication and traditional poetry as presented in Table 3 above, the curve tone forms a class of high register with level and rising while broken forms a class of low register with falling and dropping. In other words, the registers of curve and broken are reversed. Many efforts have been made to explain the unusual behaviour of curve and broken tones. Some researchers (Đoàn 1977; Hoàng 1989; Vương and Hoàng 1996, Nguyễn and Edmondson 1997) look at historical developments as an explanation for this phenomenon. They adopt Hauricourt's (1954) suggestion that curve (hỏi) was historically a low tone and broken (ngã) a high tone, and they suggest that curve and broken switched their registers during the evolution of tones. How this happened is not clear, nor is it closely examined in most accounts. Ngô (1984) and Burton (1992) propose abstract representations of tones to solve the problem of curve and broken tones in reduplication. Ngô (1984) posits a Concave Tone Reversal rule which changes the phonological high tone curve to a phonetic low tone and the phonological low tone broken to a phonetic high tone. Burton (1992) proposes a similar rule that switches the registers of curve and broken tones. Phạm

(2003) in seeking an alternative analysis from an acoustic study, showed that pitch height is not a reliable cue to differentiate tones and registers. The laryngeal features of breathiness and creakiness are more stable and provide more reliable cues. These features, along with tonal shape, account for tonal height. Curve (hỏi) is a breathy tone and broken (ngã) is creaky. Creakiness is produced at very low frequencies and makes a tone lower than does breathiness. This is a clear indicator that curve cannot be lower than broken because broken has inherent creakiness. In other words, there is no mismatch when curve patterns with the higher tones, and broken patterns with other low tones. In this experiment, in order to avoid the complication arising from this mismatch, only speakers of Southern dialect in which curve (hỏi) and broken (ngã) merge and are realised as the curve tone (hỏi) are used.

Third, in reduplications with syllables ending in final stops, there is a final stop-nasal replacement, which accompanies (or can be said to be motivated by) the tone change due to the segmental constraint on the rising and dropping distribution (e.g., *đẹp đẹp* [ɗɛp^{212} ɗɛp^{212}]->*đèm đẹp* [ɗɛm^{21} ɗɛp^{212}], *tốt tốt* [tot^{35} tot^{35}]->*tôn tốt* [ton^{33} tot^{35}], see Table 4 below). In an attempt to account for this tone and coda alternation, Ngô (1984) postulated that "phonological alternation in Vietnamese reduplication can be said to be caused by 'weak stress.' At the weakly-stressed syllabeme, the toneme has the tendency to fall back on the [-contour], as the most natural tone resolution. If the syllabeme has an obstruent coda, which prevents the tone from resolving (i.e., violating the obstruent coda-tone restriction), then the syllabeme "opens" up a little, by going up one rank of sonority (i.e., its coda is nasalised)".

Table 4. Final stop-nasal replacement rules.

coda	**examples**
p->m	đẹ**p** đẹp->đè**m** đẹp [ɗɛp^{212} ɗɛp^{212}]->[ɗɛ**m**^{21} ɗɛp^{212}] (rather pretty)
t->n	tố**t** tốt->tô**n** tốt [tot^{35} tot^{35}]->[to**n**^{33} tot^{35}] (rather good)
c->ɲ	sạ**ch** sạch->sà**nh** sạch [ʂɐc^{212} ʂɐc^{212}]->[ʂɐɲ^{21} ʂɐc^{212}] (rather clean)
k->ŋ	khá**c** khác->kha**ng** khác [xak^{35}xak^{35}]->xaŋ^{33} xak^{35} (rather different)

1.4 Hypotheses

In order to test the hypothesis that both full and sandhi disyllabic reduplications are prosodically right-headed, a list of disyllabic reduplications of adjectives and adverbs was constructed, consisting of disyllabic words with the same segmental composition and tones (e.g., *sáng <u>sang</u>* [ʂaŋ^{35} ʂaŋ^{35}]: bright bright) and their tone sandhi counterparts (i.e those with the same segmental composition but with alternate tones: e.g., *sang <u>sáng</u>* [ʂaŋ^{33} ʂaŋ^{35}]: fairly/rather bright). In addition, in order to provide a counterargument for the word-boundary effect (if the 2nd syllable is found to have longer duration than the 1st syllable), the base syllable of the reduplication (underlined above) is embedded in the initial position of two other control/baseline words of different segmental makeup: (1) in a word with the same tone on both syllables (e.g. *sáng chói* [ʂa̰ŋ³⁵ cɔj³⁵]; dazzlingly bright with the same rising tone) and (2) in a word with two different tones (e.g. *sáng choang* [ʂa̰ŋ³⁵ cwa̰ŋ³³]: very bright).

Table 5. Design of linguistic material. R for reduplicated syllable, B for base syllable, number 1-2 for syllable position 1st and 2nd, aa for same tone, ab for different tone, s for sandhi form, n for non-sandhi or full reduplicated form.

Full reduplication	**Tone sandhi reduplication**	**Control condition 1 Base same tone**	**Control condition 2 Base + diff. tone**
sáng sáng [ʂa̰ŋ^{35} ʂa̰ŋ^{35}]	sang sáng [ʂa̰ŋ^{33} ʂa̰ŋ^{35}]	*sáng* chói [ʂa̰ŋ^{35} cɔj^{35}]	*sáng* choang [ʂa̰ŋ^{35} cwa̰ŋ^{33}]
Rn1 Bn2	Rs1 Bs2	Baa1	Bab1

The design of the linguistic material, as shown in the Table 5, aims to test two hypotheses:

1) H1: If the reduplicated syllable (Rn1 and Rs1) is less acoustically prominent (indicated by shorter duration, less tone range, smaller intensity and a reduced or centralised vowel) than its corresponding base syllable in the reduplication forms (Bn2, Bs2) but not less prominent than the control syllables (Baa1 and Bab1), then the difference in acoustic cues in the constituent syllables of the reduplication form (Rn1 vs. Bn2 and Rs1 vs. Bs2) may be due to word-boundary effect (i.e. a syllable at the end of a word tends to be lengthened).
2) H2: If the reduplicated syllable (Rn1 and Rs1) is less acoustically prominent (indicated by shorter duration, less tone range, smaller intensity and a reduced or centralised vowel) than both its corresponding base syllable in the reduplication forms (Bn2, Bs2) and the control syllables (Baa1 and Bab1), then the stronger acoustic cues on the base syllable (Bn2 and Bs2 compared to Rn1 and Rs1, respectively) are due to accentual effect (i.e. a stressed or accented syllable tends to be longer than an unstressed syllable).

2. Methodology

2.1 Linguistic materials

There were 6 reduplications for each of the five Southern tones (6 Level-Level, 6 Rising-Rising, 6 Falling-Falling, 6 Curve-Curve, 6 Drop-Drop) and six for each of the 3 tone sandhi counterparts of the Rising-Rising (6 Level-Rising), Curve-Curve (6 Level-Curve), and Drop-Drop (6 Falling-Drop). The total number of items:

((5 reduplicated tones x 6) x 2 control words) + (3 tone sandhi x 6)) x 10 speakers = 780 items[1]

These reduplications were then embedded in an imperative carrier sentence in such a way that they all appeared utterance medial and between the same adjacent syllables (the same preceding preposition and following imperative particle) so as to avoid the final lengthening effect and tone coarticulation effect. All carrier sentences of reduplications have the same grammatical structure as follows (See appendix for the complete list of words):

V + O + *prep* + **adjective/adverb reduplication** + *imperative particle*

Pha trà cho **đậm đậm/đầm đậm** đi nhé

[fa^{33} ʈʂa^{21} cɔ^{33} **ɗʌm^{212} ɗʌm^{212}/ɗʌm^{21} ɗʌm^{212}** ɗi^{33} ɲɛ^{35}]

(Drop-Drop tones)/(Falling-Drop tones)

Make tea so as to strong strong particle

(Make tea rather strong)

Sơn tường cho **xanh xanh** (Level-Level tones) đi nhé

[ʂɤn^{33} tɨɜŋ^{21} cɔ^{33} sɐɲ^{33} sɐɲ^{33} ɗi^{33} ɲɛ^{35}]

Paint wall so as to blue blue particle

(Paint the wall rather blue)

2.2 Subjects

Ten speakers (5 males and 5 females) of Southern Vietnamese (Saigon dialect) participated in the study. They were all students aged 20-30 years at the University of Queensland who came from HoChiMinh City and had been in Australia from 4 months to 1.5 years.

2.3 Procedures

The utterance list of sentences was arranged in a pseudo-random order. Subjects were asked to speak the sentences as if they were instructing an imagined silent listener to do something. This was designed to elicit natural and rather spontaneous speech from subjects. Before the recording, subjects were provided sufficient time for familiarization and practice. They then spoke the sentence aloud in their normal speaking manner. The recording was made

[1]Note: Northerners have 6 tones, but the Southern dialect has 5 due to the merging of two contour tones (hoi and nga)

in a quiet room using a sound recording and editing computer software (Praat) at 20 kHz sampling rate and 16 bit precision.

2.4 Measurements

The reduplication words were then segmented via the Emu Speech Tools, (Cassidy 1999). First, the Emu Labeller was used to mark the edges of the target syllables and vowels, relying primarily on the spectrographic display in the Labeller. Then the Emu-R was used to extract vowel duration, vowel formants and fundamental frequencies. The following acoustic parameters were measured:

1) Duration of vowels, onset and coda
2) Vowel formants at vowel mid point
3) Fundamental frequency (F0) at 10 equidistant points on the tone contour of each syllable rime
4) F0 range (=F0 max-F0min)
5) Vowel intensity (db) at vowel mid point
6) Spectral tilt (which is plausibly linked to both increases in glottal effort and increases in perceived loudness). A more prominent syllable would be expected to be of lower spectral tilt than one of lower prominence. Spectral amplitude is measured at the first two harmonics (H1, H2) and the first three formants (A1, A2, A3). Four spectral parameters were calculated: H1-H2, H1-A1, H1-A2, H1-A3 (Stevens and Hanson's model, 1995).

2.5 Analysis

The use of reduplicated forms removed potentially confounding effects of inherent segment duration, fundamental frequency, or intensity upon the measurement of prosodic influences on these variables. The statistical analysis involves the acoustic parameters (listed above) as the dependent variables and two factors: (1) syllable positions (Rn1, Bn2, Rs1, Bs2, Baa1, Bab2) and (2) tone types (level[ngang], falling[huyền], rising[sắc], dropping[nặng], and curve[hỏi]) as independent variables, with words (30 test items) and speakers (10 speakers) as random factors. In order to account for the effect of speakers' differences and intrinsic segmental as well as tonal differences among the 30 test items, a restricted maximum likelihood (REML) applied to mixed model methodology was performed on each of the acoustic parameters. The fixed effects included syllable positions (Rn1, Bn2, Rs1, Bs2, Baa1, Bab1) and tone types (five tone types) and their two-way interactions. The random effects were speakers and words. A Tukey post-hoc test was then conducted to determine the significant differences among levels of the main fixed factors and their interaction effects, particularly the pair-wise comparisons among the six syllable positions. The use of REML overcomes the potentially serious deficiency of ANOVA based methods, which assumes that data are sampled from a random population and normally distributed. REML also avoids bias arising from maximum likelihood estimators in which all fixed effects are known without errors, consequently tend to downwardly bias estimates of variance components.

The results of the post-hoc pair-wise comparison among syllable positions are presented in appendix 2.

The results of the experiment will be presented in five main sections: (1) duration, (2) intensity, (3) spectral tilt, (4) vowel formant changes, and (5) F0 value and F0 contour. For convenience of the reader, we preface each section of the results with a brief statement of the prosodic effects expected for each of the variables.

3. Results

3.1 Duration

The ANOVA results on duration showed significant main effect for syllable positions across all syllable constituents (onset: $F(5,1516)=9.01$, $p<.0001$, vowel: $F(5,1516)=91$, $p<.0001$, coda: $F(5,1100)=35$, $p<.0001$ and whole syllable: $F(5,1516)= 66.5$, $p<.0001$), while no significance was found for tone types or the interaction effect of syllable positions x tone types.

As shown in Figure 1 and Appendix 2, there was a marginally significant effect for syllable onset; the control syllables had longer onset than both syllable constituents of the reduplicated form (Baa1~Bab1>Rn1~Rs1~Bn2~Bs2). The vowel of the reduplicated syllables was significantly shorter than the control syllables which was shorter than the corresponding base syllables (Rn1~Rs1 <Baa1~Bab1<Bn2~Bs2). The coda of the reduplicated syllables was significantly shorter than the corresponding base syllables and the control syllables (Rn1~Rs1 <Baa1~Bab1~Bn2 ~Bs2). Taken together, in terms of whole syllable duration, the reduplicated syllables were significantly shorter than the corresponding base syllables and the control syllables (Rn1~Rs1<Baa1~Bab1<Bn2~Bs2). This finding suggests that the shortening of the reduplicated syllables in comparison to their base syllables was not due simply to an absence of a phrase-final lengthening effect (i.e. constituent at the end of a word or phrase tends to be longer than a non-final constituent), but to an accent-related shortening (i.e. unstressed syllables tend to be shortened or reduced) at the level of the (compound) word.

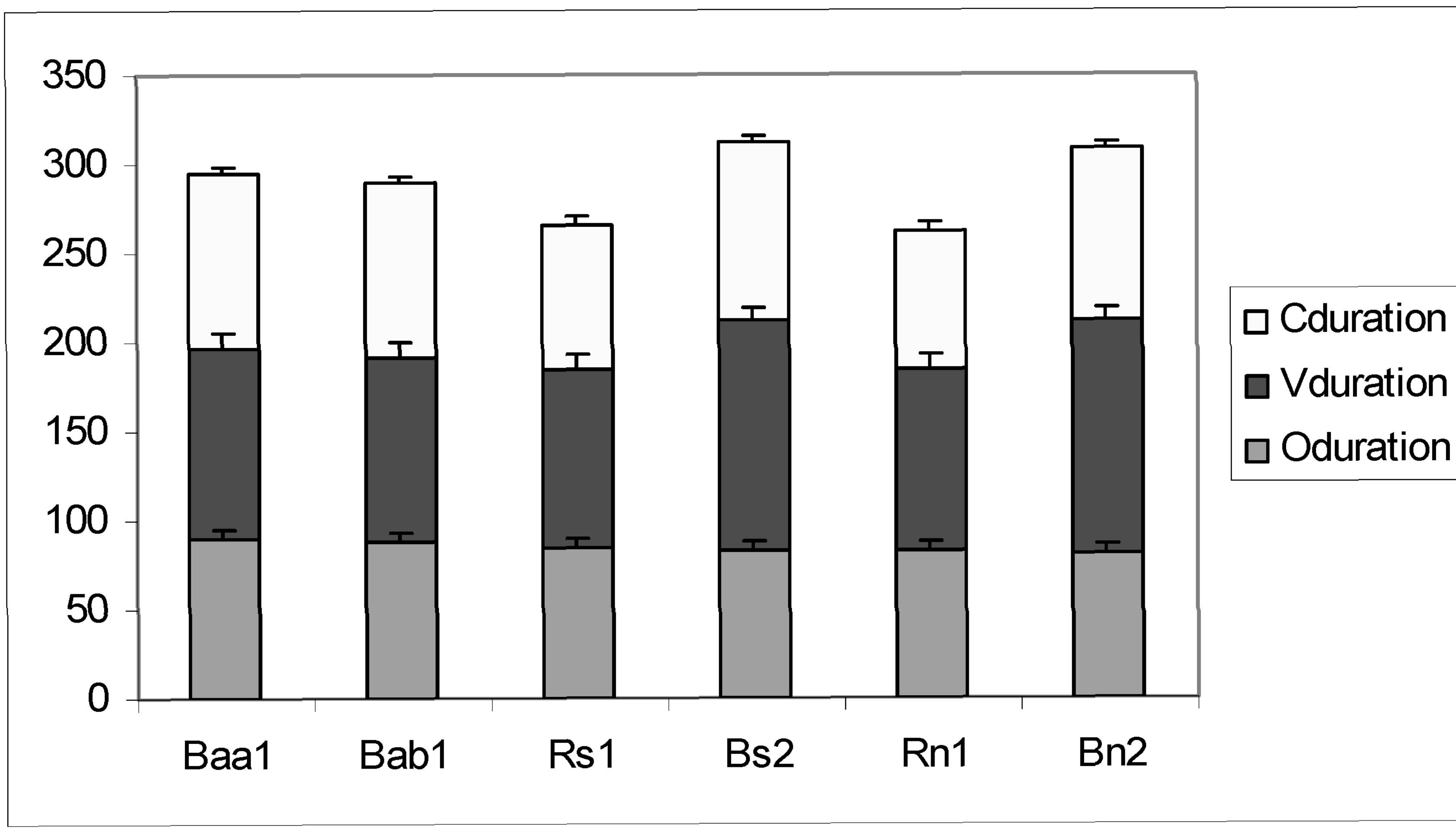

Figure 1. Mean duration (ms) of Onset, Vowel and Coda across six syllable positions.

3.2 Intensity

The ANOVA results on intensity (db) showed a significant main effect for syllable positions (F(5,1516)=20, p<.001) while no significance was found for tone types or the interaction effect between syllable positions x tone types. Post-hoc pair-wise comparisons showed that the reduplicated syllable with the sandhi tone had significantly greater intensity than the other five syllables (Rs1> Rs2~Baa1~Bab1~Rn1~Bn2, see Appendix 2). This result suggests an effect due to tonal variation rather than a prominence effect since this tone sandhi syllable had a different tone from five other syllables of the same tone. A detailed analysis by tone types (for each sandhi pair: level-curve, falling-dropping, level-rising) showed that the significant effect held for only two tone pairs: level-curve and falling-dropping (Rs1>Bs2) but not for the level-rising sandhi form (Rs1~Bs2: insignificant). Therefore, this intensity effect can be explained as an artefact due to tonal variation because the curve and dropping tones tend to be creaky/glottalised and intensity(db) tends to correlate with tonal F0 (Vũ 1981)

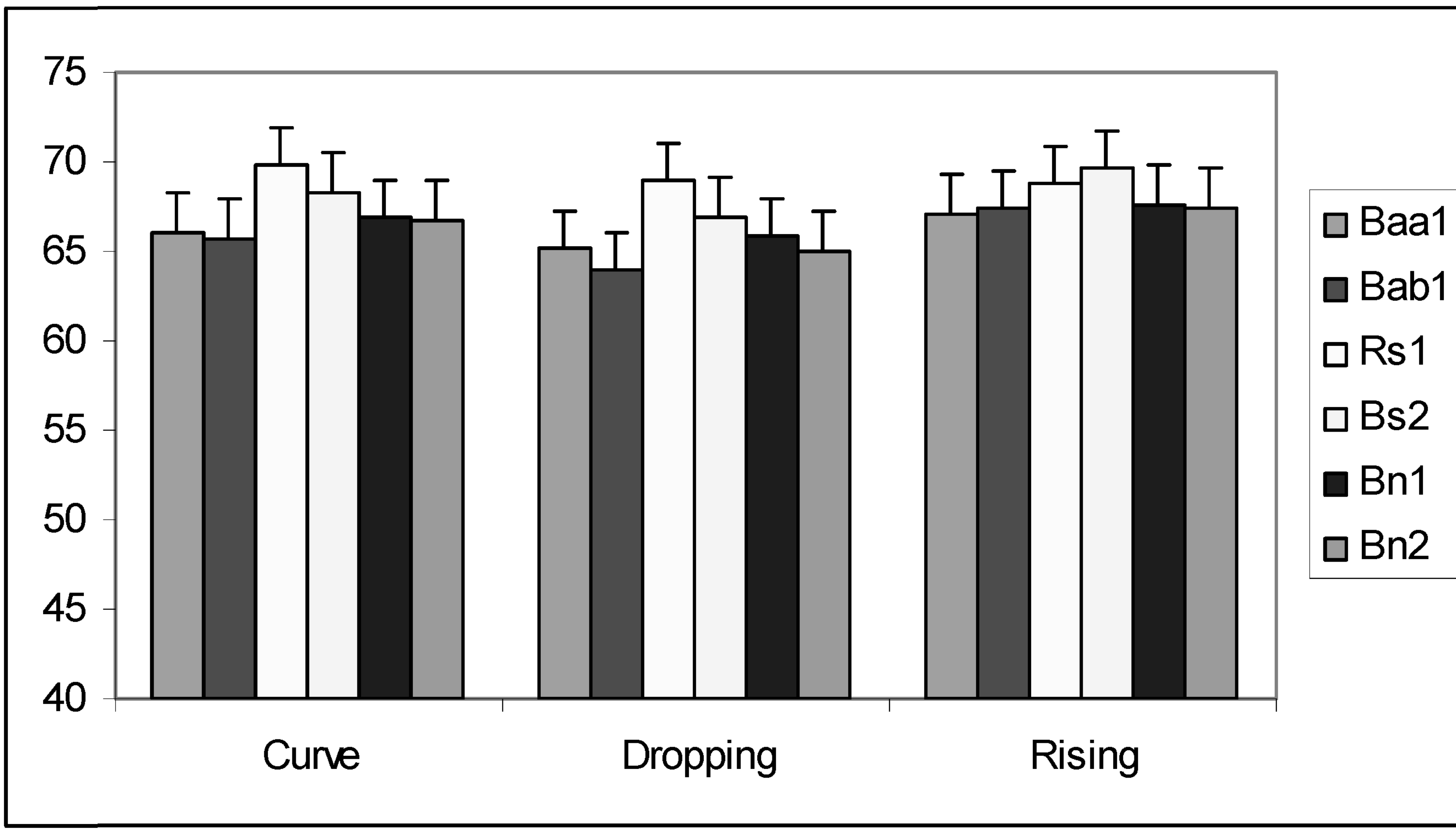

Figure 2. Mean values of intensity (db) across six syllable positions of the three dynamic tones that undergo tone sandhi.

3.3 Spectral tilt

A more prominent syllable would be expected to be of lower spectral tilt than one of lower prominence. The ANOVA results of four spectral parameters (H1-H2, H1-A1, H1-A2, H1-A3) showed significant main effect for syllable positions across all spectral slope measures (H1-H2: $F(5,1516)= 4.8$, $p<.001$; H1-A1: $F(5,1516)=14$, $p<.0001$; H1-A2: $F(5,1516)= 13$, $p<.0001$; H1-A3: $F(5,1516)= 9$, $p<.0001$) while no significance was found for tone types or the interaction effect of syllable positions x tone types. Post-hoc pair-wise comparisons showed (see Figure 3 and Appendix 2) that the reduplicated syllable with the sandhi tone had significantly higher spectral tilt than all other syllables (H1-H2, H1-A1, H1-A2, H1-A3: Rs1> Rs2~Baa1~Bab1~Rn1~Bn2) . This tone sandhi syllable had a different tone from the other five syllables of the same tone. A detailed analysis by tone types (for each sandhi pair: level-curve, falling-dropping, level-rising) showed that the significant effect held for all three tone pairs: the sandhi syllables had higher spectral tilt value than their corresponding base syllables, suggesting that the sandhi syllables were less prominent or less loud than their base syllable. This result, on the one hand, suggests that the significant difference may be due to tonal variation (tone sandhi) but, on the other hand, seems to imply an underlying prominence reduction by means of tone sandhi (i.e., tone sandhi enhances prominence difference in sandhi reduplication forms).

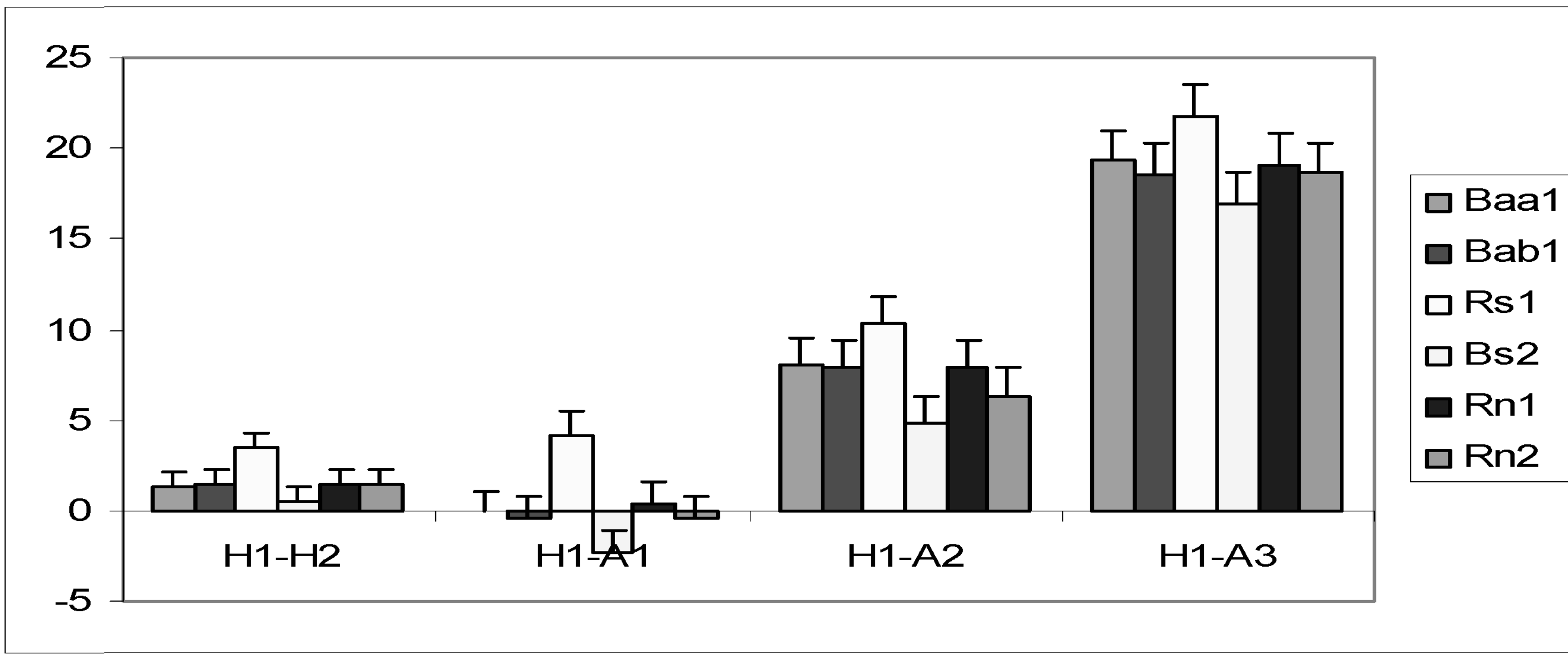

Figure 3a. (top) Mean values of spectral tilt values across six syllable positions.

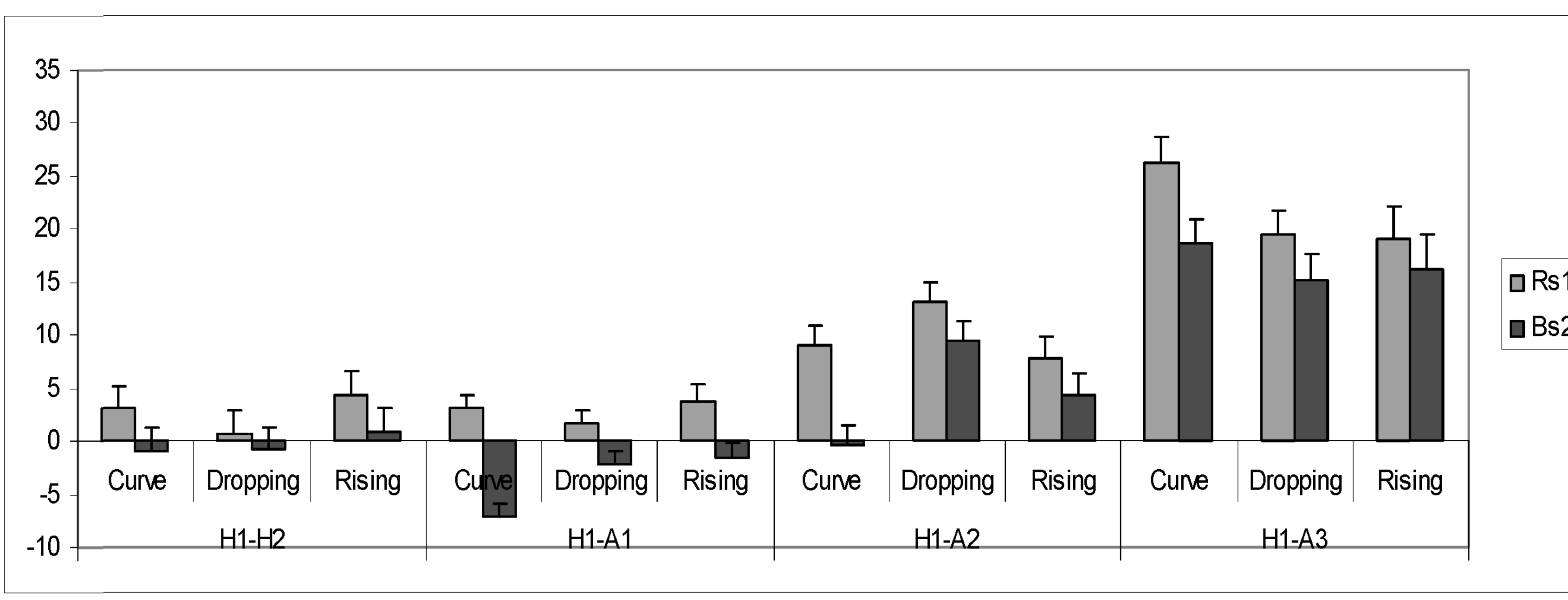

Figure 3b. (bottom) Mean values of spectral tilt values of the components of the sandhi forms.

3.4 Vowel formants

Prosodically prominent syllables may be expected to be accompanied by syllable nuclei that contain more clearly articulated vowels that attain more peripheral targets in a perceptually scaled F1- F2 formant space. It would be predicted that the average Euclidean distance between target vowels in a position of lower prosodic prominence would be significantly less than those in a higher position of prosodic prominence. We hypothesised that: a) vowel formant targets in second syllable (base) position would be more peripheral than corresponding vowel formant targets in first syllable (reduplicated) position, and that, b) vowel formant targets in first syllables of partial reduplications (tone sandhi syllables) may be less peripheral than their fully reduplicated (non-tone sandhi) counterparts.

An ANOVA analysis was performed on the Euclidean distance of vowel pairs (Rs1-Bs2): components of the tone sandhi form, Rn1-Bn2: components of the full reduplication, (Rs1-Bab1) and (Rn1-Bab1): Euclidean distance between the sandhi and non-sandhi reduplicated vowel and the control vowel in word-initial position respectively. A preliminary analysis found no significant difference between the vowels of the two word-initial control syllables (Baa1 and Bab1) and thus only one of them (Bab1) was included in the analysis and the vowel plot for spatial clarity of graphical presentation.

The ANOVA results and the formant plot (Figure 4) showed three main things. First, the vowel of the reduplicated syllables (Rs1 and Rn1) tended to be more centralised than their base syllables (Bs2 and Bn2, respectively). Second, the vowel of the word-initial control syllables (Bab1) seemed to cluster with those of the base syllables. Third, the Euclidean distance between components of the tone sandhi form was significantly larger than that between components of the full reduplication (Rs1-Bs2>Rn1-Bn2, $p<.03$). This is further supported by the fact that the Euclidean distance between the sandhi vowel and the control vowel was significantly larger than that between the non-sandhi reduplicated vowel and the control vowel (Rs1-Bab1> Rn1-Bab1, $p<.03$). This result indicated that: (1) the reduplicated syllables were centralised/reduced in comparison with the base syllables and (2) the sandhi vowels were more reduced and/or more centralised than the non-sandhi reduplicated vowels.

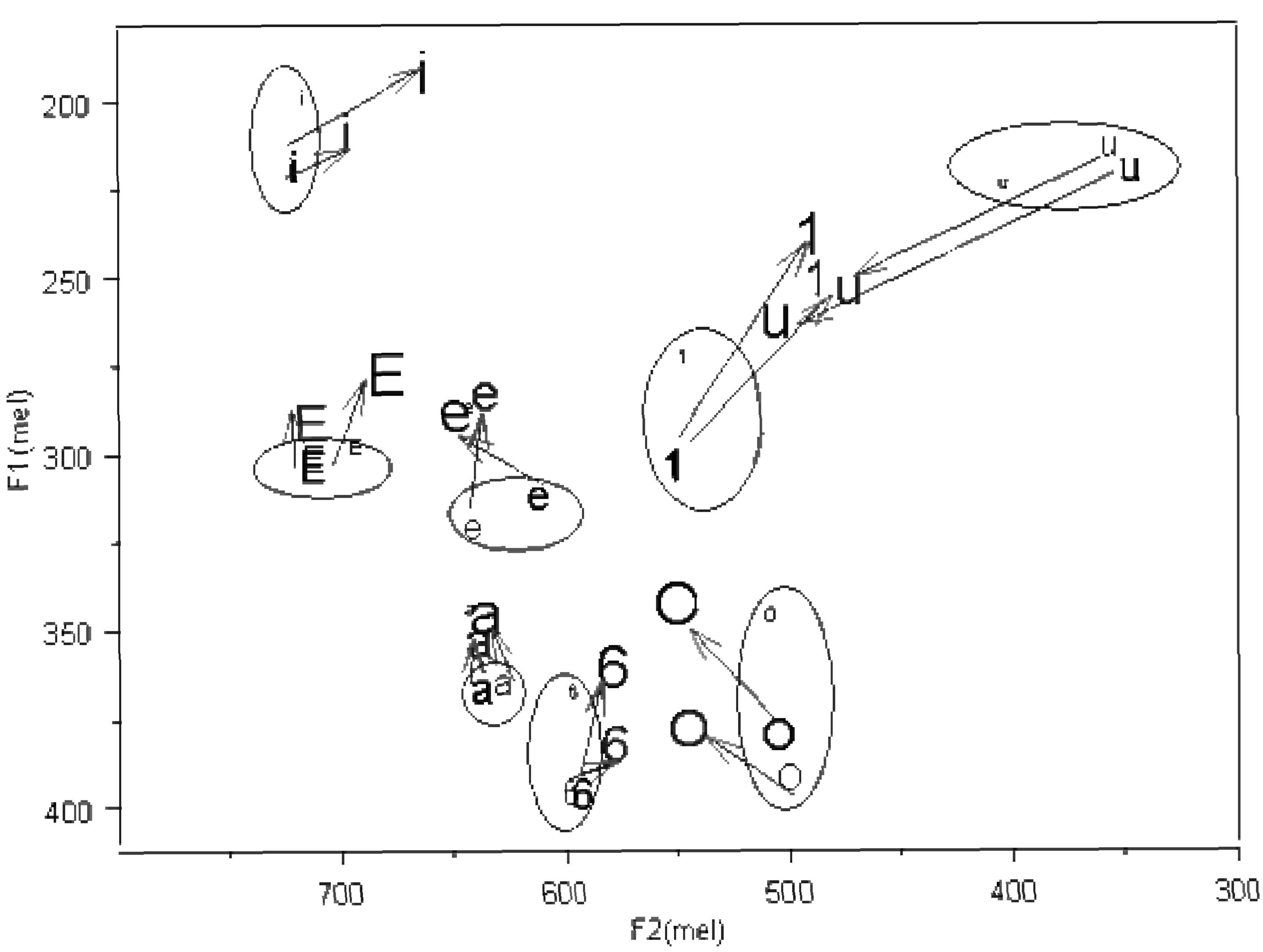

Figure 4. Formant plot of vowels in six positions: smallest font: Bab1: formant targets in the vowel in control initial position; medium unbolded font: Bn2: formant targets in the base vowels of the full reduplication word; medium bolded font: Bs2: formant targets in the base vowels of the partial reduplication words with tone sandhi; larger font: Rn1: formant targets in full reduplicated vowels; largest font: Rs1: formant targets in vowels undergoing tone shift in tone sandhi. Vowel symbols: a:/ɐ:/, 6:/ɐ:/, O:/ɔ/, E:/e/, e:/ɛ/, i:/ɩ/, 1:/ɨ/, u:/u/.

3.5 F0 range and contours

The basic prediction for F0 contours is that the dynamic range of F0 change would be expected to be greater on tones in positions of prosodic prominence. The effects of tonal sequencing or down-step and boundary marking need to be taken into account in interpreting F0 contours, as well as inherent attributes of particular tones.

Since only reduplications with the three dynamic tones (curve, dropping, rising) have a sandhi counterpart while those with the two even tones(level and falling) do not, the data were split into two separate data sets (a curve-dropping-rising set and the level-falling set) and submitted to two separate ANOVAs. The ANOVA results on F0 range showed significant main effects of syllable positions, tone types and their interactions for both data sets (curve-dropping-rising: syllable positions: $F(5,1040)=21$, $p<.0001$; tone types: $F(2,1040)=28$, $p<.0001$; syllable positions x tone types: $F(10,1040)=15$, $p<.0001$; level-falling: $F(3,453)=34$, $p<.0001$; tone types: $F(1,453)=26$, $p<.0001$; syllable positions x tone types: $F(3,453)=18$, $p<.0001$). Post-hoc pair-wise comparison among syllable positions were also conducted (Appendix 2). Figure 5 shows the pair-wise comparison of mean F0 range among syllable positions for each tone type (vertical bar) and the mean F0 contour plotted on normalised duration (horizontal line).

Level tone (Figure 5a): In full reduplications of two level tones, both syllables generally have a flat contour with a slight fall at the end. The contour of the base syllable (Bn2) is slightly lower and longer than that of three other syllables in word initial position (Baa1, Bab1, Bn1). However, there was no significant difference in F0 range among the syllables (Baa1~Bab1~Rn1~Bn2)

Falling tone (Figure 5b): The base syllable (Bn2) has lower F0 onset than that of the other three initial counterparts and thus has a flatter F0 fall. By contrast, the three initial syllables (Baa1, Bab1, Bn1) have steeper fall and a significantly larger F0 range (Baa1~Bab1~Rn1>Bn2, $p<.0001$)

Dropping tone (Figures 5c and 5d): This dropping or steep falling tone has a steeper fall on both syllables compared with the falling tone. The non-checked dropping tone (i.e., on syllables ending with sonorants, Figure 5c) had a steep fall and a gentle rise at the end, while the checked counterpart (i.e., on syllables ending with stops, Figure 5d) was shorter, consistent with previous description of F0 contour of dropping tone of the Southern dialect (Vũ 1981). The second tone (on the base syllable) was lower than those of the initial syllables. However, there was no significant difference in F0 range among syllable positions (Baa1~Bab1~Rs1~Rn1~Bs2~Bn2). The F0 contour of the tone-sandhi reduplicated (Bs1) was longer because it was on sonorant final syllable (ending in homorganic nasals) in contrast to a stop-final counterpart.

Rising tone (Figures 5e and 5f): The F0 contour of the rising tone has a level followed by a sharp rise in the final part. In checked syllables (ending with stops, Figure 5f) the rising tone was shorter while the sandhi tone (Rs1) was longer because it was on syllables ending with the homorganic nasal.

Generally, the base syllables (Bs2 and Bn2) had longer F0 contour, higher and more sharply rising tail and thus significantly larger F0 range than their reduplicated counterparts in initial positions (F0 range: Bs1<Bn1< Bs2~Bn2~ Baa1~Bab1, p<.01).

Curve tone (Figure 5g): The F0 contour of the so-called curve tone fell fairly steeply and then rose back to the original level, sometimes with creakiness. The base syllable (Bs2 and Bn2) had longer F0 contour, fell lower and more steeply and then rose higher than their reduplicated counterparts. Therefore, the base syllable had significantly larger F0 range than their reduplicated and control counterparts in initial positions (F0 range: Bs1<Bn1< Baa1~Bab1<Bs2~Bn2, p<.001).

In brief, the statistical results on F0 range and the examination of F0 contour showed four main things. First, the base syllables (Bs2, Bn2) tended to have longer tone/F0 contour than both the reduplicated syllables (Rs1 Rn1) and the word-initial control syllables (Baa1, Bab1), consistent with the result on syllable duration presented in section above. Second, the base syllable of the rising and curve tone tended to have a larger F0 range than their reduplicated counterparts. By contrast, the F0 contour of the base syllable with falling and dropping tone, though falling lower, had smaller F0 range than their initial reduplicated counterparts as a result of a flatter contour with lower F0 onset. Third, there was no significant difference in terms of F0 range and F0 contour between the two control syllables even though they were followed by two different tones: one followed by the same tone and the other followed by a different tone (Baa1 and Bab1). Even though the two control syllables were similar to reduplicated syllables in terms of a shortened tone length, they were generally more similar to the base syllables in terms of F0 range and fuller tonal shape. This result suggests that the reduplicated syllables had a more "reduced" tone in comparison to that of the base syllables. Fourth, the examination of tone contour in tone sandhi minimal pairs: dropping-dropping vs. falling-dropping (Figures 5c and 5d), and rising-rising vs. level-rising (Figures 5e and 5f), and curve-curve vs. level-curve (Figure 5g) shows that in tone-sandhi words, the tone contour of the second syllable tends to start from the ending point of the tone contour in the previous syllable. In other words, there is a smoother transition between tones in tone-sandhi words. For example, in level-dropping word (Figures 5c and 5d), a sandhi counterpart of dropping-dropping, the second dropping tone falls further from the previous falling tone. In level-rising, a sandhi of rising-rising, the second rising tone begins rising from where the previous level tone ends. Similarly, in level-curve word, a sandhi form of curve-curve, the second curve tone falls from where the level tone ends. In contrast, in non-sandhi full reduplication forms such as dropping-dropping, rising-rising and curve-curve, the second tone contour repeats the whole process of the first one except in the case of the two uni-directional tones: level-level and falling-falling (Figures 5a and 5b), the second tone simply continues staying level (in level-level) or declines a little from the first. This shows that there is tonal coarticulation in sandhi forms compared to their non-sandhi counterparts, which may stem from the ease of articulation and a tendency to avoid tone clashes. This result, together with the investigators' auditory observation that many speakers in this study tend to produce the sandhi forms in sentences in which the non-sandhi counterparts are embedded, implies three things. First, the sandhi forms stem from ease of articulation and probably also for the sake of perceptual salience which needs to be investigated in a perceptual experiment. Second, the fact that many speakers produce the sandhi form as an alternative for the non-sandhi form indicates that the sandhi forms are produced as phonetic variants of the non-sandhi counterparts, suggesting that the sandhi forms are phonologised from tonal assimilation as a result of ease of articulatory constraint. Thirdly, the fact that the reduplicated syllable is the target of the tone sandhi process supports the main finding that disyllabic forms in Vietnamese are right headed.

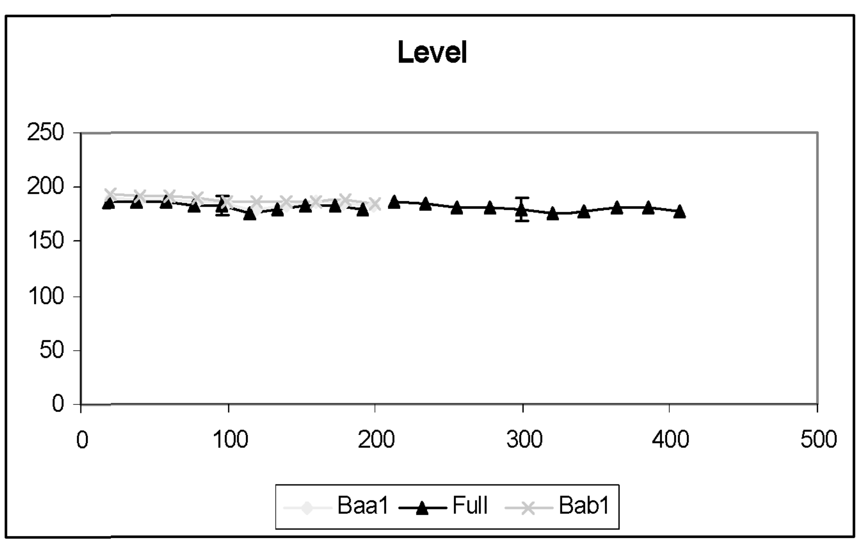

Figure 5a.

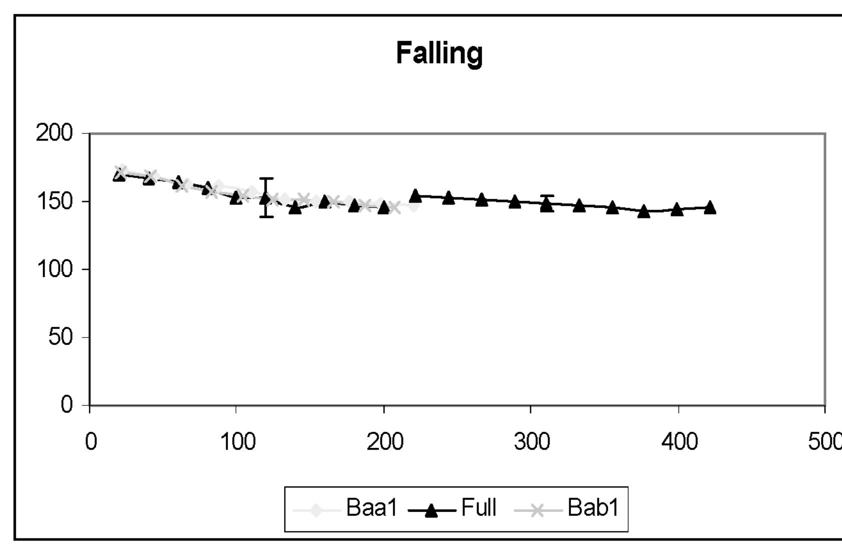

Figure 5b.

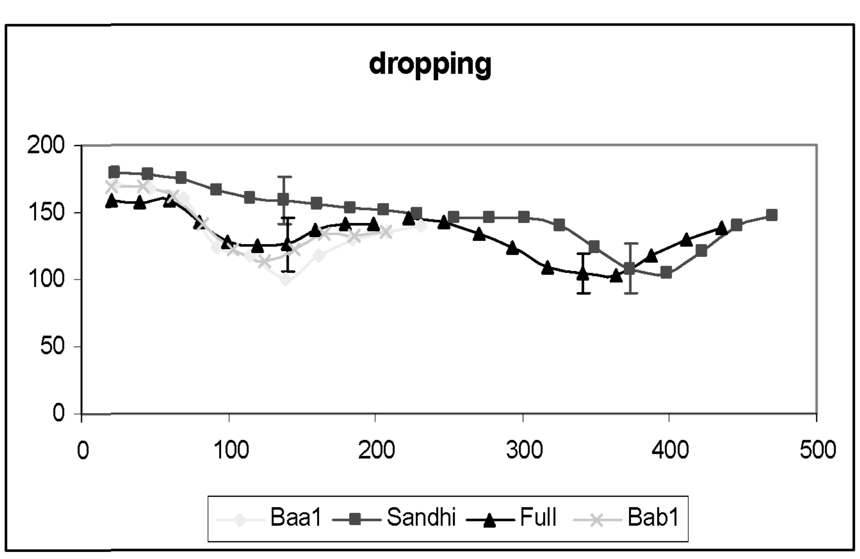

Figure 5c.

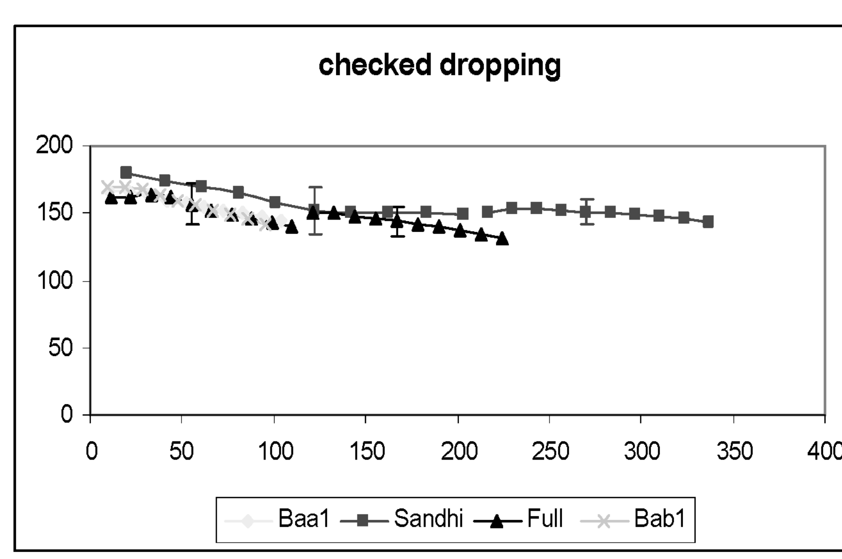

Figure 5d.

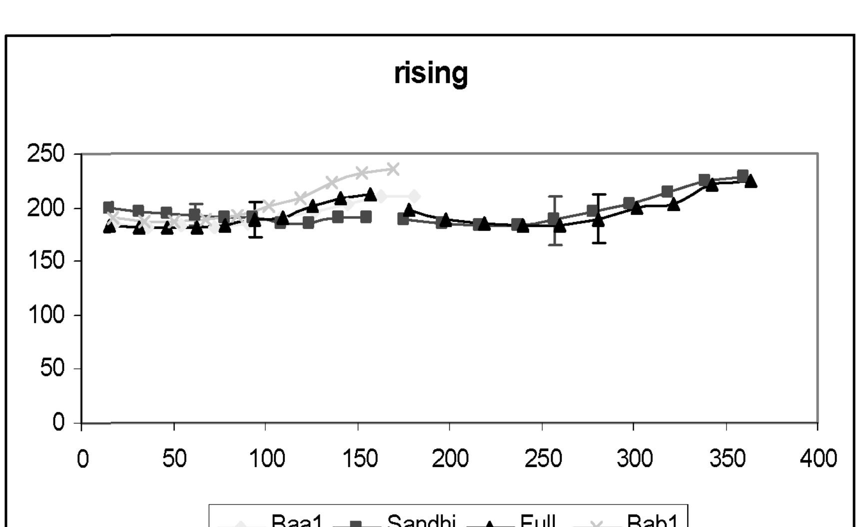

Figure 5e.

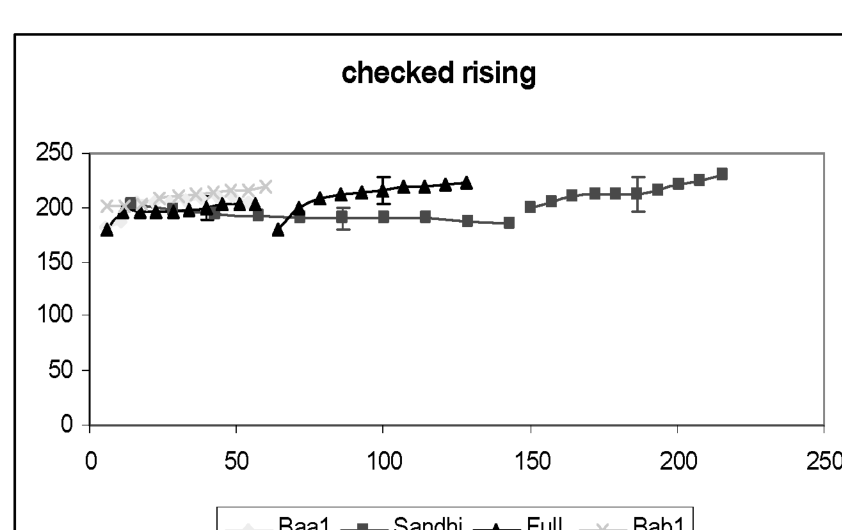

Figure 5f.

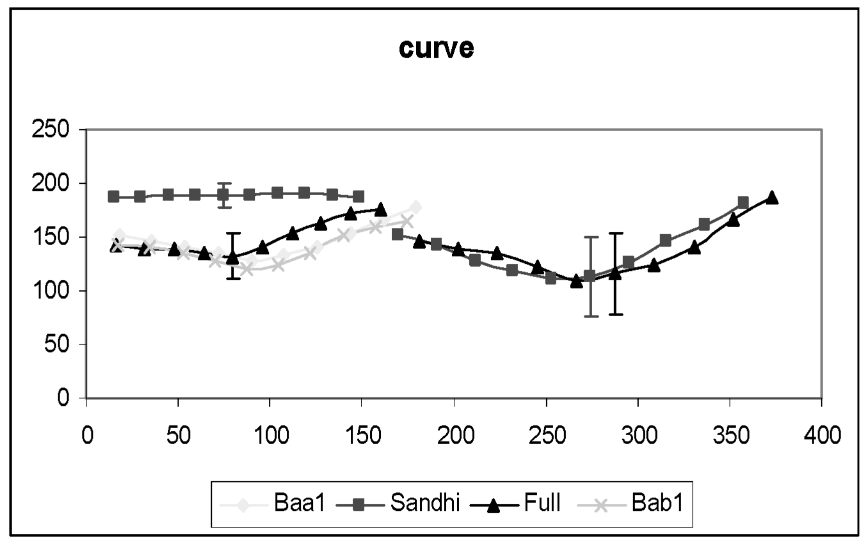

Figure 5g.

Figure 5. The average F0 contours and F0 range of the six syllable positions under investigated. Vertical bar: mean F0 range (Hz). Horizontal lines: mean F0 contours (Hz). X- axis: tone duration (ms). Y- axis: mean F0 in Hz. Baa1 and Bab1: tones of the two word-initial control syllables, sandhi: tones of the partial reduplication words with a sandhi tone, full: tones of the full reduplication words: points 1-10: the 1st syllable, points 11-20: the second syllable.

4. Discussion

First, in terms of whole syllable duration, the reduplicated syllables were significantly shorter than the control syllables which were shorter than corresponding base syllables (Rn1~Rs1<Baa1~Bab1<Bn2~Bs2). The point of discussion here is whether the lengthening of the base (second) syllables in comparison to the reduplicated syllables is due to a "word boundary lengthening" effect (boundary tone) or to a temporal effect of accentual prominence. The above result together with the insignificant difference between the coda of the word-initial control syllables in comparison with the word-final base syllables suggests that the shortening of the reduplicated syllables in comparison to their base syllables was not due to lack of final lengthening or being in a non-final position but due to a reduction, and thus rejects hypothesis 1 and supports hypothesis 2.

Second, the results on spectral tilt showed that the reduplicated syllable with a tone sandhi had greater spectral tilt than the base syllables, suggesting that the sandhi syllables were less prominent or less loud than their base syllables. This result, on the one hand, suggests that the significant difference may be due to tonal variation (tone sandhi) but, on the other hand, seems to imply an underlying prominence reduction by means of tone sandhi.

Third, the results on vowel formant change showed that the vowels of the reduplicated syllables were centralised in comparison with that of the base syllables and the sandhi vowels were more centralised than the full (non-sandhi) reduplicated vowels while the vowels of the word-initial control syllables clustered in the same space as the base vowels, suggesting that the reduplicated vowels were reduced to promote right-headed prominence effect which was further enhanced by tone sandhi.

Fourth, the results on F0 showed that the base syllables tended to have longer tone/ F0 contour, larger F0 range and more fully realised tone contour than the reduplicated syllables particularly in the two dynamic tone pairs (higher and more sharp rise of the second rising tone in the rising-rising reduplication, a deeper fall and higher rise in the second curve tone in curve-curve words). The lowering of F0 contour on the second syllable compared to that of the first for the three uni-directional tone pairs: level-level, falling-falling, and dropping-dropping can be interpreted in different ways. First, it might be interpreted as a down-step or pitch declination effect at word boundary. Second, it may show a prominence effect on the second syllable as a result of downward pitch expansion as found in Mandarin Chinese, in which tonal range is expanded both upward and downward under prominence effect: high tones become higher and low tones become lower (Shen 1990, Shih 1988). Third, the further lowering of the F0 on the second syllable can also be attributed to anticipatory or carry-over coarticulation effect due to the low offset of the preceding tone as found in Bejing Mandarin by Xu (1997) "a tone with a low offset lowered the f0 of the following tone, and a tone with a high offset raised the f0 of the following tones" (p.74). In addition, even though the two control syllables were similar to reduplicated syllables in terms of a shortened tone length, they were generally more similar to the base syllables in terms of F0 range and fuller tonal shape. This F0 result suggests that the reduplicated syllables had a more "reduced" tone in comparison to that of the base syllables. Furthermore, comparative examination of the pitch contours between fully reduplicated syllables and their sandhi counterparts showed a smoother transition in tonal contour of the latter, suggesting tone-sandhi may result from one or more of the following: a) phonologized tone assimilation to avoid tone clash, b) tonal coarticulation, in the interests of ease of articulation, and possibly also, c) 'de-accenting' to promote right syllable perceptual salience (headedness).

In brief, the results of the acoustic analysis provide evidence supporting hypothesis 2 that the difference in duration, spectral tilt, vowel formant and F0 values between the reduplicated syllables and the base syllables is due to an accentual effect rather than a word boundary effect. In other words, the reduplicated syllables were shown to be acoustically reduced in comparison to the base syllables. Furthermore, the difference between the sandhi forms in comparison with their full (non-sandhi) reduplications in terms of spectral tilt, vowel quality in addition to the tone change suggests that tone sandhi in reduplication words is a form of 'de-accenting' to promote right syllable perceptual salience (headedness). However, this needs to be confirmed in a perceptual study.

5. Conclusion

The acoustic parameters examined in this study support the conclusion that the second syllable of Vietnamese reduplication forms is more acoustically prominent. In other words, if there is a word stress pattern in these Vietnamese disyllabic reduplications, it will be right-headed. This prominence pattern is further supported by the tone sandhi which is confined to first syllables, and which can be explained on both phonetic and phonological grounds. First, phonetically, tone sandhi is motivated by tonal assimilation and preferential preservation of tonal contrast on the second syllable. Second, phonologically, tone sandhi has been postulated to occur on weak syllables (Ngô 1984; Rose 1990; Chen 2000); particularly as found in this study, tone sandhi is accompanied by enhanced vowel reduction and less articulatory effort (spectral tilt), suggesting that "tone sandhi is a reduction phenomenon occurring on prosodically weak positions"(Shih 2005). Perceptually, in a study of Bejing Mandarin, in the majority of cases, the second syllables were perceptually judged to be more prominent than those in the first (cf. Luke, Chen, Lee, and Shen 2001). From the first author's auditory observation as a native speaker, it is predicted that the same results can be obtained for Vietnamese, however, this needs to be further investigated in an empirical perceptual study. The acoustic results of this study show phonetic evidence of prosodic constituency at the level of the bisyllabic word in Vietnamese and has implication for theory of prosodic structure. However, the status of the prosodic unit - whether it constitutes a stress foot or a phonological word – is yet to be determined and awaits further study.

REFERENCES

Aves, Mark 1999. "What's so Chinese about Vietnamese." In Graham Thurgood, ed., *Papers from the Ninth Annual Meeting of the Southeast Asian Linguistic Society* 221-242.

Burton, Strang 1992. *Reduplication and the Representation of Tone in Vietnamese.* ms., Brandeis University.

Cassidy, S. 1999. "Compiling multi-tiered speech databases into the relational model: Experiments with the Emu system." *In Proceedings of Eurospeech'99*, 6:2239-2242.

Chao, Y.R. 1930. "A System of Tone Letters." *LMP* 45:24-27

Chaudhary, C. C. 1983. "Word stress in Vietnamese: A preliminary investigation." *IL* 44:1-10.

Chen, Matthew Y. 2000. *Tone Sandhi: Patterns Across Chinese Dialects.* Cambridge: Cambridge University Press.

Đỗ, T. D. 1986. *Elements Pour une E'tude Comparative de l' Intonation en Francais et en Vietnamien: L'accent de Mots en Vietnamien.* Memoire de DEA, Universite' de Paries 3 ILPGA, Paris.

Đỗ, T. D; Trần, T. H., and G. Boulakia 1998. "Intonation in Vietnamese." In Hirst, D. and Cristo, A. D., eds., *Intonation Systems: A Survey of Twenty Languages* 395-416. Cambridge University Press.

Đoàn, T. T. 1977. *Ngữ Âm Tiếng Việt (Vietnamese Phonology).* Hanoi: NXB Đại học và Trung học chuyên nghiệp.

Gsell, R. 1980. *Remarques Sur la Structure de l' Espace Tonal en Vietnamien du Sud (Parler de Saigon).* Cahiers d'etudes Vietnamiennes 4. Univversite' Paris 7.

Han, M. S. & K.-O. Kim 1974. "Phonetic variation of Vietnamese tones in disyllabic utterances." *JP* 2:223-232.

Haudricourt, Andre G. 1954. "Sur d'origine de le ton de Vietnamien." *JA* 242:69-82.

Hồ, L. 2002. *Cấu Tạo Từ Tiếng Việt Hiện Đại (Word Formation in Modern Vietnamese).* Hanoi: Khoa học xã hội Press.

Hoàng, T. and Hoàng M. 1975. *Remarques Sur la Structure Phonologique du Vietnamien.* Essais Linguistiques, Etudes Vietnamiennes 40, Hanoi.

Hoàng, T. C. 1989. *Tiếng Việt Trên các Miền Đất Nước (Vietnamese Dialectology).* Hanoi: Khoa học xã hội Press.

Hulst, van der 2005. "Exponents of accentual structure." *Invited paper to the IIAS Conference: between Stress and Tone*, Leiden, the Netherlands, June 2005.

Jones, R. B., & Huỳnh, S. T. 1960. *Introduction to Spoken Vietnamese.* Washington, D.C.

Luke, K.K, F. Chen, W. Lee, and L.Q. Shen 2001. "A phonetic study of the prosodic properties of Bisyllabic compounds in Hong Kong cantonese." *Proccedings of 5th National Conference on Modern Phonetics*, Beijing, China.

Ngô, T. N. 1984. "The syllabeme and pattern of word formation in Vietnamese." Ph.D. dissertation, New York University.

Nguyễn, D. L. 1970. *A Contrastive Phonological Analysis of English and Vietnamese (Pacific Linguistics Series, No 8).* Canberra: Australian National University.

Nguyễn, T. C. 1981. *Ngữ Pháp Tiếng Việt: Tiếng-Từ Ghép-Đoản Ngữ (Vietnamese Syntax: Word-Compound-Phrase).* Hanoi: Đại học vat rung học chuyên nghiêp.

Nguyễn, V. L. & Edmondson, J. 1997. *Thanh Điệu và Chất Giọng Trong Tiếng Việt Hiện Đại (The Tones and Voice Quality in Modern Northern Vietnamese: Instrumental Case Studies).* Ngôn ngữ 1:1-16. Hanoi.

Phạm, Andrea Hoa 2003. *Vietnamese Tone-A New Analysis.* New York: Routledge.

Rose, Phil. 1990. "Acoustics and phonology of complex tone sandhi." *Phonetica* 47:1-35.

Seitz, P. 1986. "Relationships between tones and segments in Vietnamese." Ph.D. dissertation, University of Pensylvania (UMI).

Shen, X. S. 1990. "Tonal coarticulation in Mandarin." *JP* 15:281-295.

Shih, C. L.1988. "Tone and intonation in Mandarin." In working papers of the *Cornell Phonetics Laboratory* 3:83-109.

Shih, C. 2005. "Understanding phonology by phonetic implementation." *Proceedings of Interspeech 2005*, Lisbon, Portugal. Sept 4-8.

Stevens K.N., H.M. Hanson 1995. "Classification of Glottal Vibration from Acoustic Measurements." In Fujimura O., Hirano H., eds., *Vocal Fold Physiology: Voice Quality Control.* Singular Publishing Group, San Diego.

Thompson, L. 1987. *A Vietnamese Reference Grammar.* Honolulu: University of Hawaii Press.

Trần, H. M. 1969. "Stress, tone and intonation in South Vietnamese." Ph.D. dissertation, Australian National University.

Viện Ngôn Ngữ Học, 1995. *Từ Điển Từ Láy Tiếng Việt (Dictionary of Vietnamese Reduplicative Words).* Hà Nội: Trung Tâm Khoa Học Xã Hội và Nhân Quốc Gia.

Vũ, T. P. 1981. "The acoustic and perceptual nature of tone in Vietnamese." Ph.D. dissertation, Australian National University, Canberra.
Vũ, T. P. 1982. "Phonetic properties of Vietnamese tones across dialects." *Papers in South-East Asian Linguistics* 8:55-76.
Vương, L.H. & Hoàng D. 1996. *Ngữ Âm Tiếng Việt (Vietnamese Phonology).* Hanoi, Đại học sư phạm.
Xu, Y. 1997. "Contextual tonal variations in Mandarin." *JP* 25(1):61-83.

Received: 23 July 2006

School of English, Media studies, and Art history
University of Queensland
St Lucia, QLD 4072, Australia
<j.ingram@uq.edu.au>

Appendix 1: List of test words.

Tones	**Full reduplications**	**Sandhi reduplication**	**Control condition1 Base + same tone**	**Control condition 2 Base + different tones**
Curve (hỏi)	đỏ đỏ ɗɔ^{214} ɗɔ^{214} nhỏ nhỏ ɲɔ^{214} ɲɔ^{214} cũ cũ ku^{214} ku^{214}* thẳng thẳng t̪ʰɐŋ^{214} t̪ʰɐŋ^{214} vững vững vɨŋ̟^{214} vɨŋ̟^{214}* xỉn xỉn sin^{214} sin^{214}	đo đỏ ɗɔ^{33} ɗɔ^{214} nho nhỏ ɲɔ^{33} ɲɔ^{214} cu cũ ku^{33} ku^{214} thăng thẳng t̪ʰɐŋ ^{33} t̪ʰɐŋ^{214} vưng vững vɨŋ̟^{33} vɨŋ̟^{214} xin xỉn sin^{33} sin^{214}	đỏ thẳm ɗɔ^{214} t̪ʰɐm^{214} nhỏ nhuyễn ɲɔ^{214} ɲwien^{214} cũ kỹ ku^{214} ki^{214} thẳng hẳn t̪ʰɐŋ^{214} hɐŋ^{214**} vững chải vɨŋ̟^{214} caj^{214} xỉn hẳn sin^{214} hɐŋ^{214**}	đỏ chói ɗɔ^{214} cɔj^{35} nhỏ mứt ɲɔ^{214} mɨk̟^{35} cũ rích ku^{214} ric^{35} thẳng thớm t̪ʰɐŋ^{214} t̪ʰɤm^{35} vững chắc vɨŋ̟^{214} cɐk^{35} xỉn say sin^{214} ʂɐj^{214}
Dropping (nặng)	lạnh lạnh lɐɲ^{212} lɐɲ^{212} nhẹ nhẹ ɲɛ^{212} ɲɛ^{212} rộng rộng roŋ͡m^{212} roŋ͡m^{212} nhạt nhạt ɲak^{212} ɲak^{212} đẹp đẹp ɗɛp^{212} ɗɛp^{212} sệt sệt ʂet^{212} ʂet^{212}	lành lạnh lɐɲ^{21} lɐɲ^{212} nhè nhẹ ɲɛ^{21} ɲɛ^{212} rồng rộng roŋ͡m^{21} roŋ͡m^{212} nhàn nhạt ɲaŋ^{21} ɲak^{212} đèm đẹp ɗɛm^{21} ɗɛp^{212} sền sệt ʂen^{21} ʂet^{212}	lạnh bụng lɐɲ^{212} ɓuŋ͡m^{212} nhẹ nợ ɲɛ^{212} nɤ^{212} rộng rinh roŋ͡m^{212} riɲ^{21} nhạt phèo ɲak^{212} fɛw^{21} đẹp tuyệt ɗɛp^{212} twiek^{212} sệt đặc ʂet^{212} ɗɐk^{212}	lạnh buốt lɐɲ^{212} ɓuɜk^{35} nhẹ túi ɲɛ^{212} tuj^{35} rộng tuếch roŋ͡m^{212} twec^{35} nhạt thếch ɲak^{212} t̪ʰec^{35} đẹp mắt ɗɛp^{212} mɐk^{35} sệt cứng ʂet^{212} kɨŋ̟^{35}
Rising (sắc)	sáng sáng ʂaŋ̟^{35} ʂaŋ̟^{35} nóng nóng nɔŋ^{35} nɔŋ^{35} khó khó xɔ^{35} xɔ^{35} chắc chắc cɐk^{35} cɐk^{35} sát sát ʂak^{35} ʂak^{35} khít khít xit^{35} xit^{35}	sang sáng ʂaŋ̟^{35} ʂaŋ̟^{35} nong nóng nɔŋ^{33} nɔŋ^{35} kho khó xɔ^{33} xɔ^{35} chăn chắc cɐŋ^{33} cɐk^{35} san sát ʂaŋ^{33} ʂak^{35} khin khít xin^{33} xit^{35}	sáng chói ʂaŋ̟^{35} cɔj^{35} *nóng* ấm nɔŋ^{35} ʌm^{35} *khó* lắm xɔ^{35} lɐm^{35} *chắc* cứng cɐk^{35} kɨŋ̟^{35} *sát* khít ʂak^{35} xit^{35} *khít* nút xit^{35} nut^{35}	sáng choang ʂaŋ̟^{35} cwaŋ̟^{33} *nóng* sôi nɔŋ^{35} ʂoj^{33} *khó* khăn xɔ^{35} xɐn^{33} *chắc* trân cɐk^{35} tʂʌŋ^{33} *sát* sao ʂak^{35} ʂaw^{33} *khít* khao xit^{35} xaw^{33}

Appendix 1: (Continued) List of test words.

Level (ngang)	xanh xanh sɐɲ^{33} sɐɲ^{33} ngon ngon ŋɔŋ^{33} ŋɔŋ^{33} đen đen ɗɛn^{33} ɗɛn^{33} thơm thơm t̪ʰɤm^{33} t̪ʰɤm^{33} dơ dơ jɤ^{33} jɤ^{33} dai dai jaj^{33} jaj^{33}		*xanh* đen sɐɲ^{33} ɗɛn^{33} *ngon* tươi ŋɔŋ^{33} tɨɜj^{33} *đen* thui ɗɛn^{33} t̪ʰuj^{33} *thơm* tho t̪ʰɤm^{33} t̪ʰɔ^{33} *dơ* tay jɤ^{33} tɐj^{33} *dai* hơn jaj^{33} hɤn^{33}	*xanh* thẫm sɐɲ^{33} t̪ʰɐm^{35} *ngon* mắt ŋɔŋ^{33} mɐk^{35} *đen* đúa ɗɛn^{33} ɗuɜ^{35} *thơm* ngát t̪ʰɤm^{33} ŋak^{33}*** *dơ* dáy jɤ^{33} jɐj^{35} *dai* dẻo jaj^{33} jɛw^{214}
Falling (huyền)	giòn giòn jɔŋ^{21} jɔŋ^{21}*** hồng hồng hoŋ͡m^{21} hoŋ͡m^{21} bằng bằng ɓɐŋ^{21} ɓɐŋ^{21} tròn tròn tʂɔŋ^{21} tʂɔŋ^{21}*** dày dày jɐj^{21} jɐj^{21} vàng vang vaŋ^{21} vaŋ^{21}		*giòn* đều jɔŋ^{21} ɗew^{21} hồng hào hoŋ͡m^{21} haw^{21} *bằng* hàng ɓɐŋ^{21} haŋ^{21} *tròn* đều tʂɔŋ^{21} ɗew^{21} *dày* cồm jɐj^{21} kom^{21} *vàng* hườm vaŋ^{21} hɨɜm^{21}	*giòn* tan jɔŋ^{21} taŋ^{33} *hồng* tươi hoŋ͡m^{21} tɨɜj^{33} *bằng* chan ɓɐŋ^{21} caŋ^{33} tròn vo tʂɔŋ^{21} vɔ^{33} *dày* cui jaj^{21} kuj^{33} *vàng* tươi vaŋ^{21} tɨɜj^{33}

Notes:

(*): in words such as cũ, vững, Southerners produce the curve tone(hỏi: 214) but Northerners use the broken tone(ngã: 325)

(**): in words ending in letter n such as hẳn, tròn, giòn, ngon, Southerners produce the final sound as[ŋ] while Northerners use the [n]

(***): in words ending in letter t such as nhạt, mắt, ngát, Southerners produce the final consonant as [k] while Northerners realise them as [t]

Appendix 2: Mean difference (MD) and significant level (p-value) of the post-hoc pair-wise comparison among syllable positions. Highlighted are variables of importance to the study. Bolded italics: between the control syllables (Baa1 and Bab1) and the reduplicated syllables (Rs1 and Rn1); Bolded: between the reduplicated syllables (Rs1 and Rn1) and their base (Bs2 and Bn2)

		Onset duration		Vowel duration		Coda duration		Syll. duration		Tone duration		F0 range		Intensity		H1-H2		H1-A1		H1-A2		H1-A3	
		MD	p-value	MD	p-value	MD	p-value	MD	p-value	MD	p-value	MD	p-value	MD	p-value	MD	p-value	MD	p-value	MD	p-value	MD	p-value
Baa1	Bab1	2.3	0.1	2.2	0.22	0.9	0.65	5	0.06	7	0.03	-3	0.17	0.2	0.54	-0.2	0.75	0.4	0.53	0.0	0.97	0.7	0.22
Baa1	***Rs1***	***5.3***	***<.01***	***6.7***	***<.01***	***16.2***	***<.0001***	***24***	***<.0001***	***-15***	***<.0001***	***18***	***<.0001***	***-2.8***	***<.0001***	***-2.1***	***<.001***	***-4.2***	***<.0001***	***-2.3***	***<.001***	***-2.5***	***<.001***
Baa1	Bs2	6.5	<.001	21.7	<.0001	-1.7	0.50	-17	<.0001	-22	<.0001	-6	<.01	-1.9	<.0001	0.9	0.15	2.3	<.01	3.2	<.0001	2.4	<.001
Baa1	***Rn1***	***6.5***	***<.0001***	***5.4***	***<.01***	***20.2***	***<.0001***	***27***	***<.0001***	***14***	***<.0001***	***5***	***<.03***	***0.0***	***0.98***	***-0.1***	***0.82***	***-0.5***	***0.44***	***0.1***	***0.84***	***0.2***	***0.78***
Baa1	Bn2	8.5	<.0001	23.2	<.0001	1.5	0.47	-13	<.0001	-16	<.0001	2	0.40	0.4	0.22	-0.1	0.85	0.4	0.55	1.6	<.01	0.7	0.25
Bab1	***Rs1***	***3.0***	***0.08***	***4.5***	***<.05***	***15.3***	***<.0001***	***18***	***<.0001***	***-22***	***<.0001***	***20***	***<.0001***	***-3.0***	***<.0001***	***-2.0***	***<.001***	***-4.6***	***<.0001***	***-2.3***	***0.001***	***-3.2***	***<.0001***
Bab1	Bs2	4.2	0.02	24.0	<.0001	-2.6	0.29	-22	<.0001	-29	<.0001	-3	0.15	-2.1	<.0001	1.0	0.09	1.9	0.01	3.2	<.0001	1.7	0.02
Bab1	***Rn1***	***4.2***	***<.01***	***3.2***	***<.05***	***19.3***	***<.0001***	***22***	***<.0001***	***7***	***<.03***	***7***	***<.001***	***-0.2***	***0.56***	***0.0***	***0.93***	***-0.9***	***0.16***	***0.1***	***0.87***	***-0.6***	***0.34***
Bab1	Bn2	6.2	<.0001	25.5	<.0001	0.6	0.78	-18	<.0001	-23	<.0001	4	0.03	0.2	0.54	0.1	0.90	-0.1	0.97	1.6	0.007	0.0	0.94
Rs1	**Bs2**	**1.2**	**0.53**	**28.5**	**<.0001**	**-17.9**	**<.0001**	**-40**	**<.0001**	**-7**	**0.10**	**-24**	**<.0001**	**0.8**	**0.05**	**3.0**	**<.0001**	**6.5**	**<.0001**	**5.5**	**<.0001**	**4.9**	**<.0001**
Rs1	Rn1	1.2	0.50	-1.3	0.56	4.0	0.11	4	0.28	30	<.0001	-13	<.0001	2.8	<.0001	2.0	<.001	3.8	<.0001	2.4	<.001	2.7	<.001
Rs1	Bn2	3.2	0.07	29.9	<.0001	-14.7	<.0001	-37	<.0001	-1	0.88	-16	<.0001	3.2	<.0001	2.0	<.001	4.6	<.0001	3.9	<.0001	3.2	<.0001
Bs2	Rn1	-0.1	0.99	27.2	<.0001	21.9	<.0001	44	<.0001	37	<.0001	11	<.0001	1.9	<.0001	-1.0	0.10	-2.7	<.001	-3.1	<.0001	-2.2	<.01
Bs2	Bn2	2.0	0.25	-1.5	0.50	3.2	0.20	4	0.29	6	0.10	8	0.01	2.3	<.0001	-1.0	0.11	-1.9	0.01	-1.6	0.03	-1.7	0.02
Rn1	**Bn2**	**2.0**	**0.17**	**28.7**	**<.0001**	**-18.7**	**<.0001**	**-40**	**<.0001**	**-30**	**<.0001**	**-3**	**0.16**	**0.4**	**0.23**	**0.0**	**0.97**	**0.9**	**0.18**	**1.5**	**0.01**	**0.5**	**0.38**