EFFECTS OF SYLLABLE STRUCTURE ON V-TO-V COARTICULATION (THAI VS ENGLISH)

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ABSTRACT

This paper investigates the effects of syllable structure on v-to-v coarticulation. It was hypothesized that open syllables (V#CV) would allow less v-to-v coarticulation than closed syllables (VC#V). Languages with simple syllable structure (Thai) would allow less v-to-v coarticulation than languages with complex syllable structure (English). /C_1V_1#C_2V_2/ and /$C_1V_1C_2$#V_2t/ sequences were recorded from six native speakers in Thai and English. F1 and F2 frequencies were measured. Results show that English consistently allows more v-to-v coarticulation than Thai, but open and closed syllables do not affect v-to-v coarticulation differently. The results on open and closed syllables are compatible with Öhman's model of coarticulation.

Keywords: v-to-v coarticulation, syllable structure, Thai, English

1. INTRODUCTION

There are language-specific variations in vowel-to-vowel (v-to-v) coarticulation [3] [10]. Manuel [10] proposed that vowel phoneme density affects how much v-to-v coarticulation is allowed in a language. Languages with a sparse vowel space would allow more v-to-v coarticulation than languages with a crowded vowel space. Since v-to-v coarticulation affects vowel contrasts, extreme coarticulation would blur or even obliterate phonemic contrast, which would presumably be detrimental to perception. However, contrary to Manuel's hypothesis, Beddor *et al*. [3] and Choi and Keating [6] demonstrated that American English, a language with a crowded vowel space, allows more v-to-v coarticulation than languages with sparser vowel spaces. Mok [16] also showed that Cantonese and Beijing Mandarin do not differ in degree of v-to-v coarticulation despite having different phoneme densities in the lower part of the vowel space. The complicated relationships between vowel phonemes and allophonic vowel qualities in the two languages indicate that phonemic analysis focussing on paradigmatic contrasts may be inadequate in accounting for the v-to-v coarticulatory patterns in a language.

Besides phonemic contrasts, syllable structure of a language can be a potential factor influencing language-specific v-to-v coarticulation because v-to-v coarticulation essentially reflects syntagmatic relationships between vowels. The effects of syllable structure on v-to-v coarticulation remain poorly understood. Most studies on v-to-v coarticulation only dealt with one syllable type, i.e. CV. It is thus necessary to extend the investigation of v-to-v coarticulation to different syllable types, and to compare languages in which syllable structures have different realisations.

Despite not having a clear definition of a phonetic syllable, there are many studies showing that syllable onset and coda are different acoustically, articulatorily, typologically and perceptually. Onset consonants are thought to be longer and more stable, e.g. [2][5][13], and to exhibit a stronger cohesion with the vowels than coda consonants [15]. Articulatory studies also show that syllable onset and coda consonants coordinate differently with the vowels, and that gestures for onset consonants are stronger and more distinct than those for coda consonants, e.g. [4][5][8]. Onset consonants are more frequent in the world's languages [9], and are more distinguishable than coda consonants in noise [13]. VC syllables are perceived as CV syllables under certain conditions, even though they can still be distinct acoustically [7]. Since onsets are shown to be more stable and to have a tighter coordination with vowels, and codas to be weaker and more variable, it is conceivable that with the same segmental sequence, closed syllables (VC.V) would allow more v-to-v coarticulation than open syllables (V.CV) in general.

Besides the inherent differences between onsets and codas, languages can have different syllable structures, and different realisations of the same structure. Thai, an Asian tone language with a simple syllable structure, is compared with British English, in order to explore the effects of language-specific realisation of syllable structure on v-to-v coarticulation.

Thai has a simple syllable structure [1]: $(C_1)(C_2)V_1(V_2)(C_3)$, where elements in brackets are optional. C_2 can be /l, r, w/ only. There are only eleven onset clusters /pr, pl, p^hr, p^hl, tr, kr, kl, k^hr, k^hl, kw, k^hw/ but clusters with /l/ and /r/ are very often pronounced as a single consonant without them in conversation. C_3 can be /p, t, k, m, n, ŋ/ and possibly an extra [ʔ]. All final stops in Thai are unreleased with no audible explosion and no aspiration. They cannot be linked to the following vowels. The use of lexical tone also contributes to the discreteness of the syllable in Thai because the domain of lexical tone is the whole syllable. There are five tones in Thai, traditionally labelled as mid, low, falling, high and rising. Tonal contrasts are preserved in unstressed syllables.

Unlike Thai, English has a complex syllable structure allowing a large number of consonants and consonant clusters in both onset and coda. English onsets can have up to three segments, e.g. *spring* /spr/, and codas can have up to four segments, e.g. *sixths* /ksθs/. Coda stops are released with different degrees of aspiration and can be released onto the following vowels. Locating syllable boundaries in English is not straightforward. The syllabification of intervocalic consonants in English, both singleton and clusters, has been a controversial issue, e.g. see [14].

If the realisation of syllable structure is important, then Thai, a tone language with simple and discrete syllable structure, will allow less v-to-v coarticulation than English, a language with complex syllable structure and variable realisations of its structure.

2. METHOD

Six native speakers of standard Bangkok Thai, three male and three female, and six native speakers of Standard Southern British English, two male and four female, were recorded. All speakers were graduate students in their twenties or thirties with no speech impairment. They were paid for participating in the experiment.

Monosyllabic real words in Thai and English were used to form the target sequences (Table 1). The resultant disyllabic sequences are nonsense sequences in both languages. Two vowels (/i, a/ in Thai, /i, ɑ/ in English) and two intervocalic consonants (/p, t/) were used for the experimental materials in the form of $/C_1V_1\#C_2V_2/$ (for open syllables) and $/C_1V_1C_2\#V_2t/$ (for closed syllables). C_1 were /t/, /s/ or /h/ (for forming real words).

Table 1: Target sequences for open versus closed syllables in Thai and English. "." represents a syllable boundary. /a/ should be /ɑ/ in English.

Intervocalic consonants	Open syllables		Closed syllables	
/p/	/Ca.pa/	/Ca.pi/	/Cap.at/	/Cap.it/
	/Ci.pa/	/Ci.pi/	/Cip.at/	/Cip.it/
/t/	/Ca.ta/	/Ca.ti/	/Cat.at/	/Cat.it/
	/Ci.ta/	/Ci.ti/	/Cit.at/	/Cit.it/

The target sequences were embedded in carrier phrases which have a structure similar to "Not a ×× , it's a ××" in each language in order to elicit contrastive stress. The target sequences were always placed in the second half of the carrier phrase. Both the first and the second syllables in the critical sequences can be the target syllable, depending on the direction of coarticulation: the first syllable for investigating anticipatory coarticulation and the second syllable for investigating carryover coarticulation. For example, in "Not a Tape Art, it's a Harp Art again" in English, the sequence "Harp Art" is the one used. Contrastive stress falls on "Harp" which is not analysed, while "Art" is the target syllable. The target syllables always bear no contrastive stress to allow more v-to-v coarticulation. Fillers were also included in the materials. In Thai, the target syllables had mid level, low level or falling tones. All vowels are phonologically long.

All speakers were recorded in a sound-treated room at the phonetics laboratory at the University of Cambridge. Before the actual recording, the speakers practised by reading a randomised list of the materials several times. All speakers were instructed to read the materials with a normal speaking rate. The Thai materials were presented to the Thai speakers in Thai script. The speech was recorded using a DAT tape via a Sennheiser MKH 40 P48 microphone and a Symetrix SX 202 amplifier into a Sony DTC-60ES recorder and later digitised using *Xwaves* with a sampling frequency of 16 kHz.

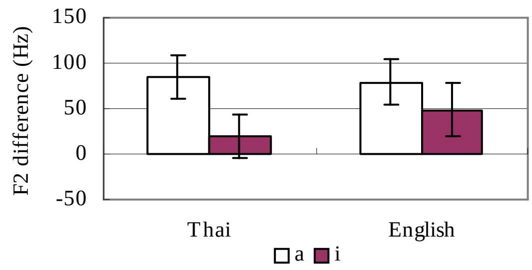
The frequencies of the first two formants (F1 and F2) were measured from 18 pole 25 ms autocorrelation LPC spectra with a Hanning window, supplemented by wide band spectrograms and DFT spectra. The temporal locations were identified from the waveform where the beginning and ending of periodic vocalic voicing was taken for the onset and offset of the target vowels. The spectra windows were centered 12.5 ms inward from these two locations. Only F1 and F2 measurements at the offset of the first syllables without contrastive stress (for anticipatory coarticulation) and onset of the second syllables without contrastive stress (for carryover coarticulation) were taken. The intervocalic duration between the two measuring points was also measured.

Differences in F1 and F2 frequencies (Hz) between symmetrical (e.g. /hapa/) and asymmetrical (e.g. /hapi/) pairs are used as the measure of coarticulation. F1 difference scores were calculated by subtracting the vowels with an /i/ context from the vowels with an /a/ context; while F2 difference scores were calculated by subtracting the vowels with an /a/ context from the vowels with an /i/ context. Differences between symmetrical and asymmetrical pairs with arithmetic signs were used for statistical analysis. The F1 and F2 data were submitted to four 4-way repeated measures ANOVAs (2 formants × 2 directions): Language (Thai vs English) × Target vowels (/a, i/ in Thai, /ɑ, i/ in English) × Stops (/p, t/) × Syllable Forms (open, closed).

3. RESULTS

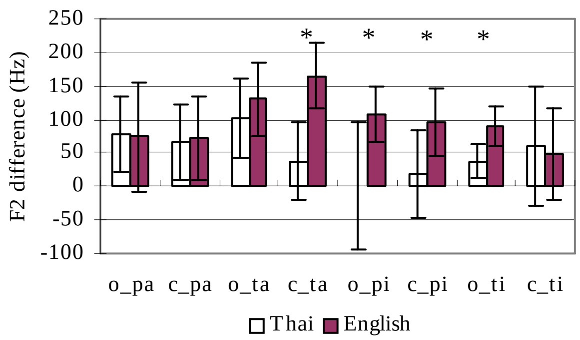
English allows more v-to-v coarticulation than Thai for both anticipatory and carryover coarticulation. For anticipatory coarticulation (with the first target syllable), there is no significant Language difference in F1. In F2, the Target × Language interaction is significant [$F(1,10) = 8.462$, $p = 0.016$] (see Figure 1). Two-tailed t-tests show that Target /a/ allows more coarticulation than Target /i/ for each language (Thai [$t(5) = 7.565$, $p = 0.001$]; English [$t(5) = 3.771$, $p = 0.013$]). English allows more v-to-v coarticulation than Thai with Target /i/ [$t(10) = -1.835$, $p = 0.048$] (one-tailed). There is no other significant difference involving Language or Syllable Form for anticipatory coarticulation.

Figure 1: F2 difference in anticipatory coarticulation for Target /a/ (/ɑ/) and Target /i/ in Thai and English. Error bars show one standard deviation.



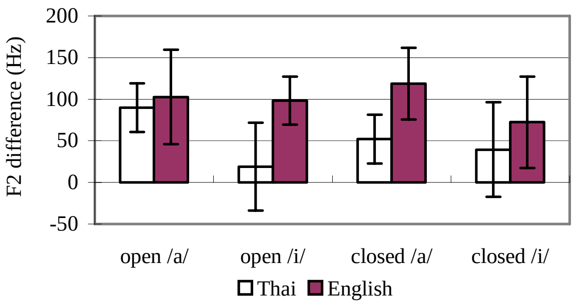
For carryover coarticulation (with the second target syllable), there is no significant Language difference in F1. In F2, the Language main effect [$F(1,10) = 12.592$, $p = 0.005$] shows that English allows more v-to-v coarticulation than Thai in general (mean difference 98 Hz vs 50 Hz). A high-order interaction of Target × Stop × Syllable Form × Language [$F(1,10) = 14.150$, $p = 0.004$] involving all factors is shown in Figure 2. Independent two-tailed t-tests reveal that English significantly allows more coarticulation than Thai under four conditions (shown with an "*" in Figure 2). Target /i/ shows greater Language differences than Target /a/. Thai never significantly allows more coarticulation than English.

Figure 2: F2 difference in carryover coarticulation for Thai and English under different Target vowels ('a' or 'i'), Stops ('p' or 't') and Syllable Forms ('o' for open syllable or 'c' for closed syllable). Error bars show one standard deviation. "*" = $p < 0.05$.



Two factors of interest are involved in the F2 Target × Syllable Form × Language interaction [$F(1,10) = 17.675$, $p = 0.002$]: Language and Syllable Form (see Figure 3). Again, English allows more v-to-v coarticulation than Thai, and the difference is significant for Target /i/ in open syllables [$t(10) = -3.224$, $p = 0.009$] and Target /a/ in closed syllables [$t(10) = -2.673$, $p = 0.023$]. Closed syllables exhibit more coarticulation than open syllables for Target /i/ in Thai (compare the white bars for "open_i" and "closed_i" in Figure 3) [t(5) = -2.690, p = 0.043], but the difference is small (only 21 Hz). In fact, Target /a/ shows the opposite pattern, but it is not significant. No Syllable Form difference is found in English.

Figure 3: F2 difference in carryover coarticulation of two Target vowels ('a' or 'i') and two Syllable Forms ('open' or 'closed') in Thai and English. Error bars show one standard deviation.



The language difference in v-to-v coarticulation is not confounded by intervocalic duration because it is not significantly different in English and Thai. Results of the statistical analyses can be provided upon request.

4. DISCUSSION

The results show that English consistently allows more coarticulation than Thai. There is no consistent pattern of Syllable Form effect on v-to-v coarticulation in Thai and English.

The current results showing that onsets and codas do not affect v-to-v coarticulation differently are compatible with Öhman's [12] model of coarticulation, in which vowels form a continuous diphthongal movement where consonants are superimposed onto this continuous carrier. His hierarchical model predicts that onset and coda consonants would not affect v-to-v coarticulation differently because consonants and vowels are not regarded as a linear sequence of successive gestures, so they do not interact with each other depending on syllable structure. Rather, the superimposed consonants, with separate motor commands, only distort the dominant continuous vowel trajectory momentarily. The present results seem to support Öhman's proposal. More investigation on the effects of syllable structure is needed to verify this proposal.

The Thai and English comparison gives strong support to the claim that the syllable structure of a language and its realisations affect degree of v-to-v coarticulation. Languages with simple syllable structure allow less v-to-v coarticulation than languages with complex syllable structure. Shona, an African tone language with very simple syllable structure (mainly CV), also exhibits less v-to-v coarticulation than American English, despite having only five vowel phonemes [3]. This is strong independent evidence supporting the importance of syllable structure on v-to-v coarticulation. More investigations comparing languages with different syllable structure complexities can further verify this conclusion.

ACKNOWLEDGEMENTS

The author thanks Sarah Hawkins, Francis Nolan and John Coleman for helpful discussions.

5. REFERENCES

[1] Abramson, A. 1962. The vowels and tones of standard Thai: acoustical measurements and experiments. *International Journal of American Linguistics 28,* Part III.

[2] Anderson, S., Port, R. 1994. Evidence for syllable structure, stress and juncture from segmental durations. *Journal of Phonetics 22,* 283-315.

[3] Beddor, P., Harnsberger, J., Lindemann, S. 2002. Language-specific patterns of vowel-to-vowel coarticulation: acoustic structures and their perceptual correlates. *Journal of Phonetics 30,* 591-627.

[4] Browman, C., Goldstein, L. 1988. Some notes on syllable structure in Articulatory Phonology. *Phonetica 45,* 140-155.

[5] Byrd, D. 1996. Influences on articulatory timing in consonant sequences. *Journal of Phonetics 24,* 209-244.

[6] Choi, J., Keating, P. 1991. Vowel-to-vowel coarticuation in three Slavic languages. *UCLA Working Papers in Phonetics 23,* 78-86.

[7] de Jong, K. 2001. Rate-induced resyllabification revisited. *Language and Speech 44,* 197-216.

[8] Krakow, R. 1999. Physiological organization of syllables: a review. *Journal of Phonetics 27,* 23-54.

[9] Maddieson, I. 1984. *Patterns of Sounds*. Cambridge: Cambridge University Press.

[10] Manuel, S. 1990. The role of contrast in limiting vowel-to-vowel coarticulation in different languages. *J. Acoust. Soc. Am. 88,* 1286-1298.

[11] Mok, P.K.P. 2006. Influences on vowel-to-vowel coarticulation. PhD thesis. University of Cambridge.

[12] Öhman, S. 1966. Coarticulation in VCV utterances: spectrographic measurements. *J. Acoust. Soc. Am. 39,* 151-168.

[13] Redford, M., Diehl. R. 1999. The relative perceptibility of initial and final consonants in CVC syllables. *J. Acoust. Soc. Am. 106,* 1555-1565.

[14] Redford, M., Randall, P. 2005. The role of juncture cues and phonological knowledge in English syllabification judgments. *Journal of Phonetics 33,* 27-46.

[15] Sussman, H., Bessell, N., Dalston, E., Majors, T. 1997. An investigation of stop place of articulation as a function of syllable position: a locus equation perspective. *J. Acoust. Soc. Am. 101,* 2826-2838.