

# Domain-initial strengthening in Taiwanese: a follow-up study

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## Introduction

In a previous study (Hsu & Jun 1998; reported in Keating et al. 1998, this volume) we investigated whether Taiwanese consonants show domain-initial strengthening of consonant articulations of the sort we have found in other languages. Taiwanese is of interest in this regard because its prosodic domains are less well-established than in other languages. Most previous work on the prosody of Taiwanese (and related dialects, e.g. Chen 1987) has concerned the tone sandhi group (the domain in which tone sandhi takes place), but this domain is not strictly layered under the Intonational Phrase, and Hsu & Jun (1996) found no strengthening of consonants at the beginning of the tone sandhi domain. Therefore Hsu & Jun (1998) compared the articulation of the consonant /t/ when initial in only three prosodic domains: Syllable, Word, and Intonational Phrase. The measures of articulation were peak linguopalatal contact, Voice Onset Time, and acoustic closure duration. The result of the experiment was that, while both speakers distinguished all three domains by duration, and neither speaker distinguished them by VOT, only one of the two speakers distinguished all three by contact. The other speaker made no articulatory difference between Word-initial and Intonational-Phrase-initial /t/s. While this result was unexpected, Keating et al. were reluctant to conclude that Taiwanese behaves differently from other languages studied, because the Taiwanese study was the smallest of the set, and the corpus was not designed to be exactly parallel to those of the other studies. However, it would certainly be an interesting result if Taiwanese, a tone language, were in fact different from the other languages in this respect.

Therefore a second study was undertaken, designed to be more like those of French and Korean (this volume). To this end, additional prosodic domains were identified for Taiwanese, and an additional consonant was included.

## Methods

Two subjects participated in the study, one female (Speaker 1, the second author) and one male (Speaker 2). These are the same subjects as in the original study.

The test domains began with unaspirated /t/ or /n/, followed by /a/, and were also preceded by /a/. The corpus for /t/ consisted of sentences containing real words, and is shown in Table 1. In some cases the target syllable was underlyingly /taʔ/; however, syllables closed by /ʔ/ become open syllables within the tone sandhi domain. The corpus for /n/ consisted of reiterant versions of the /t/ corpus, in which all syllables in the model sentences were instead pronounced as /na/. Both speakers were able to produce reiterant speech without difficulty.

The domains included in this study, along with the test sentences in the /t/ corpus, are listed in Table 1. The Syllable and Word domains differ from the previous study in that our test

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words are not reduplicated forms of the test syllables. The Intonational Phrase domain in our study is specifically defined as not set off by pause, but only by a large break. The Utterance domain in our study, as in Cho & Keating's Korean study (1999, this volume; also Keating et al. 1998 and this volume) is defined as an Intonational Phrase set off by pause; in Taiwanese it may also be marked by a small rise in pitch at the end. The other new domain in the present study is a small phrase, consisting of a heavy subject Noun Phrase. This domain is not tonally marked, but is characterized by a break greater than that between words.

Table 1. Corpus for /t/. Taiwanese forms are given in IPA plus punctuation. The test word is in boldface and the test syllable is underlined. Tones are marked only for the test syllable and the syllables on either side of it.

<i>Domain</i>	<i>Taiwanese</i>	<i>English meaning</i>
Utterance	wa u k <sup>h</sup> uã-tiɿ papa <sup>55</sup> . <b><u>ta</u><sup>23</sup><b>ta</b><sup>55</sup></b> k <sup>h</sup> ai ia? be lai?	I can see Dad. Why isn't Tata here yet?
Intonational Phrase	wa k <sup>h</sup> uã-tiɿ a! papa <sup>55</sup> , <b><u>ta</u><sup>23</sup><b>ta</b><sup>55</sup></b> k <sup>h</sup> ai ia? be lai?	I see it. Dad, why isn't Tata here yet?
Small Phrase	hit e laŋ e papa <sup>55</sup> <b><u>ta</u><sup>31</sup>-<b>tiɿ</b><sup>31</sup></b> tsit-tsia katsua?	That person's dad stepped on a cockroach.
Word	wa ka li kɔŋ, papa <sup>55</sup> <b><u>ta</u><sup>31</sup>-<b>tiɿ</b><sup>31</sup></b> tsit-tsia katsua?	Let me tell you, Dad stepped on a cockroach.
Syllable	wa kina kuã-tiɿ <b><u>ta</u><sup>33</sup><b>ta</b><sup>33</sup></b> tsim <sup>53</sup> a kɿ iŋ kiã.	Today I saw Auntie Tata and her child.

Speaker 1 read ten repetitions of each test sentence containing /t/ and six repetitions of the reiterant versions with /n/. Speaker 2 read fifteen repetitions of each test sentence containing /t/ and ten repetitions of the reiterant versions with /n/. Electropalatographic and audio signals were recorded with the Kay Elemetrics Palatometer, as in all our previous studies.

Peak EPG contact was measured over the whole palate: the percentage of electrodes contacted in each data frame was calculated, and the frame with the most contact was identified for each test consonant. Also, for each token, the number of data frames showing a complete stop occlusive seal was counted. This gives a measure of articulatory duration.

Two acoustic measures were also taken. The first was the VOT of /t/, as in previous studies. The second was a set of formant frequency measures: F1 and F2 were measured at the mid-point of the vowel following the test consonant, using LPC with a 25-ms window. Thus we could test whether the vowel of a domain-initial syllable shows any effect of its prosodic position.

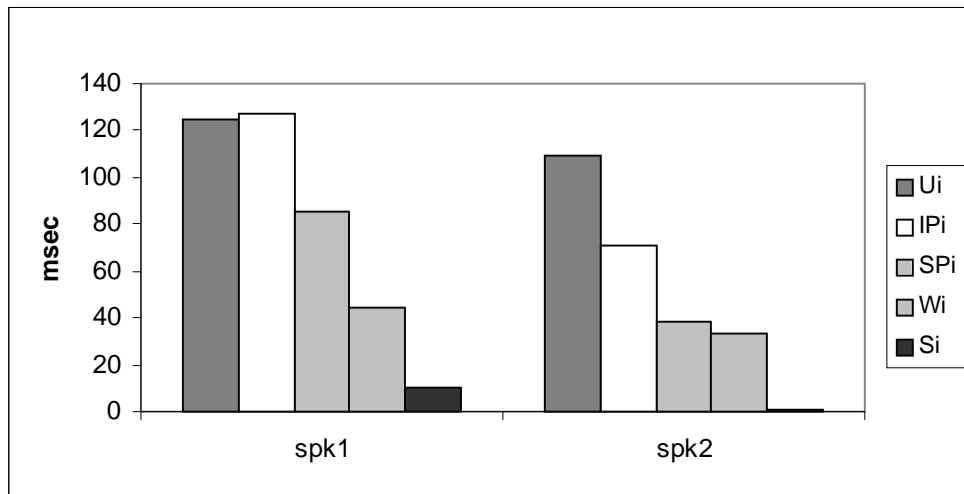
Analysis of Variance was followed by Fisher's PLSD post-hoc tests in pairwise comparisons of the different prosodic positions, for each speaker and each consonant.

## Results

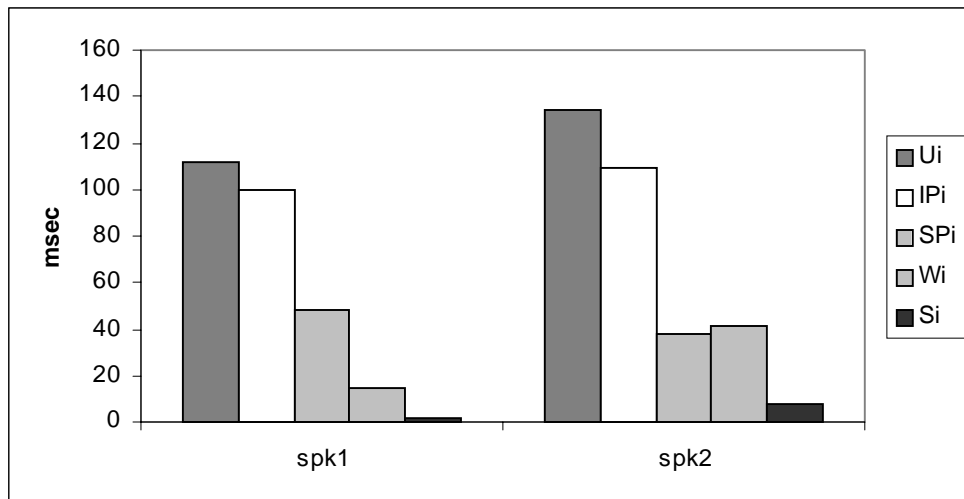
### *Consonant Linguopalatal Contact*

Taiwanese does in fact show phrasing effects like English, French, and Korean. First, prosodic position does affect the amount of contact, as seen in Figures 1-2. The overall effect of position on contact was highly significant for both speakers for both consonants. Generally, more overall contact was made by both speakers for both test consonants in the higher domains than in the lower domains. Differences in amount of contact across domains were more obvious for /t/ than for /n/, but most posthoc comparisons were significant at the .0001 level. Nonetheless, Speaker 1 distinguished only one pair of domains for /n/ (IPi vs. SPi,  $p < .0001$ ), and did not distinguish Ui from IPi /t/s ( $p = .2721$ ). Speaker 2 distinguished all four pairs of levels for /t/ and three for /n/, failing only to distinguish SPi vs. Wi ( $p = .8157$ ).

*Figure 1. Peak EPG contact for /n/ when initial in five prosodic domains.*



*Figure 2. Peak EPG contact for /t/ when initial in five prosodic domains. Consonant Seal Duration*



The articulatory seal durations, seen in Figures 3-4, show at least a two-way distinction, between lengthened higher prosodic domains (U-initial and IP-initial) and shortened lower domains (SP-initial, W-initial and S-initial). Both speakers make such a distinction for both test consonants. Whether there are additional reliable differences varies between the speakers, with the exception that both speakers distinguish between W-initial and S-initial for /t/. Speaker 1 fails to distinguish Ui from IPi for both consonants, while Speaker 2 fails to distinguish SPi from Wi for both consonants.

Figure 3. Duration of stop seal for /n/ when initial in five prosodic domains.

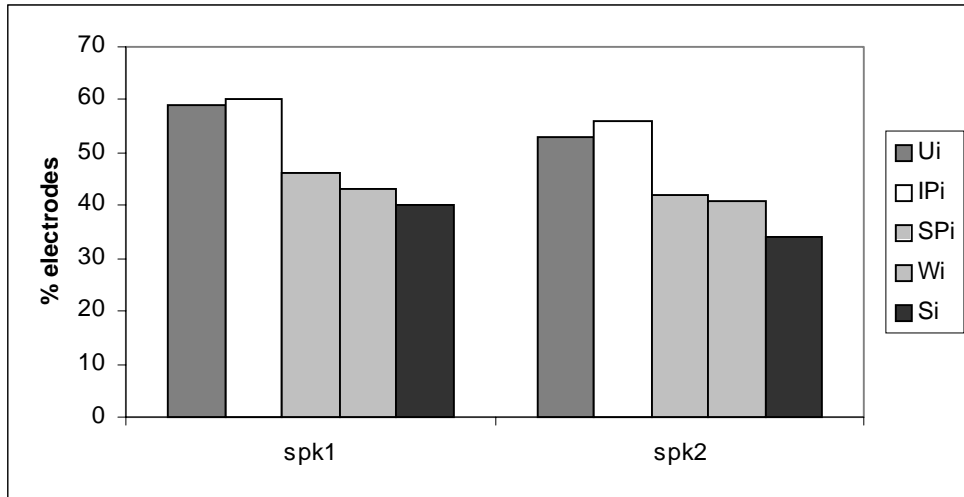
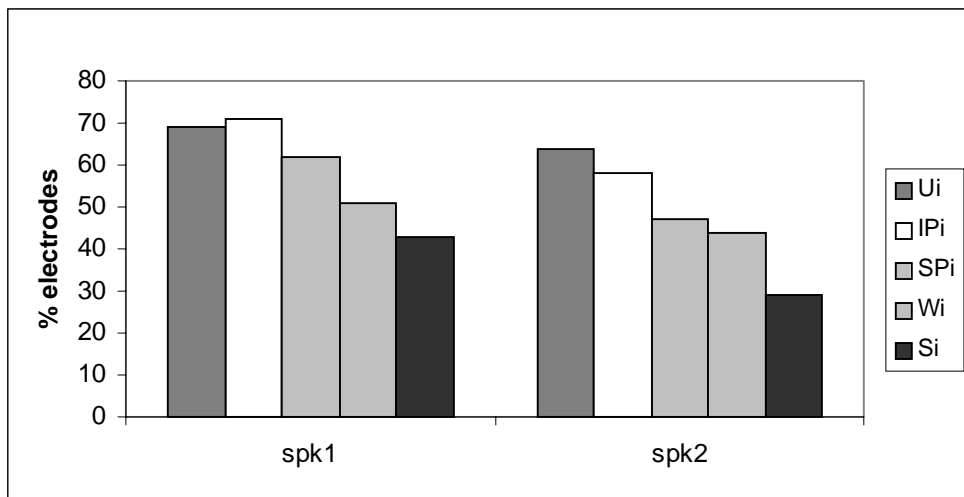


Figure 4. Duration of stop seal for /t/ when initial in five prosodic domains.



### *VOT of /t/*

Similar to French, there was almost no reliable effect of prosodic position on VOT of the unaspirated /t/. Speaker 2 made the only distinction, which was between W-initial and S-initial.

### *Vowel formant frequencies*

The formant data show no direct effect of prosodic position on F1 and F2 of both test consonants. There are no obvious patterns or tendencies in the formant data as with peak contact and seal duration. However, we do know that after a pause or utterance initially, the mouth tends to open slightly wider which causes the tongue to pull down and thus the F1 to increase. Speaker 2's F1 for /n/ in the U-initial position is significantly higher than the F1 values for the other domains, which shows that Speaker 2 has a more open mouth after a pause. This could explain why Speaker 2 generally makes less contact than Speaker 1.

## **Discussion**

The results of this study are in accord with those of the studies of other languages. Linguopalatal contact varies systematically with prosodic position, with more contact in initial position of higher prosodic domains. Seal (closure) duration patterns similarly, and is furthermore strongly correlated with contact. However, neither VOT of the initial consonant, nor the formant frequencies of the following vowel, vary with prosodic position. The results for VOT agree with those from Korean and French, in that very-short-lag voiceless unaspirated stops seem not vary in VOT across prosodic positions.

This study resulted in more distinctions being made between initial positions in the different prosodic domains, than were found in the earlier study. The corpus in the present study was carefully between them as much as possible, designed to provide a larger set of prosodic domains, and to control the comparisons

## **Acknowledgment**

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