Informativity and cost allocation in tonal coarticulation in Taiwan Southern Min and Taiwan Mandarin

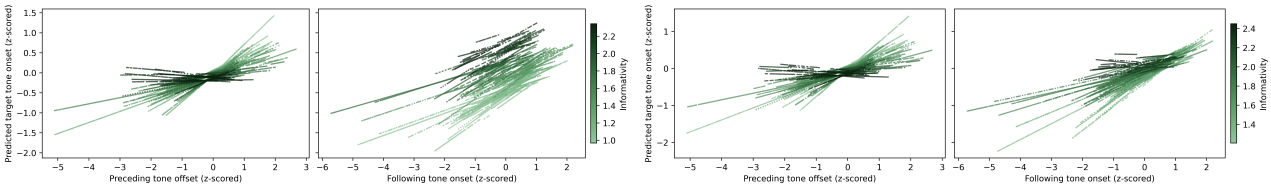
Keywords tonal coarticulation; informativity; cost allocation; Taiwan Southern Min; Taiwan Mandarin

Introduction & background Lexical tones in tonal languages are contrasted with pitch levels and/or contours. In continuous speech, however, tones are subject to tonal coarticulation (TC) with preceding (*carryover*) and following (*anticipatory*) tones (cf. Chao, 1968). Cross-linguistically, carryover effects are generally found to be assimilatory and stronger, while anticipatory effects are dissimilatory and weaker (Chang & Hsieh, 2012). However, discrepancies across languages have also been attested (Peng, 1997; Wang, 2002; Brunelle, 2009; Huang, 2023), raising the question of whether TC is subject to language-invariant biomechanical needs (e.g., Shen, 1992; Huang) or to some extent conditioned by phonological constraints (e.g., Brunelle). In Brunelle, Northern Vietnamese, which uses both F0 and laryngealization for tonal contrast, was found to exhibit higher TC magnitudes than Southern Vietnamese, which only uses F0, supporting the latter stance. Huang, likewise, investigated the influence of tone inventory sizes between Taiwan Southern Min (TSM) and Taiwan Mandarin (TM) but found comparable magnitudes of TC, despite the larger tone inventory in TSM and the subsequent higher possibility of perceptual confusion. In this study, we provide perspectives from information theory (Shannon, 1948) and show that while the past studies of TC focus mainly on production and perception, the functional-cognitive aspects are also likely involved and that the lack of difference in production found in Huang (2023) is likely due to neglection of these aspects. Specifically, Cohen Priva (2015, 2017) found that information-theoretic constraints provide a potential explanation for the (non-)avoidance of systematic variations. Crucially, informativity outperforms other constraints in predicting the actuation of lenition across languages, with less informative targets more readily lenited. Since TC, like other systematic variations, involves the pull between articulatory costs and contrastive needs, it is likely to also be conditioned by the informativity of the individual coarticulating tone pairs. In this study, we put forth evidence from TSM and TM and argue that informativity is at least partially responsible for the discrepancies in TC attested in the literature. Additionally, we further propose that the cost a language pays to maintain faithfulness is not always global across the language but may be locally tuned given contrastive context.

Methodology The data in this study comes in two parts: 1) the F0 data of coarticulated tone pairs in TSM and TM and 2) the informativity of these tone pairs collected from a TSM corpus and a TM corpus. Linear mixed-effects models (LMMs) were then used for statistical analyses. F0 data Eleven TSM native speakers and fifteen TM native speakers (15 females; 20–27 y.o., mean=22.62) participated in the production experiment. The TSM speakers were also native speakers of TM. The speakers did not have any experience with other tonal languages. In TM, all (4) tones were investigated. In TSM, checked tones (T4 and T8) were excluded due to the inherently shorter durations, leading to 5 chosen tones. For both languages, one disyllabic word was chosen for each tone pair. There were a total of 16 (4×4) TM and 25 (5×5) TSM tone pairs. There were 10 repetitions for each word. The participant was first familiarized with the word lists, and then the stimuli were presented on slides one at a time on a MacBook Pro (13-inch, 2018). The audio was recorded with a microphone (Audio-Technica Carcoid AT2035) connected to a portable audio interface (USBPre 2) and saved as WAV files with a sampling frequency of 4.41k Hz. Syllable boundaries were then manually labeled in *Praat* (Boersma & Weenink, 2018), and F0 values were extracted using *Parselmouth* (Jadoul et al., 2018). Within each syllable, F0 values were sliced into 11 portions. The means of the last portion in the preceding syllable and the first portion in the following syllable were taken as their respective onset/offset. Informativity To estimate the informativity of each tone pair, one corpus was built for each language. The TSM corpus was taken from the textual portion of the TAT_MOE Corpus (Liao, 2022). The word boundaries and tones were determined directly with the Tâi-lô orthography system provided in the corpus. Disyllabic words were chosen as the final corpus, comprising 306,001 words. The TM corpus was built with 21,668 posts on a Taiwan BBS forum PTT. The texts were first preprocessed, with only Chinese characters preserved. Spaces and punctuations were taken as sentence segmentation markers. *CKIP segmenter* (Tsai & Chen, 2004) was then used to perform word segmentation of each sentence. Disyllabic words were then chosen as the final corpus, comprising 3,717,386 words. *pypinyin* was then used to label the tones of the words. Atonal characters were discarded. The informativity of the tone pairs was then calculated based on Cohen Priva's formula with and without consideration of tone sandhi. Statistical analyses Eight LMMs were modeled for the two languages and the two positions (carryover vs. anticipatory), with and without tone sandhi. The target tone value was taken as the predicted value, and the context tone value and informativity and their interaction were taken as predictors, with participants and syllable onset/offset segment types (vowels, liquids, nasals, or obstruents) as random effects.

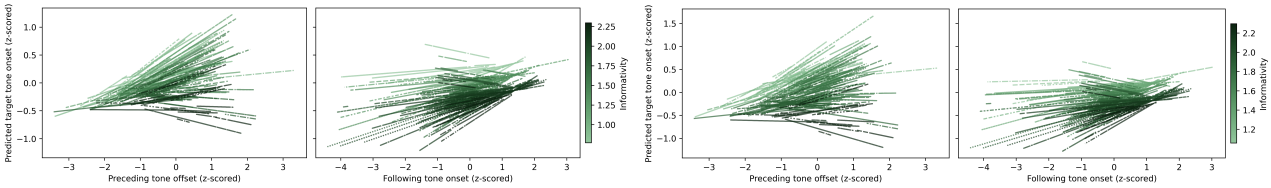
Results In TSM, with and without tone sandhi, informativity was found to be inversely correlated with the degree of tonal coarticulation in both the carryover and anticipatory directions (all p's$<$.001). In both situations, the carryover position was found to be subject to this effect more than the anticipatory position (both p's$<$.001). In TM, however, the effect of informativity was not found, although, like TSM, the carryover position was found to be subject to an increase in the inverse correlation between informativity and tonal coarticulation more than the anticipatory position with tone sandhi considered (p=.001). Illustrations of the fitted models are shown in Figures 1 and 2.

Discussion The inverse correlation between informativity and the magnitude of TC in TSM strongly suggests that TC may also be conditioned by functional constraints other than purely phonetic-phonological factors. Specifically, differences have been found between TSM and TM, where such an effect from informativity seemed weak. This suggests that TSM speakers avoid strong TC on more informative pairs and allow less informative ones to bear on more coarticulation. In contrast, TM speakers are rather oblivious to informativity, at least as far as tonal coarticulation. In Cohen Priva (2015, 2017), it is proposed that the informativity of an element indirectly entails the cost a language pays to maintain its faithfulness. Likewise, in Huang, it is stipulated that the biomechanical needs and articulatory costs constrain TC, which is why TSM has been seen to have comparable magnitudes of TC as TM despite the larger size of tone inventory. Together, the results suggest that while the global articulatory costs that TSM and TM speakers pay are comparable, a more fine-grained local allocation of such costs is also at work. In TSM, with higher perceptual pressures, speakers strategically allocate costs based on how informative a tone pair is. On the flip side, in TM, perceptual confusion is less probable, and a fine-grained allocation of costs is of less importance.



(a) With tone sandhi (b) Without tone sandhi

Figure 1: Fitted target tone values in carryover (left)/anticipatory (right) positions in TSM with (a)/without (b) tone sandhi.



(a) With tone sandhi (b) Without tone sandhi

Figure 2: Fitted target tone values in carryover (left)/anticipatory (right) positions in TM with (a)/without (b) tone sandhi.

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