# The Interaction of Stress and Tone in Standard Chinese: Experimental Findings and Theoretical Consequences

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Prosodic systems can be broadly divided into two types: tone systems and stress systems. There are, however, a range of systems intermediate between these two extremes, languages in which tone and stress co-occur (Hyman 2006). In some register tone languages of this profile, a relationship holds between prominence and tone as follows: stressed position attracts high tone and high tone attracts stress (Liberman 1975, Selkirk 1984, 1995, Goldsmith 1987); low tone attracts non-prominence and non-prominent position attracts low tone (de Lacy 1999, 2002, 2007). However, the relationship between tone and stress is only confirmed for register tone languages. Given that contour tone languages constitute the other major type of tone system in the world and that both contour and level tones exist in such languages, an investigation of the interaction between tone and stress in this type of language is essential to further our understanding of the tone–stress relationship. This paper strives to fill this gap.
The language under focus is Standard Chinese (SC). SC has an extensive tonal inventory that includes both level and contour tones; the contour tones are both rising and falling (Yip 2002). To investigate the relationship between tone and stress, it is essential to consider how tone is affected by varying the prosodic context. Accordingly, we focus on Tone 2 (T2) Sandhi, as it is the only tone sandhi process in SC uniformly accepted as being triggered by stress (see e.g. Chao 1968, Luo & Wang 1981). According to Chao (1968), in T2 Sandhi, the T2 (high rising tone) present on a medial unstressed syllable in a trisyllabic construction becomes T1 (high level tone) when the initial syl-lable carries T1 or T2 and the final syllable carries any tone except T0 (low tone). See (1) overleaf.
Although there is general agreement that T2 Sandhi is sensitive to stress, there is significant controversy on the type of stress system that SC has. We argue that SC optimally builds uneven (heavy-light) trochees (following Goad, White & Steele 2003), in contrast to the proposal that SC builds syllabic trochees (Feng 1995), dual trochees (Duanmu 2007), or has some type of right-dominant rhythmic unit (Chen 2000). We propose that SC word-level stress falls on the leftmost heavy syllable in the prosodic word, in contrast to the proposal that there is no word-level stress (Gao & Shi 1963, Yip 1990) or that word-level stress is indeterminate (Kratochvil 1974, Hoa 1983). Consistent with our assumptions about SC prosodic structure and the general consensus that T2 Sandhi is triggered by stress, our hypothesis concerning this sandhi process is in (2).
Because of disagreement concerning some of the basic facts of T2 Sandhi, our paper starts with a carefully controlled experiment on this process. The underlying tonal profile and syntactic structure of the selected trisyllabic constructions, as well as the onset and rhymal profiles of the medial T2 syllables, were controlled. Disyllabic constructions with initial and final T2 syllables were included for comparison purposes. A carrier sentence was used to control for any utterance final lengthening effects. Furthermore, gender, age and dialect of the speakers were controlled, and speech rate was taken into consideration. All productions were analyzed using Praat (Boersma & Weenink 2010). The pitch contour of T2 syllables was examined in pitch tracking graphs, narrow band spectrograms and pulse intervals in expanded waveforms.
The experimental results support the hypothesis in (2). What then is the relationship between

tonal profile and stress; that is, why is T1 (high level) the sandhi form of T2 (high rising)? We propose that there is a link between syllable weight and tonal profile in SC. T2 can only be licensed by heavy (stressed) syllables. This is consistent with Zhang's (2001) observation that rising tones have longer duration than other tones. T1, as a level tone, can be licensed by light syllables in SC. More generally, we propose that the results indicate that the underlying tonal profile of trisyllabic constructions – a factor considered in previous research to affect T2 Sandhi (e.g. Chao 1968) – is instead the factor governing stress assignment in SC.
The relationship between tone and stress we have proposed for T2 Sandhi is supported by examining T3 Sandhi in SC. In T3 Sandhi, T3 (low falling) becomes T2 (high rising) when followed by T3; see (3). As we have proposed, T2, the only rising contour in SC, is confined to heavy sylla-bles; as a result, it can never occur in unstressed position. T3, by contrast, never occurs in stressed (foot-initial) position. We propose that T3, as a low falling tone, is light, consistent with the obser-vation that it has the shortest duration in SC, aside from T0 (neutral tone) (Shih 1988, Xu 1997).
Taking all aspects of our proposal together, we conclude the following: (A) SC optimally builds uneven trochees. (B) T2 Sandhi applies only when T2 syllables occur in foot-dependent position, as shown in (4) for the example in (1): the vowel in [p$^{h}$ii2] shortens and the tone becomes T1 when in foot-dependent position. (C) A correlation between contour/level tone and presence/absence of stress is attested in SC: prominence makes tone high and rising (T3 Sandhi); non-prominence makes tone level (T2 Sandhi). (D) A correlation between high/low register and presence/absence of stress is confirmed in SC as well, consistent with what has been observed for register tone languages.

(1) 'paɬ2 p$^{h}$ii2 'ʂuu1 → 'paɬ2 p$^{h}$i1 'ʂuu1 "white covered book"

(2) Hypothesis:
T2 Sandhi applies whenever the targeted T2 syllable occurs in foot-dependent position.

(3) T3 Sandhi: [(fən3 pii3)Ft]PWd → [('fən2 pi3)Ft]PWd "chalk"

(4) T2 Sandhi: [(paɬ2 p$^{h}$ii2)Ft (ʂuu1)Ft ]PWd → [('paɬ2 p$^{h}$i1)Ft ('ʂuu1)Ft ]PWd "white-covered book"

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