Speech planning influences application and realization of Mandarin Tone 3 sandhi

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Phonological alternation across word boundaries has been reported to vary depending on various factors in previous literature. Recent studies suggest that the variability can be seen as the consequence of speech production planning. In this study, we investigated how two specific factors, syntactic boundary and speech rate, influence the application and realization of morpho-syntactically complex Mandarin Tone 3 sandhi (T3S). In Mandarin, Tone 3 (T3) surfaces as Tone 2 (T2) when it immediately precedes another T3 syllable. This alternation is complex and variable at the phrasal level [1].

The Production Planning Hypothesis (PPH) accounts for the application variability by proposing that the application of the alternation is constrained by the availability of phonological information across word boundaries during online production planning [2]. According to PPH, the phonological context embedded in the forthcoming word is less likely to be available across a larger syntactic boundary during the current word production. Consequently, there is a decrease in the likelihood of T3S application across a bigger boundary. A slower speech rate is associated with a more incremental planning strategy and a narrower planning window [3]. As a result, it's less likely for the upcoming word to be available at a slower speech rate, leading to a lower likelihood of T3S application. Besides examining the T3S application, we further explored the effect of syntactic boundary and speech rate on the acoustic realization of T3S to probe how speech planning regulates an alternation at the level of phonetic implementation.

We conducted a production experiment of Mandarin T3 sequences that manipulated the syntactic boundary in the stimuli (see an example in Table 1) and speech rate using blocked-design SOAs to test these predictions of PPH. Syllables that immediately precede the manipulated syntactic boundaries were directly compared on T3S application and realization.

Production results showed that syntactic boundary significantly predicts T3S application. The probability of T3S application for the larger boundary Predicate-Object is marginally lower than the smaller boundary Modifier-Noun (β = -1.328, p = .064). No significant differences were found for Predicate-Object vs. Subject-Predicate or Modifier-Noun vs. Subject-Predicate. Speech rate and any interaction terms involving it do not significantly contribute to the model, indicating that no speech rate effect was observed. The syntactic boundary effect Predicate-Object < Modifier-Noun aligns with the prediction of PPH that alternation application is less likely to apply across a larger syntactic boundary. The unexpectedly high application likelihood of the Subject-Predicate might be caused by its significantly higher trigger word frequency than Modifier-Noun and Predicate-Object ($p < .001$ for both comparisons). The lack of speech rate effect suggests that speech rate alone cannot influence production planning and, thus, the application of alternation. Previous studies found that speech rate serves as an indicator of factors that can influence planning such as memory span, processing load, and prosodic or syntactic boundaries in natural speech production [3]. However, speech rate itself might not directly affect speech planning.

Acoustic data revealed that the F0 trajectory has a shallower rising slope and a less U-shaped shape before a larger syntactic boundary (linear: β = -6.56, p <.001; quadratic: β = -7.70, p <.001) and at a faster speech rate (linear: β = -6.92, p <.001; quadratic: β = -7.85, p <.001). The syntactic boundary effect cannot be explained by pre-boundary lengthening, where more pitch movement is expected for the longer duration resulting from a larger boundary [4]. The speech rate effect does not support contextual tonal variation of pre-low raising, as more pitch raising would be predicted at a faster speech rate [5]. Therefore, our results, which suggest that a larger syntactic boundary and faster speech rate give rise to a less T2-like and more T3-like target, are more consistent with the hypothesis that syntactic boundary regulates the effect of T3 allomorphs cascading from lexical selection to phonetic implementation during speech planning.

Table 1. An example of stimuli with three different syntactic structures.

[σ[σσ]]	Modifier-Noun		Predicate-Object		Subject-Predicate	
Example	nü3.	sheng3.zhang3	zhu3.	shui3.jiao3	ni3.	gan3.jin3
Gloss	woman	governor	boil	dumpling	you	be quick

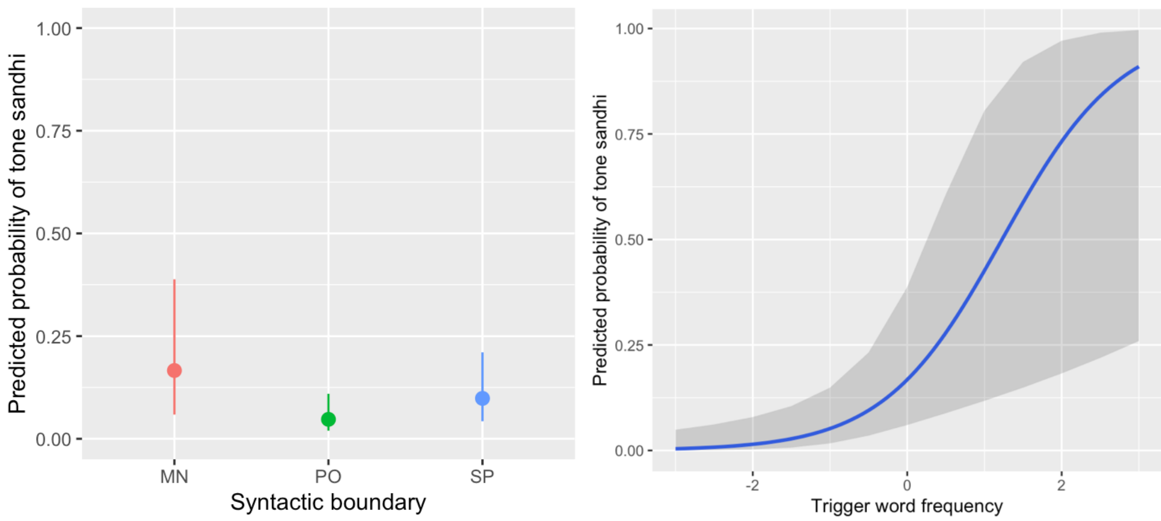

Fig. 1. Predicted T3S application probability by syntactic boundaries (left) and trigger word frequency (right).

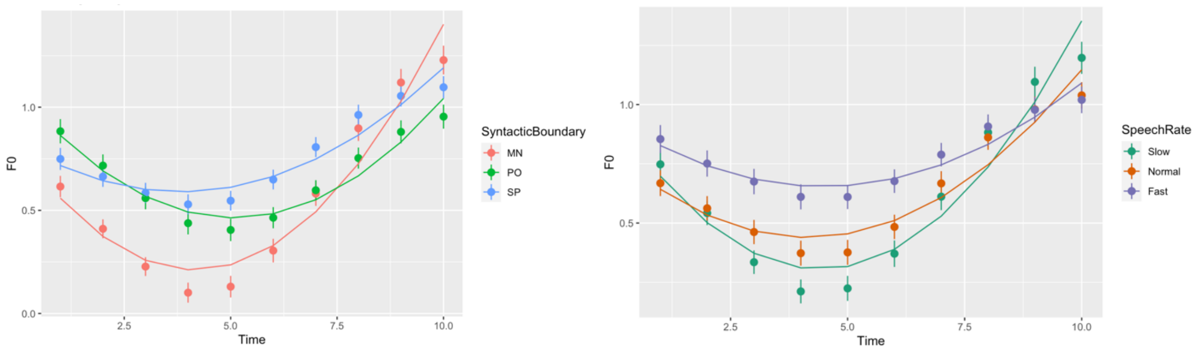

Fig. 2. Syntactic boundary (left) and speech rate effect (right) on F0 trajectories of sandhi T3 trials.

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