The representation of variable tone sandhi in Shanghai Chinese

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Introduction. Variation in phonological patterns challenges models of spoken word recognition. One crucial question is how listeners process and represent variant forms in the mental lexicon. It has been shown in behavioral experiments that more frequent forms were responded to more quickly than less frequent forms (e.g., American English word-final *t/d* deletion, Deelman & Connine, 2001). Ranbom & Connine (2007) further showed that in *nt*-flapping in English (e.g., [sɛɾɚ] for *center*), the less frequent form [nt] also had a strong phonological representation in the lexicon, suggesting that both forms of a phonological alternation contribute to lexical access. These studies, however, mainly focused on variation of phonetic reduction processes, which can be interpreted as processes of late phonology (Coetzee & Pater, 2013). The processing of morpho-syntactically conditioned phonological alternations, which presumably occur earlier in the derivation, has received considerably less attention. The current study investigates one such alternation — a variable tone sandhi pattern in Shanghai Chinese.

The majority of disyllabic verb-noun (V-N) combinations in Shanghai Chinese can undergo a tonal extension tone sandhi, whereby the base tone of the first syllable is spread onto the entire disyllable. But the sandhi applies variably. For example, /tsʰã24/ "to sing" + /ku53/ "song" can be realized with either the sandhi form ([tsʰã33 ku44]) or the non-sandhi form ([tsʰã24 ku53]). In a series of subjective rating experiments, Yan (2016) found that native speakers generally preferred the non-sandhi form over the extension sandhi form in V-N, and that more frequent V-N items preferred the non-sandhi form even more.

However, how V-N items with variant sandhi forms are processed during spoken word recognition remains unclear. To this end, we designed an auditorily primed lexical decision experiment in which disyllabic V-N targets were primed by a monosyllable that shared the segments of the first syllable with different tonal conditions. Based on Yan (2016), we expect the prime with the non-sandhi tone to elicit facilitative priming in general, suggesting that the non-sandhi form is represented in the mental lexicon. Moreover, we also predict that the priming effect may be modulated by the familiarity ratings of the V-N items, with the non-sandhi tone prime facilitating the recognition of more frequent V-Ns, and the sandhi tone prime facilitating the recognition of less frequent ones. These results would suggest that both variant forms of a V-N item are represented in the mental lexicon and activated to different degrees depending on frequency of the item.

Methods. Thirty-six native Shanghai speakers performed a lexical decision task. Each disyllabic target was preceded by a sandhi tone prime, which shared the same tone with the initial syllable of the extension sandhi, a non-sandhi tone prime, which had the same underlying tone as the first syllable of the non-sandhi form, and an unrelated tone prime, which was not related to the first syllable of the target in tone (see Table 1). Given that the extension sandhi form applies variably in V-N disyllables, the stimuli-recording speaker was asked to produce the disyllables as naturally and comfortably as possible without considering variation. She applied the non-sandhi form to all V-N critical targets, which is consistent with Yan (2016). Hence, the non-sandhi form was used for all the V-N targets in the current study. All primes shared the same segments with the first syllable of the target. After the priming experiment, a familiarity rating task on the disyllabic targets was conducted with the same participants.

Table 1. Examples of the three prime types sandhi target.

53 + 13 → 44 + 13 (non-sandhi) or 55 + 31 (tonal extension)		
Prime Type		Target
Sandhi Prime	[sɔ55]	[sɔ44 vɛ13] /sɔ53 vɛ13/ "to cook a meal"
Non-sandhi Prime	[sɔ53] "a little"	
Control Prime	[sɔ24] "to sweep"	

Results and discussion. The overall accuracy rate for the V-N stimuli, including both critical and filler words, is 85% (1662/1944 trials). For the reaction time analyses on the critical stimuli, inaccurate responses (6%, 42/648 trials) and responses over two standard deviations from the mean reaction time of critical words (5%, 35/648 trials) were excluded. To reduce the skewness of the raw data, reaction times were log-transformed, and then modeled with a series of Linear Mixed-Effects models with *participant* and *item* as random effects, *prime* and *familiarity* as fixed effects, and by-subject random slopes for *prime*.

Model comparisons under likelihood ratio tests showed that the best model is the model with *prime*familiarity*. The interaction can be seen in Figure 1. Although both Sandhi and Non-sandhi primes facilitate V-N recognition in general compared to the Control prime (Figure 1a), *familiarity* regulates the priming effects of different *prime* types (Figure 1b). The model shows that the slope of *familiarity* regression line for the Control primes is significantly less negative than that for the Non-sandhi primes (EST.=-0.035, SE=0.014, t=-2.440, p=0.015) and marginally significantly less negative than that for the Sandhi primes (EST.=-0.027, SE=0.014, t=-1.886, p=0.060).
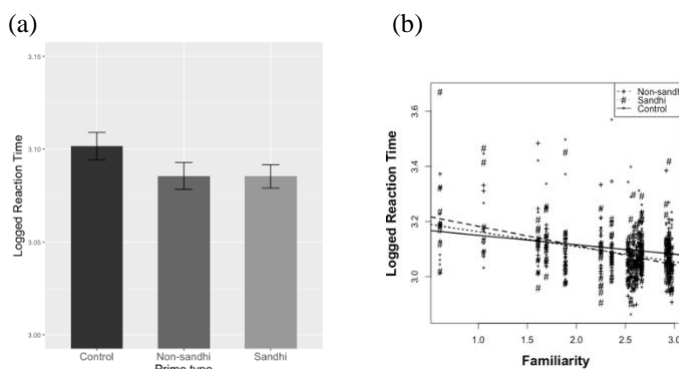
(a)
(b)

Figure 1. (a) Logged reaction times and standard error bars for control, non-sandhi, and sandhi primes in the lexical decision task. (b) Reaction time elicited by the non-sandhi (+), sandhi (#), and control (*) prime as a function of familiarity for Shanghai V-N items (each point represents a target word primed by a certain type of prime, which was differentiated by symbols).

These data suggest that both the underlying and tonal-extension forms are represented in the mental lexicon due to tone sandhi variation. The finding that the more frequent variant — the non-sandhi form — has an effect on V-N recognition is in accordance with previous findings (e.g., Connine, 2004). The fact that the Non-sandhi primes have the most negative slope for *familiarity* is consistent with our prediction that Non-sandhi primes are more likely to have a facilitation effect for V-N items with higher frequency. But our prediction that less frequent V-N items should be more facilitated by the Sandhi primes was not borne out, and it is unclear to us why we obtained an inhibition effect for both Sandhi and Non-sandhi primes for items with lower familiarity ratings.

Taken together with Yan et al.'s (in revision) earlier finding that for modifier-noun (M-N) combinations in Shanghai, in which the extension tone sandhi applies obligatorily, their recognition is primarily primed by sandhi primes, these results indicate that both grammatical factors, such as syntactic structures, and usage factors, such as frequency, contribute to the representation and processing of tone sandhi forms in Shanghai. Like variation as the result of reduction in late phonology, variation that is syntactically sensitive should be represented in the lexicon as well.

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