COPiL CAMBRIDGE OCCASIONAL PAPERS *in* LINGUISTICS
Volume **13**, Article 8: pp. 158–167, 2021 | ISSN: 2050-5949

Priming the Mental Representation of Tone Sandhi in Kunming Dialect

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1 Introduction

To recognize spoken words, one needs to map the auditory information to the stored representation in the mental lexicon. However, there is high variability in the acoustic signal. The realization of sounds can be quite different from the stored representation due to different speaking styles, speaking rate and phonological factors such as coarticulation and phonological alternation. Therefore, one of the central goals of research on spoken word recognition are to elucidate the nature of speech sounds, i.e. how are they represented in the mental lexicon, as it could inform the recognition process that accesses those representations.

There are two views on the representation of speech sounds. The abstract representation view argued that speech sounds are abstractly represented in the brain, ignoring certain sources of variation and leaving the redundant surface acoustic-phonetic details underspecified. For example, in English, the nasals in coda position are usually not fully specified and tend to assimilate the place of articulation of the following plosives (Lahiri & Reetz 2010). The surface representation view maintained that episodic details of speech sounds are retained in the brain. For example, talker-specific effects were found in repetition priming (Dufour & Nguyen 2014).

Most research in this field has focused on the representation of segmental features, but the representation of suprasegmental elements such as tone is also important, especially for languages that use tone to distinguish word meanings. Tone can go through phonological alternation as well: even though a tone has its citation value when it is produced alone, it may change its value in certain phonological environment, which is called tone sandhi. The alternations may happen because of the adjacent tones or their morpho-syntactic position etc. (Chen 2000). It is unclear whether the words that undergo tone sandhi are stored as the surface forms, i.e. the way they are heard or stored in the underlying forms, i.e. base tone is accessed during spoken word recognition.

Recently, a few studies have been done to investigate the representation of tone sandhi in some Chinese dialects. However different dialects seem to internalize the sandhi patterns differently in the mental lexicon.

Chien, Sereno & Zhang (2016a) has conducted an auditory-auditory lexical decision priming experiment on standard Mandarin tone sandhi. In Mandarin, Tone 3 (T3; tone value: 213) would change into tone 2 (T2; tone value: 35) when preceding another T3. For example, T3 syllable 主 /tʂu213/ changes into T2 /tʂu35/ when followed by another T3 syllable 演 /jen213/. The disyllabic word 主演 ('to act a leading role') is then pronounced as /tʂu35 jen213/. The results of the priming experiment showed that surface primes (T2), such as /tʂu35/, which overlap with the surface tone of the first syllable of the disyllabic targets such as /tʂu35 jen213/, did not elicit a facilitatory effect compared with the unrelated control primes; while the underlying prime (T3) such as /jen213/, which overlaps with the base tone of the first syllable of the disyllabic targets, showed a strong facilitation effect, regardless of the target word frequency. The results suggested that native speakers of standard Mandarin stored the underlying representation of the tone sandhi in the mental lexicon.

However, not all types of tone sandhi patterns are stored in their underlying form. The sandhi patterns of Taiwanese are much more complicated than Mandarin due to its circular opacity. Tones in non-phrase-final positions would go through circular chain shifts (Zhang, Lai & Sailor 2011) Figure 1. For example, a syllable with a tone value of 24 would change into 33 when it precedes another syllable in the disyllabic words. Chien, Sereno & Zhang (2016b) conducted another study on Taiwanese tone sandhi, in particular, sandhi rules 24→33 and 51→55. In Taiwanese, even though these two sandhi rules are applied to real words, their application rates to novel words are very different, with an 80% application rate for 24→33 sandhi and only 40% for 51→55 sandhi (Zhang et al. 2011). The results were indeed different. For the more productive 24→33 sandhi, the recognition of the target words was more facilitated by the underlying primes; but for the less productive 51→55 sandhi, the recognition was more facilitated by the surface primes. It showed that even within the same language, the way native speakers represent the sandhi patterns in the mental lexicon can still be different.

$$\begin{array}{c} 51 \rightarrow 55 \rightarrow 33 \leftarrow 24 \\ \nwarrow \qquad \swarrow \\ 21 \end{array}$$

Figure 1 Taiwanese sandhi patterns.

Zhang (2016, 2019) argued that the opacity of the tone sandhi plays a crucial role in determining how tone sandhi is represented in the mental lexicon. He defined that a transparent tone sandhi is a phonological alternation that is driven by surface-true phonotactic generalizations and the output of the sandhi will not go through another sandhi rule. An opaque sandhi is any sandhi rule that does not conform to any one of the above-mentioned rules. For example, the T3 sandhi in standard Mandarin is transparent, because it is driven by a phonotactic generalization that bans a T3 before another T3 and the derived T2 syllable is not an undergoer of another sandhi rule. However, Taiwanese tone sandhi is opaque as the tones in Taiwanese go through circular chain shifts. Hence, the output of the sandhi rule can be the undergoer of another rule.

Based on the experiment results, Zhang (2019) maintained that the recognition of words that undergo transparent tone sandhi is consistently more facilitated by the underlying forms, as they can be derived from productive sandhi rules; while the recognition of words undergo opaque sandhi is consistently more facilitated by surface forms, as surface allomorphs were stored in the mental lexicon. More evidence from other Chinese dialects can help validate this account.

2 The Current Study on Kunming Dialect Tone Sandhi

Kunming dialect is a major variety of Southwestern Mandarin. It has four citation tones and exhibits tone sandhi. The tone values are shown in Table 1 (Gui 2001, Lin 2019).

	Citation tone value	Allotone value
T1	/44/	[35]
T2	/31/	
T3	/53/	[55]
T4	/11/	

Table 1 The value of citation tone and allotone in Kunming dialect.

With regard to the tone sandhi of Kunming dialect, it is right-dominant and mainly includes T1 and T3 sandhi. T1 would change from /44/, a flat tone, to [35] a rising tone when it is followed by any other tone categories in a disyllabic word, but it would remain a flat tone when it is followed by T1. T3 would change from /53/, a falling tone, to [55], a flat tone, as long as it is not the last syllable of the disyllabic word.

According to the definition provided by Zhang (2016), T1 sandhi is opaque. T1 /44/ changes into a rising tone [35] in most cases as long as it is in non-phrase-final position, but it remains flat when it is followed by another T1. Compared with the T3 sandhi in standard Mandarin, it also violates the Obligatory Contour Principle which states that consecutive identical autosegments are banned (Leben 1973, McCarthy 1986) . There is no phonetic motivation for T1 to remain unchanged in this situation, seemingly phonetically arbitrary.

On the other hand, T3 sandhi is transparent. It changes from a falling tone /53/ to a flat tone [55] if it is not the final syllable. It is driven by a surface-true phonotactic generalization that bans the citation T3 in nonfinal positions. Besides, the output of the phonological alternation is not the undergoer of another sandhi rule. Thus, it is a transparent tone sandhi.

As Kunming dialect has both opaque and transparent sandhi patterns, it provides a rare opportunity to see whether the mental representations of sandhi patterns in a language could differ due to the difference in opacity. It could also validate Zhang's (2016, 2019) account, regarding whether the opacity of tone sandhi can crucially determine the way native speakers store and process the sandhi patterns. As T1 sandhi is opaque and T3 sandhi is transparent, it could be predicted that for words with T1 sandhi, it is the surface forms that are stored in the mental lexicon and accessed during spoken word recognition; while for words with T3 sandhi, it is the underlying representations that are stored and contribute to the recognition.

3 Methodology

3.1 Participant

36 native Kunming dialect speakers were recruited for this experiment (21 males and 15 females; mean age: 28). None of them have any language disorder. This experiment has received ethical approval from the University of Cambridge. No monetary compensation was given and the participants took part in the experiment voluntarily.

3.2 Stimuli

36 common disyllabic words were chosen from the latest *Dictionary of Kunming Dialect* (Zhang & Mao 2008) as the critical items. Because there is no frequency corpus for Kunming dialect, participants were asked to do a familiarity rating task for these words at the end of the experiment (Balota, Pilotti & Cortese 2001). 18 of the critical items were T1 sandhi words and the other 18 were T3 sandhi words. Each critical item was preceded by one of the three types of primes: surface, underlying and control prime. They all have the same segmental content but differ in tone values. For example, regarding the primes for a T1 target word 开门 /k^{h}ɛ35 mən31/ ('open the door'), the surface prime of it would be /k^{h}ɛ35/, sharing the same tonal contour as the onset of the target word; the underlying prime would be /k^{h}ɛ44/, carrying the tone value of the citation T1; the control prime could carry an unrelated tone such as T4, in this case, it would be /k^{h}ɛ11/.

Apart from the critical items, 60 real words were selected to be fillers. 96 nonwords needed for the lexical decision task were also created by combining two existing morphemes together, but the resulting disyllabic word did not make any sense in Kunming dialect. Both the fillers and the nonwords were preceded by two types of primes: primes that have the same tone or different tone as the first syllable of the words, because tone 2 and tone 4 do not go through tone sandhi in most cases.

3.3 Stimuli recording

All stimuli were recorded by a 53-year-old native speaker of Kunming dialect who only speaks Kunming dialect. He was instructed by the author to read the primes, disyllabic words and nonwords as naturally as possible.

3.4 Procedure

This experiment was conducted using Gorilla. Participants were given clear instructions before starting the experiment. They were first asked to sign the consent form and fill in the language background questionnaire. Then they put on their earphone to start the auditory-auditory priming lexical decision experiment. They were given 8 practice trials first and they were informed about whether they made the right decision. After the practice trial, the main trials started, and the participants did not know whether they did it right or wrong after each trial. In total, there were 192 mains trials. All the stimuli in the experiment were randomized for different participants. Latin-square design was used to ensure that each target word was only heard once by each participant, i.e. each participant would only hear one type of prime.

In each trial, the participants first heard a monosyllabic prime. After a 250ms interval with a cross showing on the center of the screen, they heard a disyllabic target word. They needed to judge whether the word was a real word or a nonword as quickly and accurately as possible by clicking the right bottom ('a real word') or the left bottom ('a nonword') on the screen. The intertrial interval was 3000 ms.

After the priming experiment, the participants were asked to do the familiarity rating task. They needed to indicate their subject familiarity with the target words, with a response scale ranging from 1 'never heard or used it' to 5 'used and heard it very often'. The entire experiment was around 20 minutes.

4 Results

Prime type (surface, underlying, control) and tone type (T1, T3) were treated as independent variables with the reaction times as the dependent variable. Reaction times and error rates were obtained from the lexical decision task. For all the stimuli, including fillers and nonwords, 82 responses were overtime (3s), among which 9 responses were from critical trials. Overall the mean error rate for all the stimuli was 7.86% (537 / 6830 trials). The error rate for the critical stimuli was 4.12% (53 / 1287 trials).

Regarding the analysis of response time on critical stimuli, responses over two standard deviation from the mean reaction time of critical stimuli (M = 1266, SD = 312) and incorrect responses (4.7%, 61 / 1287 trials) were excluded.

Linear mixed-effects (LME) analyses were conducted on the reaction times using the lmerTest package in R (Kuznetsova, Brockhoff & Christensen 2017).

Familiarity is controlled by picking common words from the dictionary. The results of the familiarity rating (M = 4.79, SD = 0.58) and the correlation between familiarity rating and reaction time (r = 0.0012) indicate that familiarity of the critical items is controlled and do not need to be treated as a fixed effect in the LME model.

Several likelihood ratio tests were run to examine the effect of tone type (T1, T3) and prime type (underlying prime, surface prime, control prime) as well as the interaction between tone type and prime type. In the initial model, tone type and prime type were treated as the covariates. Subject and items were treated as random intercepts. Some participants may be slow responders and some words may be more difficult than others, resulting in longer response time and vice versa. Hence, by-subject and by-word adjustments are needed to provide a fine-tune baseline mean as these are not the main factors of the model (Baayen, Davidson & Bates

2008). Reaction time to the disyllabic targets was log-transformed to reduce the skewness of the data and was the dependent variable. In terms of the baseline of the model, the control prime was set as the baseline to which the surface prime and underlying prime conditions were compared to examine whether there was any facilitatory effect. A few models were created by making one change at a time in the structure of the random effects, e.g. include by-subject slopes and compared it with the full model using the anova() function. The significance level was used to indicate whether the simpler model was justified (Baayen 2008). In the end, the model that considered by-subject and by-word random intercepts was chosen.

Results generated from the likelihood ratio tests showed no main effects for tone type or nor any interactions between tone type and prime type. With regard to T1 sandhi, surface tone primes elicited significantly faster reaction time compared to the control primes (β = -.029, SE = .007, t = -4.420, $p < .001$). Though there was a trend for the reaction times of the underlying primes to be faster than the control primes, it was not statistically significant (β = -.013, SE = .007, t = -1.902, p = .0575).

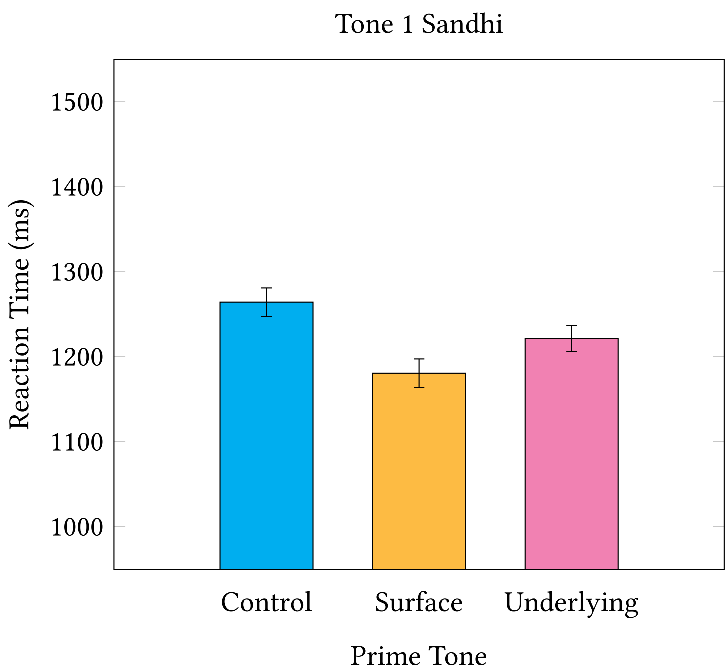

Figure 2 Mean reaction time (ms) and error bars for control, surface and underlying prime conditions for targets with T1 sandhi. Error bars represent standard errors.

Similarly, with regard to words with T3 sandhi, surface primes also significantly speeded up the reaction time compared to the control primes (β = -.027, SE = .007, t = -3.950, $p < .001$), while the response times of targets with underlying primes were not significantly different from those with control primes (β = -.013, SE = .007, t = -1.897, p = 0.0581).

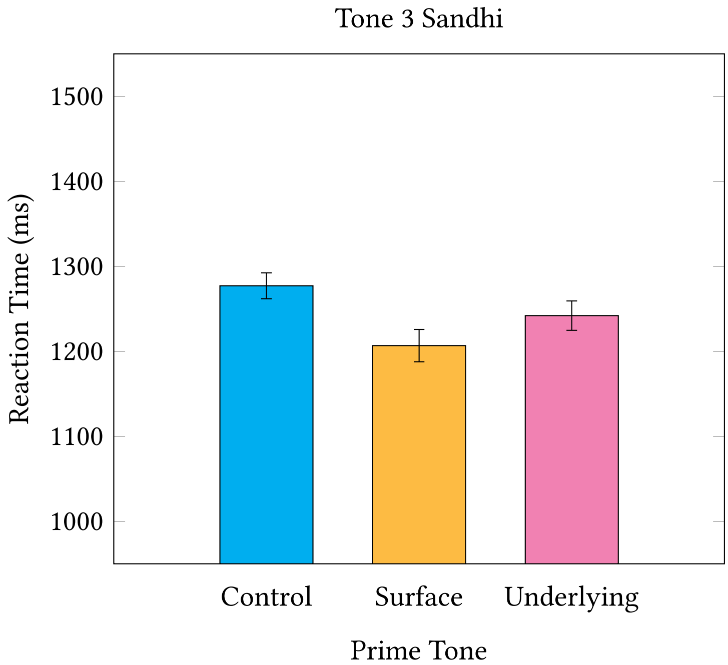

Figure 3 Mean reaction time (ms) and error bars for control, surface and underlying prime conditions for targets with T3 sandhi. Error bars represent standard errors.

5 Discussion

The experiment results showed that participants' reaction times to both T1 and T3 sandhi words were significantly facilitated when the primes matched the surface form of the first syllable of the disyllabic targets. It strongly suggests that the surface forms are stored in the mental lexicon and are accessed during spoken word recognition for both T1 sandhi words and T3 sandhi words. Even though the results meet the prediction made for T1 sandhi words, they pose a challenge to Zhang's (2016, 2019) account as they are against the previous prediction about T3 sandhi words - T3 sandhi satisfies the definition of a transparent sandhi. Hence, T3 sandhi words are supposed to be more facilitated by the underlying primes compared with the surface primes.

Hailu Hakka has a sandhi rule that is almost the same as the T3 sandhi rule in Kunming dialect. It is also positionally triggered, 13→33/__X, i.e. changing from a rising tone to a flat tone in non-phrase final position. This sandhi rule of Hailu Hakka is transparent (Zhang 2016). However, the results of the priming experiment in Hailu Hakka showed that only the underlying primes elicited faster reaction time (Zhang, Yan, Lai & Lyu 2016). This suggests that the opacity of the tone sandhi is not the only and sufficient indicator of the mental representation of tone sandhi in different languages. There are more factors at play, which could possibly explain why the results from the current experiment can run counter to the previous account (Zhang 2016, 2019).

Productivity of the sandhi patterns may be a better indicator of the representation of the sandhi forms. As mentioned in the introduction, Taiwanese sandhi patterns are opaque. However, the recognition of words with sandhi 24→33 was significantly more facilitated by underlying primes compared with the surface primes, though both surface and underlying primes significantly reduced reaction time compared with the control group (Chien et al. 2016b). It is against the prediction of an opaque tone sandhi in Zhang's (2016) account. However, the productivity of Taiwanese tone sandhi can better indicate how sandhi words are represented. It was found that sandhi rule 24→33 is much more productive than sandhi rule 51→55. Their application rates to novel words are 80% and 40% respectively (Zhang et al. 2011). Based on the results of Chien et al.'s (2016b) priming experiment, for the less productive sandhi rule 51→55, it seems that the surface representation is stored in the mental lexicon, as it could be very hard to access the underlying representation via an unproductive sandhi rule in spoken language recognition; For sandhi rule 24→33, which is more productive than 51→55, it seems that there is a higher contribution of the underlying representation compared to the surface form. As this sandhi rule is not fully productive, we could speculate that surface forms are also stored, though, to a much lesser extent compared to the 55→51 rule. During spoken word recognition, it is likely that both surface and underlying representation are activated, as they both showed a facilitatory effect in the priming experiment compared to the control primes. For Mandarin, which is known to be fully productive (Zhang & Lai 2010), it is very likely that only the underlying forms are stored in the mental lexicon, as the underlying representation can be easily accessed via this extremely productive sandhi rule. This prediction matched the results from the priming experiment (Chien et al. 2016a).

Here the representation of sandhi patterns is not all-or-none but complementary (Goldinger 2007). Both the surface and underlying representations are stored in the mental lexicon but with contribution to a different extent depending on factors such as productivity. Future studies could also examine the productivity of the sandhi rules of Kunming dialect to see whether the productivity of sandhi rule can explain the way sandhi words in Kunming dialect are stored in the mental lexicon.

The results of the current experiment could result from the limitations of this study. It is possible that the target words are too frequently used. Word frequency influences recognition. People took less time recognizing high-frequency words compared with words of lower frequency (Chien et al. 2016b). This study does not examine the effect of word frequency on word recognition. The target words chosen for the critical trials were words that are very commonly used, such as 手机 ('phone'). The results from the familiarity rating task also showed how common these words are, with a mean of 4.79 (5 being very often heard and used). It is possible that because these words are so frequently used, the surface representations of those disyllabic words are weighed more heavily and are easily accessed in the mental lexicon. Future study could include words of high and low frequency to see whether the contribution of surface and underlying representation changes

In sum, this paper examined the representation of T1 and T3 sandhi in Kunming dialect. It casts doubt on the role of opacity in determining the representation of phonological patterns. Even though T1 sandhi and T3 sandhi differ in their opacity, the results of the priming experiment showed the recognition of both sandhi patterns was more facilitated by the surface forms. It also shows the complexity of the representation of tone sandhi. Different sandhi patterns may weigh surface and underlying representations differently depending on the nature of the tone sandhi. As the productivity of the sandhi rules could better explain the difference in representations, where opacity failed. Future study could investigate whether the productivity of the sandhi rule could crucially determine the representation of sandhi words and how they are processed during spoken word recognition.

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