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Priming the Representation of Taiwanese Tone Sandhi Words

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Abstract

Tone sandhi is a tonal alternation phenomenon in which a tone changes to a different tone in certain phonological environments. Taiwanese tone sandhi realizes itself in a circular chain-shift fashion. This study aims to investigate how Taiwanese disyllabic words with sandhi T51 → T55 and sandhi T24 → T33 are represented in the listeners' mental lexicon, namely, whether Taiwanese listeners are more sensitive to the surface representations or underlying representations of Taiwanese sandhi words in spoken word recognition. An auditory priming lexical decision experiment was conducted to examine priming effects between monosyllabic primes and their corresponding disyllabic targets. Each target was preceded by either a surface-tone prime (e.g., ping55-ping55tsun24; pue33-pue33jong51), an underlying-tone prime (e.g., ping51-ping55tsun24; pue24-pue33jong51), or an unrelated control (e.g., ping21-ping55tsun24; pue21-pue33jong51). Results showed that for sandhi T51 → T55, surface tone primes elicited a stronger facilitation effect than underlying tone primes, with sizeable frequency effects, while for sandhi T24 → T33, underlying tone primes elicited a stronger facilitation effect than surface tone primes. Our data show that the phonological nature of tone sandhi influences how listeners process and represent tone sandhi words.

Index Terms: tone, Taiwanese, tone sandhi, spoken word recognition

1. Introduction

During spoken word recognition, acoustic inputs often do not match their corresponding underlying linguistic representations in a straight-forward fashion due to different factors such as coarticulation, variations in speech rate and phonological alternation [1]. Tone sandhi is a phonological alternation phenomenon where a tone changes to a different tone due to the influence of an adjacent tone [2]. In these cases, the surface forms of tone sandhi words differ from their underlying representations, raising questions of how speakers of these tone languages process tone sandhi words and whether it is the surface representation or the underlying representation of tone sandhi words that contributes to spoken word recognition. The current study aims to investigate how Taiwanese speakers process Taiwanese tone sandhi words.

Two contrasting views concerning how tone sandhi words are represented in the mental lexicon have been proposed [3]. An underlying or canonical representation view states that tone sandhi words are represented as the concatenation of the citation forms of their constituent morphemes. Therefore, according to an underlying representation view, the Mandarin word [pɑw2 ɕjɛn3] /pɑw3 ɕjɛn3/ "insurance", would be represented as /pɑw3 ɕjɛn3/ in Mandarin speakers' mental lexicon due to the tone 3 sandhi rule T3 → T2 / __T2. On the other hand, a surface representation view posits that tone sandhi words are represented based on their surface forms. According to this view, the Mandarin tone 3 sandhi word [pɑw2 ɕjɛn3] /pɑw3 ɕjɛn3/ "insurance" would be represented as /pɑw2 ɕjɛn3/. Previous experimental research on processing of tone sandhi has produced conflicting results in Mandarin [3].

To further investigate how Mandarin tone 3 sandhi words are processed, Chien, Sereno and Zhang conducted an auditory-auditory priming lexical decision experiment [4]. Each disyllabic Mandarin tone 3 sandhi target (e.g., /fu3 dao3/ 輔導, "to counsel") was preceded by one of three corresponding monosyllabic primes, namely, a tone 2 prime (e.g., /fu2/ 服, "to assist"), a tone 3 prime (e.g., /fu3/ 輔, "to guide"), or a control prime (e.g., /fu1/ 敷, to put on). Results showed that tone 3 primes (underlying form overlap with the first syllable of the tone 3 sandhi targets) facilitated participants' lexical decision responses relative to the unrelated control primes, while tone 2 primes (surface form overlap with the first syllable of the tone 3 sandhi targets) did not show facilitation relative to the unrelated control primes. Moreover, these priming effects occurred regardless of the targets' word frequency. These data show that tone 3 primes (e.g., /fu3/ 輔, "to guide") facilitated reaction times to all tone sandhi targets (e.g., /fu3 dao3/ 輔導, "to counsel") due to morpheme level activation between primes and the underlying representation of the first syllable of the targets. Tone 2 primes (e.g., /fu2/ , 服, "to assist"), although matching targets on the surface, did not show priming effects, indicating that surface matching did not result in faster sandhi word recognition. Chien, Sereno and Zhang [4] concluded that Mandarin tone 3 sandhi words are represented as /tone 3 tone 3/ in listeners' mental lexicon.

This pattern of results is in agreement with data from an experiment showing that, in production, Mandarin speakers have systematic knowledge of the Mandarin tone 3 sandhi rule [5]. Mandarin speakers, in a nonword probe test, were asked to combine two tone 3 monosyllables and produce them as a disyllabic word. The F0 height and F0 contour of the first syllable of the disyllabic stimuli were then analyzed. Results showed that Mandarin tone 3 sandhi applied without exception to the resulting disyllable combinations.

Taiwanese tone sandhi is also right-dominant, in which the tone at the right edge of a tone sandhi domain maintains its citation tone, while the others in the same domain undergo tone sandhi [2]. For Taiwanese disyllabic words, however, tone sandhi is manifested in a circular chain-shift fashion in the non-XP final position, as shown in Figure 1. For example, for the syllable 馬 /ma51/ "horse", the citation tone of the syllable changes from a high-falling tone (ma51) to a high-level tone (ma55) when it precedes another syllable (上 /sjoŋ33/). Thus, the surface form of the Taiwanese disyllabic sandhi word 馬上 /ma51 sjoŋ33/ "immediately" is [ma55 sjoŋ33].

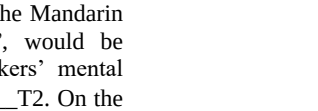

Figure 1. Taiwanese tone sandhi circle

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The current study aims to investigate how Taiwanese native speakers process Taiwanese tone sandhi words and to directly examine how Taiwanese tone sandhi words are represented in the mental lexicon.

An auditory lexical decision priming experiment was conducted with monosyllabic Taiwanese primes and disyllabic tone sandhi targets. Zhang, Lai and Sailor [6] showed that although Taiwanese sandhi rules 51 → 55 and 24 → 33 consistently apply to real words, they differ dramatically in terms of their application to novel words, with 80% application for 24 → 33 and only 40% application for 51 → 55. Thus, Taiwanese tone sandhi 51 → 55 and 24 → 33 were examined in the current study. Each tone sandhi disyllabic target was preceded by either a surface tone prime, an underlying tone prime, or an unrelated control prime. For tone sandhi 51 → 55, priming effects on targets (e.g., [ping55 tsun24] /ping51 tsun24/) across three priming conditions (surface: [ping55], underlying: [ping51], control: [ping21]) were evaluated. For tone sandhi 24 → 33, priming effects on targets (e.g., [pai33 kai51] /pai24 kai51/) across three priming conditions (surface: [pai33], underlying: [pai24], and control: [pai21]) were evaluated.

2. Methods

2.1. Participants

Thirty-six native Taiwanese speakers were recruited for this study. None of them had any reported language impairments. Their ages ranged from 30 to 55 years old at the time of testing.

2.2. Stimuli

Thirty-six disyllabic Taiwanese tone sandhi words were selected as critical targets. Eighteen of them had the surface tonal melody 55-24 (51 → 55 on the first syllable), while eighteen of them had the surface tonal melody 33-51 (24 → 33 on the first syllable). They were all chosen from an online Taiwanese dictionary entitled "*教育部臺灣閩南語常用詞辭典*" [7]. Since the corpus did not provide word frequencies for all selected tone sandhi targets, an additional subjective familiarity rating task was conducted to ascertain that targets with tone sandhi (51 → 55 and 24 → 33) did not differ. Participants provided familiarity ratings for the 36 critical tone sandhi targets ranging from 1, representing "never heard or said", to 7 "very often heard and said" [8]. An independent-samples t-test showed no significant difference between the subjective familiarity ratings for the two types of tone sandhi stimuli (for 51 → 55: $\bar{x}$ = 5.55 (sd = 1.25); for 24 → 33: $\bar{x}$ = 5.47, (sd = .98)) ($t(34) = .221$, $p = .826$).

Each of the 36 tone sandhi targets was preceded by one of the three corresponding monosyllabic primes: a surface tone prime, an underlying tone prime, and an unrelated control prime. The monosyllabic primes were all real Taiwanese morphemes. For example, the tone sandhi target [ping55 tsun24] /ping51 tsun24/ 翻船 "ship wreck" was preceded by either a surface tone prime [ping55] /ping55/ 冰 "ice", an underlying tone prime [ping51] /ping51/ 翻 "turn over", or an unrelated tone prime [ping21] /ping21/ 併"combine". The tone sandhi target [pai33 kai51] /pai24 kai51/ 排解 "mediate" was preceded by either [pai33] /pai33/ 敗 "lose" (a surface tone prime), [pai24] /pai24/ 排 "arrange" (an underlying tone prime), or [pai21] /pai21/ 拜 "worship" (an unrelated control prime).

In addition to the 36 critical sandhi targets, 60 disyllabic words selected from the same Taiwanese dictionary and Taiwanese Spoken Corpus [9] served as filler words. These filler words were preceded by monosyllabic primes which were real Taiwanese morphemes. Ninety-six disyllabic nonwords were also included. Each nonword was preceded by a Taiwanese monosyllabic prime, which was a real Taiwanese morpheme. Numbers of each tone were balanced across critical targets, filler words, and nonwords.

2.3. Stimulus recording

A 29-year-old female native Taiwanese speaker produced all of the stimuli and was recorded in an anechoic chamber with a cardioid microphone (Electrovoice, model N/D767a) and a digital solid-state recorder (Marantz, model PMD671), using a sampling rate of 22,050 Hz at the University of Kansas.

2.4. Procedure

An auditory-auditory priming lexical decision experiment was conducted using the Paradigm [10] software. All stimulus trials (prime-target) in the experiment were randomly presented over headphones. Eight practice trials were presented first, followed by 192 main trials.

Of the 192 main trials, 36 were critical trials and presented with a Latin Square design, such that each participant only heard a critical target once, preceded by its corresponding surface tone prime, underlying tone prime, or unrelated control prime. The remaining 156 trials were shared across all participants.

For each trial, participants heard a monosyllabic prime first. After a 250 ms interval, they heard a disyllabic target, either a word or a nonword. The participants' task was to judge whether the disyllabic target was a real word or not by clicking the left button of the mouse, representing "yes", or the right button of the mouse, representing "no", as quickly and accurately as possible. The intertrial interval (ITI) was 3000 ms.

After the lexical decision experiment, participants were given the subjective familiarity judgment task. The total duration of the lexical decision experiment and the subjective familiarity judgment task was around 30 minutes.

3. Results

Statistical analyses were conducted on reaction times and errors obtained from the lexical decision task. Across all 36 participants, the overall mean error rate was 12.9% (SD = 1.9) (892 trials/6912 trials). For the reaction time analyses, incorrect responses (8.8%) (114 trials/1296 trials) and responses over two standard deviations (3%) (39 trials/1296 trials) were excluded.

A series of linear mixed-effects analyses were conducted on participants' log-transformed reaction times and errors using the lme4 package in R [11]. Likelihood ratio tests were performed to evaluate effects of Prime (Surface, Underlying, Control), Sandhi Type (51 → 55, 24 → 33), Familiarity, Prime X Sandhi Type, Prime X Familiarity, Sandhi Type X Familiarity, and Prime X Sandhi Type X Familiarity.

Participants' log-transformed reaction time to Taiwanese sandhi targets was set as a dependent variable. Prime and Sandhi Type were categorical independent variables, while Familiarity was a continuous independent variable. For Prime, Control was selected as the baseline to which Surface and Underlying were compared in order to examine facilitation and inhibition effects. Participant and Item were considered random variables. Seven models were created and compared.

Results generated from the likelihood ratio tests showed an effect of Familiarity ($\Delta\chi^2 = 36.344$, df = 1, $p < .001$), indicating that participants responded to familiar targets significantly faster than to unfamiliar targets. Results generated from the likelihood ratio tests also showed an effect of Prime X Sandhi Type ($\Delta\chi^2 = 13.968$, df = 2, $p < .001$), and an effect of Prime X Sandhi Type X Familiarity ($\Delta\chi^2 = 11.514$, df = 2, $p = .003$).

There were no main effects for Sandhi Type, nor any Prime X Familiarity or Sandhi Type X Familiarity interactions.

Additional linear mixed-effects analyses were conducted to examine the significant Prime X Sandhi Type interaction. Two additional analyses were conducted for targets with tone sandhi 51 → 55 and for targets with tone sandhi 24 → 33.

For targets with tone sandhi 51 → 55, Surface tone primes elicited significantly faster reaction times than did Control primes (β = -.030, SE = .007, *t* = -4.45, p < .001), and there was a trend for Underlying tone primes to yield faster reaction times than did the Controls (β = -.011, SE = .007, *t* = -1.66, p = .097). Reaction times for the Surface prime condition were also significantly faster than those for the Underlying prime condition (β = .020, SE = .007, *t* = 2.92, p = .004). As shown in Figure 2, the facilitation priming revealed that for the targets with tone sandhi 51 → 55, Surface tone primes (+120 ms facilitation priming effect) significantly facilitated participants' lexical decision responses. While Underlying tone primes (+32 ms facilitation priming effect) showed significantly less facilitation, a facilitation effect (relative to Control primes) was still evident.

For targets with tone sandhi 24 → 33, Surface primes yielded significantly faster reaction times than did the control primes (β = -.023, SE = .006, *t* = -3.65, p < .001), and so did the Underlying prime compared to the Control prime condition (β = -.036, SE = .006, *t* = -5.68, p < .001). Furthermore, for tone sandhi 24 → 33, the Underlying condition elicited significantly faster reaction times than did the Surface condition (β = -.013, SE = .006, *t* = -2.07, p = .039). As shown in Figure 2, for targets with tone sandhi 24 → 33, both Underlying and and Surface prime conditions significantly facilitated participants' lexical decision responses; however, the facilitation effect yielded by the Underlying condition (+136 ms facilitation priming effect) was significantly stronger than that observed in the Surface (+93 ms facilitation priming effect) condition.

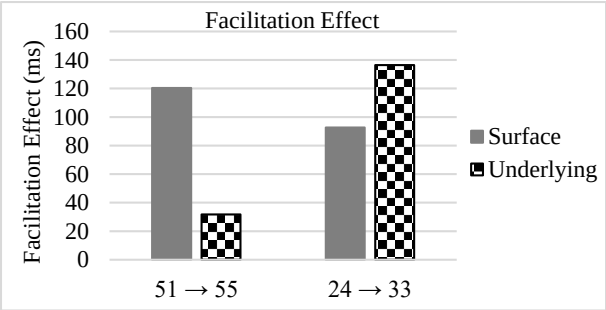

Figure 2. Facilitation effects for the Surface and Underlying prime conditions (relative to baseline Control condition) for targets with tone sandhi 51 → 55 and 24 → 33.

In order to further examine the effect underlying the three-way interaction of Prime X Sandhi Type X Familiarity, two series of likelihood ratio tests were also conducted on participants' log-transformed reaction times for tone sandhi 51 → 55 and 24 → 33, respectively.

Results showed an effect of Familiarity for both tone sandhi 51 → 55 ($\Delta\chi^2$ = 27.309, df = 1, p < .001) and tone sandhi 24 → 33 ($\Delta\chi^2$ = 11.367, df = 1, p < .001), indicating that participants responded to familiar targets significantly faster than to unfamiliar targets regardless of Sandhi Type. However, an interaction between Prime X Familiarity was only observed for tone sandhi 51 → 55 ($\Delta\chi^2$ = 10.137 , df = 2, p = .006) but not for tone sandhi 24 → 33, confirming the three way interaction obtained above, and suggesting significantly different reaction time patterns across Surface, Underlying, and Control conditions as a function of Familiarity for words with tone sandhi 51 → 55 compared to words with tone sandhi 24 → 33 (see Figure 3 and Figure 4). This interaction effect resulted from the fact that for tone sandhi 51 → 55, both Surface and Underlying conditions facilitated participants' lexical decision responses when participants were highly familiar with the tone sandhi targets, but only the Surface condition elicited a facilitation effect when participants were less familiar with the targets. In contrast, for tone sandhi 24 → 33, both Underlying and Surface conditions yielded a priming effect regardless of Familiarity.

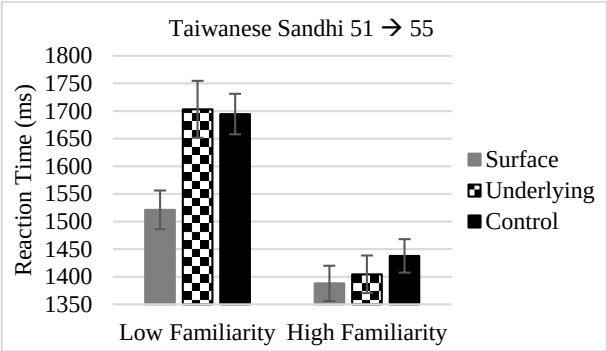

Figure 3. The effect of Prime X Familiarity for sandhi 51→55.

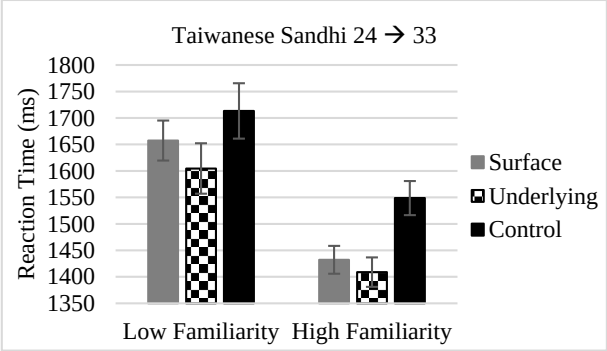

Figure 4. The effect of Prime X Familiarity for sandhi 24→33.

A series of likelihood ratio tests of linear mixed-effects analyses were also conducted on participants' errors. Results showed that only Familiarity was a factor in influencing participants' errors in the lexical decision task, with less familiar targets eliciting more errors (β = .508, SE = .050, *z* = 10.111, p < .001). No additional effects of Prime, Sandhi Type, or any interactions were observed for the error analyses.

4. Discussion

The current study investigated how Taiwanese speakers process Taiwanese words with tone sandhi 51 → 55 and tone sandhi 24 → 33 and how these words are represented in the mental lexicon. We used a priming methodology in which participants heard monosyllabic prime words followed by disyllabic tone sandhi targets and participated in a lexical decision task.

We found facilitation effects due to the overlap between the primes and the first syllables of disyllabic tone sandhi targets. Our data show that for targets with tone sandhi 51 → 55 and tone sandhi 24 → 33, both underlying and surface tone primes significantly facilitated participants' lexical decision responses compared to an unrelated control prime condition. The facilitation effect in the current study on Taiwanese can be attributed to morpheme level activation due to the overlap between primes and the first syllables of the tone sandhi targets. Otherwise, no priming effects would have been observed.

Priming occurred when there was overlap either in terms of underlying or surface representation. Both representations reasulted in facilitation.

In addition, differences in priming across the two Taiwanese sandhi types were observed. While both sandhi types exhibited facilitatory priming effects, the contribution of underlying and suface forms across sandhi types was distinct. For targets with tone sandhi 51 → 55, surface tone primes showed significantly more facilitation than underlying tone primes while for targets with tone sandhi 24 → 33, underlying tone primes showed significantly more facilitation than surface tone primes.

The present data are different from the priming effects we found for Mandarin tone 3 sandhi. For Mandarin tone 3 sandhi, only underlying facilitation was observed. Unlike Taiwanese tone sandhi in which both the underlying and surface representations play a role, Mandarin tone 3 sandhi words showed only underlying priming effects.

Productivity of the sandhi forms may provide an explanation. Zhang and Lai [5] and Zhang, Lai and Sailor [6] examined productivity of Mandarin and Taiwanese tone sandhi. They found that Mandarin tone 3 sandhi was very productive and applied without exception to the resulting disyllabic novel word combinations. They also found productivity differences across the Taiwanese tone sandhis. While Taiwanese tone sandhi 24 → 33 elicited around 80% sandhi application for novel disyllabic words, tone 51 → tone 55 sandhi yielded only 40% correct application for novel disyllabic words. They suggested that the overall lower productivity for Taiwanese tone sandhi compared to Mandarin tone 3 sandhi might be due to the opaque nature of Taiwanese tone sandhi (the circular chain shift). They further suggested that tone 51 → tone 55 is less productive compared to tone 24 → tone 33 because it is phonotactically legal for tone 51 to occur in the non-XP final position while it is illegal for tone 24 to occur in that position in Taiwanese (see Figure 1). The relatively unproductive nature of Taiwanese tone sandhi suggested that Taiwanese speakers might be less sensitive to Taiwanese tone sandhi patterns compared with Mandarin speakers' awareness of Mandarin tone 3 sandhi.

Interestingly, the present results also showed effects of familiarity on priming. Recall that for words with tone sandhi 51 → 55, surface primes showed greater facilitation while for words with tone sandhi 24 → 33, underlying primes showed the most facilitation. We found familiarity effects that differed across sandhi types. For tone sandhi 51 → 55, familiarity effects emerged, with surface primes yielding the most facilitation when participants were less familiar with the targets. However, for words with tone sandhi 24 → 33, both underlying and surface primes elicited a facilitation effect across the entire range of familiarity, with the underlying primes yielding a stronger effect than the surface primes.

These data suggest that Taiwanese words with different tone sandhi characteristics were processed differently, with the sandhi pattern 51 → 55 processed mainly based on the surface representation for less familiar words. However, words with the sandhi pattern 24 → 33 are processed based on both representations, with the underlying representation playing a more crucial role during spoken word recognition, irrespective of familiarity.

These findings suggest that Taiwanese words with tone sandhi 51 → 55 must be represented as both /tone 51 tone X/ and /tone 55 tone X/ when speakers are more familiar with them, and only as /tone 55 tone X/ when speakers are less familiar with them, while Taiwanese words with tone sandhi 24 → 33 must be represented both as /tone 33 tone X/ and /tone 24 tone X/ in the Taiwanese mental lexicon.

The current priming data for Taiwanese and the data for Mandarin [4] support a view in which the more productive a tone sandhi rule is, the greater the contribution of the underlying representation. The data suggest that native speakers may represent productive sandhi words in their underlying representations in the mental lexicon (e.g., Mandarin tone 3 sandhi and Taiwanese tone sandhi 24 → 33). However, the less productive the sandhi is, the more the surface form of the words contributes (e.g., Taiwanese tone sandhi 24 → 33 and Taiwanese tone sandhi 51 → 55). Moreover, when the surface representation plays a role, the contribution of familiarity also increases, as shown by the current results for tone sandhi 51 → 55, showing a strong familitarity interaction. Familiarity or frequency, therefore, seems to affect the representation of words with less productive tone sandhi. These findings suggest that words with less productive tone sandhi may be represented in their surface representations when they are less familiar to speakers, but represented both as the surface and underlying representations when the they are more familiar to speakers.

5. Conclusions

Taken together, the present study demonstrates that disyllabic Taiwanese tone sandhi words are represented differently based on their individual tone sandhi characteristics. The data here and those in [4] together show an influence of sandhi productivity on participants' sensitivity to the surface and underlying representations of tone sandhi words, with more productive sandhi eliciting more underlying priming, and less productive sandhi yielding more surface priming. Furthermore, for less productive sandhi, the role of the surface representation seems to be modulated by familiarity. Our data suggest that Taiwanese words with tone sandhi 51 → 55 are represented as /tone 51 tone X/ and /tone 55 tone X/ when they are more familiar to speakers, but only represented as /tone 55 tone X/ when they are less familiar to speakers. Taiwanese words with tone sandhi 24 → 33 are represented as /tone 24 tone X/ and /tone 33 tone X/ regardless of familiarity.

6. References

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