Tonal bilingualsim: the case of two related Chinese dialects

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5 Tonal Variability in Lexical Access[9]

Abstract

How do different types of tonal variability contribute to lexical access? We addressed this question by investigating a type of variability in Jinan tonal patterns, which is lexically non-contrastive but potentially contrastive in other words. This variability was tested against three levels of variability, viz. 'acoustic identity', 'within-category variation', and 'lexically-contrastive variation', in an auditory lexical decision task. The tonal pattern variation induced a similar but smaller facilitation effect compared with the acoustic identity and the within-category variation. In contrast, an inhibition effect was induced by the lexically-contrastive condition. Additionally, we tested the participants' tonal awareness. The effect of tonal awareness was smaller on the targets than on the primes. We conclude that, in lexical access, tonal patterns may have representative status but can converge in a lexically-specific way, and that the contribution of tonal awareness is reduced when the form is repeated.

5.1 Introduction

Listeners need to handle different types of variability in speech processing in order to access the correct lexical item, selectively relying on or ignoring the differences between acoustic signals. Most previous work on the processing of variability in lexical access has studied segmental alternations (e.g. Mitterer & Blomert, 2003), or the variability within a specific phoneme category (e.g. Andruski, Blumstein, & Burton, 1994). While much has been learned from studies on segmental variability, it is important to note that many languages make use of suprasegmental properties to signal lexical differences. For instance, pitch works as an important cue in the perception of lexical stress in English (e.g. Fry, 1958). Pitch is also crucial for the distinction of lexical tones in tonal languages. Sixty to 70% of the world's languages systematically use pitch variation to distinguish lexical meanings (Yip, 2002).

However, the limited number of studies on the processing of tone suggests that tones are processed differently from segments in lexical access. In implicit priming, for instance, in contrast to the traditional facilitation effect observed due to segmental primes, the overlap of Mandarin tones alone (J. Y. Chen, Chen, & Dell, 2002) and the surface tonal overlap accompanied with segmental sharing (Y. Chen, Shen, & Schiller, 2011) produced no facilitatory priming effect in a speech production task. During phonological encoding, reaction time in a phoneme monitoring task (Ye & Connine, 1999) and reaction time and onset latency of the N200 component in a go/nogo task (Zhang & Damian, 2009) showed that segmental information became available prior to tonal information in Mandarin. This difference in priority might also hold for the phonological decoding of auditory

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lexical access (Cutler & Chen, 1997). Although lexical adaptation seems to work similarly in tones and consonants (McQueen, Cutler, & Norris, 2006; Mitterer, Chen, & Zhou, 2011), more research is needed to understand the role of tonal variability in lexical access.

We will address the issue with data on tonal variability in Jinan Mandarin, a northern Mandarin dialect of Chinese. Jinan Mandarin has four monosyllabic tones traditionally described as Low-rising, High-falling, High-level, and Low-falling (Qian, 1995). In Jinan, the following type of variability has received relatively little attention in the literature. The same compound word can be accessed through two forms, with the same segmental structure but with distinctive tonal patterns. For instance, the same segmental structure /tɕiɛn tan/ with two different tonal patterns, either HL or LH, provides access to the same word 'simple'. This may sound similar to the phonological variants, such as the flapped /t/ and released /t/, tested earlier (Connine, 2004; Mitterer & Ernestus, 2006). However, unlike the two allophonic variants of /t/, the two tonal patterns of the Jinan word 'simple' are potentially contrastive for certain other segment strings. For instance, /ʂou tɕi/, with the HL tonal contour, provides access to the lexical item 'cell-phone' However, with the LH tonal pattern, it provides access to 'collect'. Thus, if the lack of contrast of the two different tonal patterns from specific words (such as /tɕiɛn tan/) generalizes to the whole vocabulary (including words like /ʂou tɕi/), this could result in confusion regarding many tonal minimal pairs. It is worth noting that the two tonal patterns exist within the same speaker. This is different from the dialectal differences such as American English *tomAYto* versus British English *tomAHto*.

Jinan also has two other types of tonal variability, which are common across the world's languages. One is non-contrastive within-category variation, where two renditions of the same word 'very' can be realized with slight differences in the shape of the pitch contour, although their tonal pattern remains the same. The other is lexically contrastive variation which involves two members of a tonal minimal pair, such as /ɕiɛn ʂʅ/ (HL) 'display'versus /ɕiɛn ʂʅ/ (LH) 'reality'.

Figure 1 illustrates these three types of tonal variability. The tonal pattern variation is similar to contrastive variation and different from within-category variation in that it involves different tonal patterns. However, the two tonal patterns in tonal pattern variation provide access to the same word. This makes it similar to within-category variation but different from contrastive variation.

How this tonal pattern variation is processed in lexical access remains an open question. Are the two forms treated like two different words similar in sound; or are they treated like two renditions of the same word different only in acoustic details? To shed light on these questions, one useful approach is to pit the tonal pattern variation against the other types of tonal variability in the process of lexical access. In the present study, we compared the possible priming effect of (1) acoustic identity, (2) non-contrastive within-category variation, (3) lexically non-contrastive tonal pattern variation, and (4) lexically contrastive tonal variability in an auditory priming paradigm employing the lexical decision task. If the difference between any two types of tonal variability leads to a difference in size of the priming effect, be it facilitation or interference, the two types are likely to be distinguished in their level of perceptual process before their final lexical access.

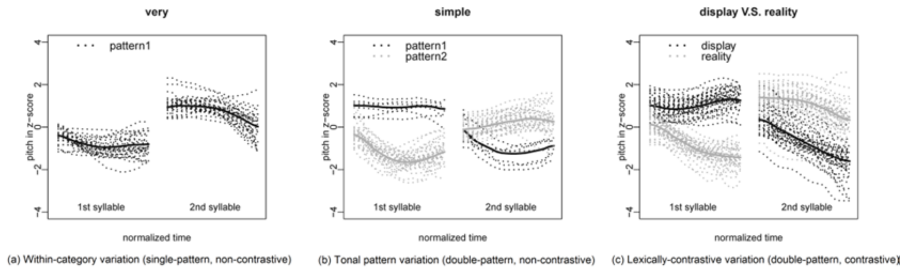

Figure 1. *Illustrations of the three types of variability. Each plot was made with recordings produced by 42 Jinan speakers (1 or 2 outliers excluded). Pitch values were z-transformed semitones (the mean and SD were calculated with about 600 recordings for each speaker).*

Based on the reports that tone-mismatch primes lead to inhibition in associative priming (Zhou, Q, Shu, Gaskell, & Marslen-Wilson, 2004), the contrastive variation condition (Condition 4) in the current study is also expected to yield an inhibition effect. The other three conditions are lexically non-contrastive (including the acoustic identity). If non-contrastive tonal variants converge into one representation at some stage of lexical access, both within-category variation and tonal variability should have a priming effect similar to that of the acoustic identity condition, given that both the target and the prime are linked to the same word in all of these conditions. However, if tonal patterns play a role at this stage of lexical access, the amount of priming of tonal pattern variation should differ from within-category variation, given their different quantity and quality of variability. Specifically, the priming effect of tonal pattern variation should be mitigated given that it involves two different tonal patterns.

In addition, general cognitive skills might also affect task performance and individual variation. For instance, tonal awareness, as a subset of phonological awareness, reveals listeners' aptitudes for discriminating and identifying tones (X. Chen et al., 2004; Shu, Peng, & McBride - Chang, 2008). In the current study, this was assessed as a between-participant factor through a tonal oddity task. We introduced this test for two reasons. Firstly, the phonological awareness level may help to explain possible individual variation in the priming/inhibition effect. Secondly, we are interested in the potential differences and interactions between the two seemingly similar processes, one involving conscious identification and discrimination of tonal categories (Burton, Small, & Blumstein, 2000; Zatorre, Evans, Meyer, & Gjedde, 1992), the other involving unconscious usage of tonal information for lexical access (Damasio & Damasio, 1980). According to previous studies on segmental processing, the two processes are carried out in two distinct pathways of the human brain (Hickok & Poeppel, 2000, 2007; Myers, Blumstein, Walsh, & Eliassen, 2009). In the current study, the former process is related to the tonal oddity task, and the latter to the lexical decision task.

5.2 Method

5.2.1 Participants

Twenty native speakers of Jinan, six males and fourteen females, participated in this experiment in exchange for payment. They were all right-handed and their ages ranged from 23 to 39. An oddity test was carried out first to divide the participants into two groups according to their tonal awareness (X. Chen et al., 2004; Shu et al., 2008).

5.2.2 Design and stimuli

A mixed design was adopted. The within-subject variable involved four levels of tonal variability and the between-subject variable involved two levels of tonal awareness (high and low). Disyllabic stimuli were selected from a corpus of high-frequency disyllabic Chinese words produced by six native speakers (3 male and 3 female) of Jinan Mandarin. Each word was read twice in random order. The same group of speakers also produced pseudowords. In total, we elicited four sets of 160 stimuli. All six speakers contributed to each set. The first set included twenty pairs of acoustic identity (Condition 1). The same stimulus was presented first as a prime and then as a target. In this condition, primes and targets were always identical. The second set included twenty pairs of stimuli with within-category variation (Condition 2). Within this set, each pair of stimuli showed the same tonal pattern with only very subtle differences in their actual instantiation of the pitch contour or in other acoustic dimensions (such as duration and intensity). The third set included twenty pairs of words with tonal pattern variation (Condition 3). In this condition, we picked words which were produced by the same speaker but with different tonal patterns in her/his two renditions of the same stimulus words, with one rendition as the prime and the other as target. The fourth set included lexically contrastive tonal pairs (Condition 4). In this condition, tonal minimal pairs (which share the same segmental structure) from the same speaker were chosen with one as the prime and the other as the target. In addition, 160 pseudowords and 20 real words were included as fillers. Figure 2 illustrates the four conditions with examples.

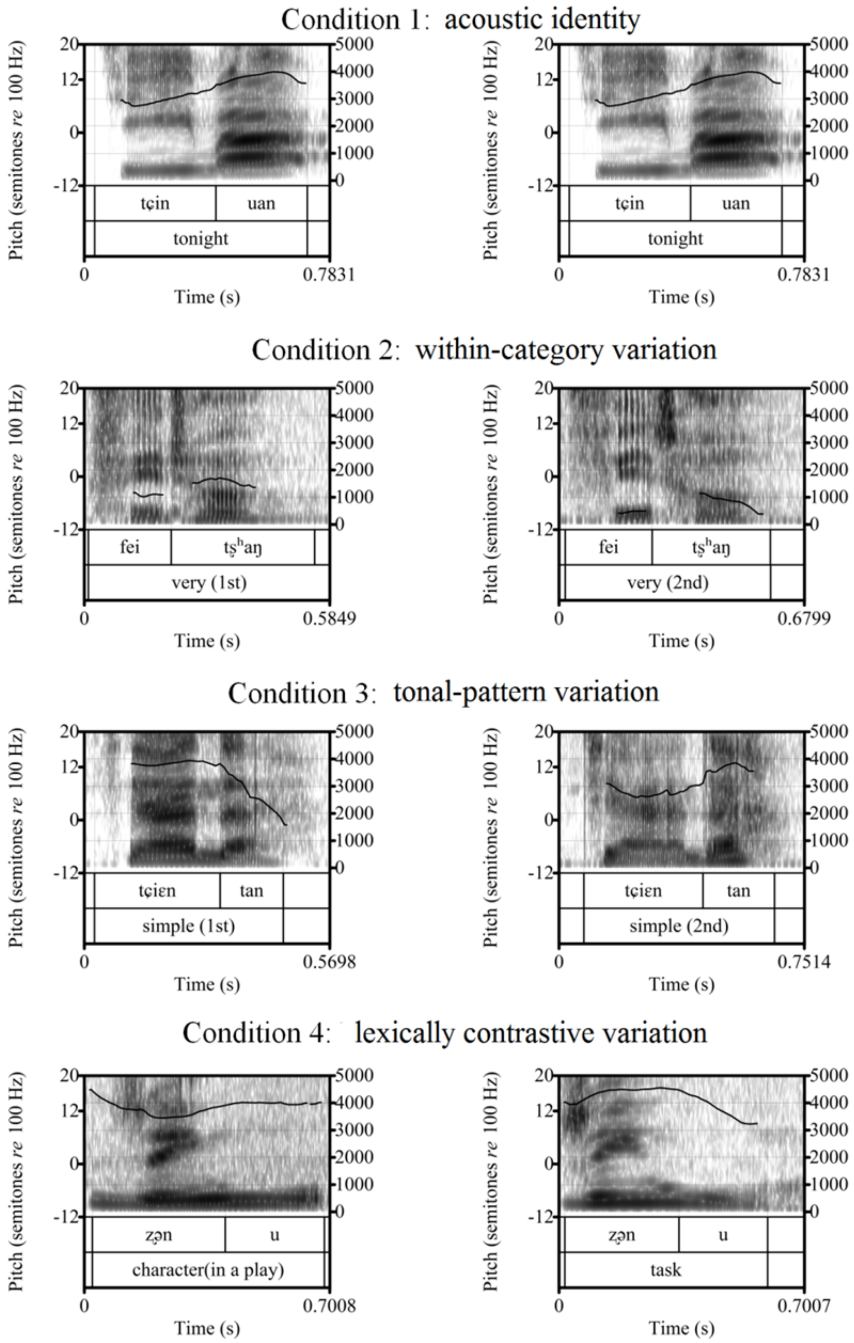

Figure 2. *Examples of the prime (left) and the target (right) in conditions 1-4, with pitch contours and spectrograms plotted.*

5.2.3 Procedure

Participants were tested individually in a quiet room. In the tonal oddity test, they listened to twelve sets of four monosyllabic Jinan words. Within each set, there was one word which had a different lexical tone, commonly labelled as the odd member. Participants pressed a number key on the keyboard to indicate the odd word (in the order of the presentation). The accuracy rate was calculated for each participant, according to which the participants were divided into two groups with high vs. low tonal awareness.

Then the participants were told that they would hear a series of disyllabic sound sequences in Jinan Mandarin and they had to decide whether or not each of these sound sequences was a real word. The presentation of the stimuli was controlled by E-Prime 2.0 run on a laptop equipped with a Creative SBX-FI5.1 pro sound card. Each item was played binaurally through headphones, with instructions on the screen. The target of each pair was played 4 to 6 items after its corresponding prime. Pairs in each group were presented in different random orders to the participants, while stimuli from the same condition were never presented directly following one another. A blank screen was displayed between every two items.

A *priming effect* was defined as the reaction time difference between the first occurrence (prime) and the second occurrence (target)(Pallier, Colomé, & Sebastián-Gallés, 2001). If the reaction to the target is faster than that to the prime, the priming effect will be positive; if it is slower, the priming effect will be negative. Here, a positive value is taken as facilitation and a negative value is taken as interference.

We performed two sets of analyses. First, Analyses of Variance (by-participants and by-items) were performed on the *priming effect* to assess the differences across tonal conditions and between participant groups. Then, mixed-linear-effect analyses were performed on the *reaction times* to further investigate the influence of tonal awareness on the process of primes and targets.

5.3 Results

5.3.1 Analysis 1

The average *priming effects* are plotted in Figure 3, as a function of the following factors: Contour Condition (acoustic identity vs. within-category variation vs. tonal pattern variation vs. lexically contrastive variation) and Tonal Awareness (low vs. high). The 95% error bars are based on the within-subjects repeated ANOVAs.

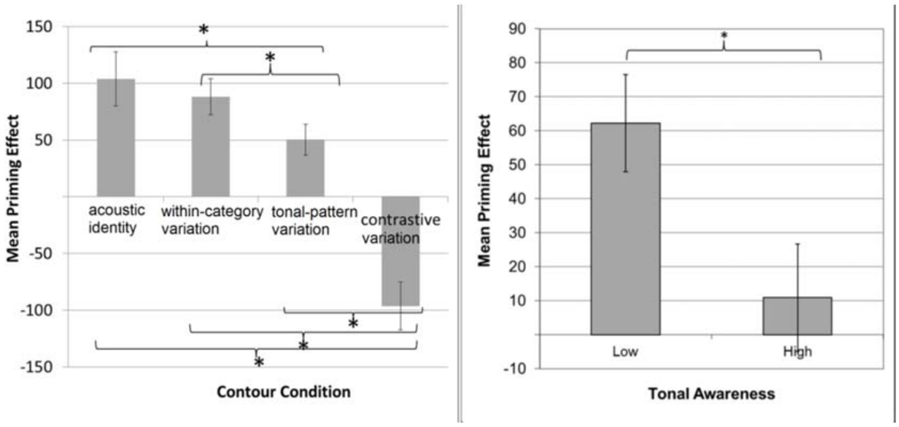

Figure 3. *Mean priming effect for each contour condition (left) and tonal awareness conditions (right).*

Contour Condition had a significant main effect (by participants, $F1(3, 54) = 24.87$, $MSE = 6,641$, $p < 0.05$, and by items, $F2(3, 76) = 5.36$, $MSE = 28,416$, $p < 0.05$). Tonal Awareness also had a significant effect in the by-participants analysis, $F(1, 18) = 5.79$, $MSE = 9,003$, $p < 0.05$, r = 0.49. There was no significant interaction between Contour Condition and Tonal Awareness. The LSD test after the by-participants analysis showed that only tonal pattern variation (Condition 3) and lexically contrastive variation (Condition 4) were significantly different from all the other conditions. Only contrastive variation (Condition 4) was significantly different from the acoustic identity and within-category variation in the Games-Howell test after the by-items analysis and in the Bonferroni test after the by-participant analysis. Generally speaking, the priming effect was smaller (lower in absolute value if positive; higher in absolute value if negative) for participants with higher tonal awareness.

The difference between cross-lexical vs. within-lexical variability was very robust. When the tonal difference between the prime and the target was lexically contrastive, the priming effect was always negative, indicating an interference effect. In other words, there seems to be an inhibition effect when word pairs with different lexical tones were presented. In the other three conditions, the difference between the prime and the target is not lexically contrastive. In this case, the priming effect was always positive, suggesting a facilitation effect. As for the within-lexical variability, the facilitation effect varied, however, according to the degree of similarity between the prime and the target. When a tonal pattern difference was involved, the priming effect was much more reduced than that of the other two conditions (i.e. acoustic identity and within-category variation conditions), where there was no significant priming difference.

5.3.2 Analysis 2

A linear mixed effects analysis was performed on the *reaction times*, using R (R_Core_Team, 2013), *lme4* (Bates, Maechler, Bolker, & Walker, 2013), and *lmerTest* (Kuznetsova, Brockhoff, & Christensen, 2013). The model included the fixed effects of Condition (acoustic identity, within-category variation, tonal pattern variation, and lexically-contrastive variation), Tonal Awareness (high or low), Type of Stimulus (prime or target), and their two-way and three-way interactions, as well as the random effects of by-item intercept, and by-participant slopes for the effect of order with its intercept. Several likelihood-ratio tests were first performed to justify the way the random terms were introduced. As shown in Table 1, with Satterthwaite approximation for degrees of freedom (Kuznetsova et al., 2013; SAS, 1978), significant effects were found for items and the by-participant slopes for the effect of order. The main effect of Condition and the interactions of Tonal Awareness and Type were significant. As shown in Figure 4, Tonal Awareness had a larger effect on primes than on targets.

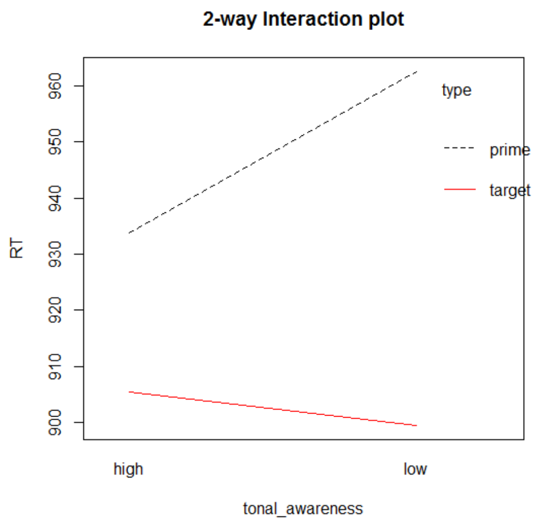

Figure 4. *2-way interaction plot of tonal awareness (high or low) and the type of stimuli (prime or target) on reaction time data*

Table 1. Summary of Mixed Effects Model for variables predicting reaction times (RT)

Fixed effects	Df	F	p
Condition	3	4.6549	<0.01
Tonal awareness	1	0.1023	>0.05 (n.s.)
Type	1	3.7895	>0.05 (n.s.)
Condition: Tonal awareness	3	0.2636	>0.05 (n.s.)
Condition: Type	3	1.9959	>0.05 (n.s.)
Tonal awareness: Type	1	7.6229	<0.01
Condition: Tonal awareness: Type	3	0.6909	>0.05 (n.s.)
Random effects		X^2	
1 | item	1	942	<0.0001
1 + order | participant	1	11	<0.0001

5.4 Discussion

5.4.1 Main results and interpretations

The current result shows that the two forms of tonal pattern variation share a joined representation in lexical access. Priming across these forms yielded facilitation effects, which are similar to the positive priming induced by acoustic variants but significantly different from the negative priming induced by contrastive variants. Note that the difference between the tonal pattern variation and the contrastive variation cannot be attributed to the amount of acoustic difference, because the amounts are roughly the same (see Figure 1 (b) versus 1 (c)). The only possible reason is that this priming happens at a stage where a joint representation is formed for the two tonal forms linking to the same word but the separation of two lexically contrastive forms is maintained. Thus, the interference effect may be due to the competition of the two activated lexical items, while the facilitation effect may rather be due to the previous activation of the form.

Note that the two tonal patterns in the tonal pattern variation condition are potentially contrastive in other words. This suggests that at this particular level of processing, there cannot be tonal generalization, as otherwise the minimal contrastive pairs involved would become indistinguishable as well. Our results thus support the claim that tonal pattern variation is processed in a lexically specific way.

Priming between tonal pattern variants reduced the size of the facilitation effects, compared with the priming effect induced by within-category variation. This difference cannot be attributed to any difference in lexical contrast, since it is the same in both conditions that the prime and the target are lexically non-contrastive. This difference may either be attributed to the amount of acoustic difference or to the fact that there are two tonal patterns involved in the tonal pattern variation. Although the current results cannot differentiate between these two possibilities, tonal pattern variation may also have its own representational status in the process of lexical access, different from the access of the purely acoustic tonal variability.

Moreover, the tonal awareness, which involves grouping words according to tonal categories and explicit access to tonal phonemes, also influences word recognition. The priming effect data showed that the low-tonal-awareness participants yielded more facilitation in the non-contrastive condition but less interference in the contrastive condition. The reaction time data further showed that lower tonal awareness resulted in slower lexical decisions to the primes but not to the targets. This indicates that no matter whether the corresponding lemma is selected (Conditions 1, 2, 3) or not (Condition 4), a participant's tonal awareness only affects the speed of the first activation of the lexical node. Further studies are needed to explain the mental mechanism behind tonal awareness and its contribution to lexical access.

5.4.2 Theoretical implications

According to Levelt's theory of language production, stress functions like an abstract lexical frame (Levelt, Roelofs, & Meyer, 1999). Cutler & Van Donselaar, 2001 showed that minimal stress pairs have distinctive representations in lexical access in Dutch. If tonal patterns work like stress, different tonal patterns should also have distinct representations in lexical access. Supportive evidence was found in the current study. First, contrastive tonal minimal pairs showed a different type of priming (interference) compared with non-contrastive pairs involving only one tonal pattern (facilitation). Second, the non-contrastive facilitation was significantly mitigated when different tonal patterns (though non-contrastive) were presented for the same word.

However, by including a previously untested condition, the current study also revealed new evidence for the joined representation of different tonal variants for the same word. When different tonal patterns link to the same word, the priming was positive, just like in the other lexically non-contrastive conditions. It is different from the negative priming across tonal minimal pairs. This result is in line with earlier studies on the storage of pronunciation variants, and supports that both tonal-pattern variants are stored under the same lemma (e.g. Bürki, Ernestus, & Frauenfelder, 2010; Ernestus, 2014; Pitt, 2009).

One may argue that the results are also compatible with the possibility of tonal under-specification, which leads to listeners' tolerance of phonemic tonal mismatches. This would then be similar to what have been reported on segmental mismatch and the flexibility of such mismatch in lexical processing (Connine, Blasko, & Titone, 1993; Lahiri & Marslen-Wilson, 1991; Marslen-Wilson & Zwitserlood, 1989; McClelland & Elman, 1986; McMurray, Tanenhaus, & Aslin, 2009; Milberg, Blumstein, & Dworetzky, 1988). While our results lack direct evidence to rule this possibility out, it is very important to note that our results in general cannot be explained by under-specification of lexical representation or listeners' tolerance of mismatches in processing. First, the prime and the target only varied along the tonal dimension, biasing the listeners to tune into tonal variation. Thus, it is highly unlikely that listeners were not sensitive to tonal mismatches. Second, had listeners been generally flexible about tonal information, we would not have found the different priming effects due to different types of tonal mismatch, since segmental sharing was consistent across all conditions and all conditions should have then yielded the same priming effects.

Taken together, we have shown that it is important to examine what and how different levels of tonal representations are involved in lexical access. The lexically non-contrastive tonal pattern variation, which previously received little attention in the literature, provides us with a great opportunity to look into the role of tonal patterns in lexical access. The current results support that different tonal variants have separate representations at the lexeme level and share the same representation under the same lemma. The evidence for the joined representation is relatively new.

Some questions require further investigation. When does the convergence of lexically non-contrastive tonal patterns take place in the process? Is it processed at a separate stage? Note that the convergence needs to be lexically specific because otherwise other words distinguished via these tonal patterns would be confused. How to incorporate the observed convergence in the models of lexical access remains an open question.

This study provides evidence for the representational status of tonal patterns in lexical access, while the existence of joint tonal representations depends on the existence of lexical contrasts. The effect of tonal awareness is mitigated when a similar form has been heard shortly before. On aggregate, these results call for a model of lexical access, which incorporates the representations of tonal patterns, the lexical specific convergence of non-contrastive tonal forms, and a mechanism to account for its interaction with tonal awareness.

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