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The Effects of Tonal Information on Lexical Activation in Mandarin

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Recent research about the role of lexical tone in Chinese word recognition has arrived at varying conclusions. It remains unclear how tone is represented in the mental lexicon and how tone constrains the activation of lexical candidates. In a set of priming experiments, we manipulated the effect of tonal information on lexical processing by comparing the response times to prime and target syllables that share no segmental content but that either match or mismatch in lexical tone. In two experimental paradigms, shadowing and lexical decision, subjects consistently responded more slowly to target words that were preceded by a prime that contained a matching lexical tone. We argue that our results suggest a group activation of words with the same lexical tone that then compete during lexical selection. Our findings support the view that tones constrain lexical activation, but differently than reported in previous studies.

0. Introduction

The role of tonal information in perceptual processing and in spoken and visual word recognition of Chinese has become a prominent topic in recent research. However, it remains to be seen how tonal information is represented in the mental lexicon or how tonal information constrains lexical activation. For example, is tonal information processed early during lexical activation, similar to segmental information, or is it processed only after lexical retrieval (Cutler, 1986)? Conflicting results are found in current studies. In a priming study with a lexical decision task, Lee (2007) found that monosyllabic Mandarin words differing only in tone (i.e. segmentally identical, but tonally distinct) failed to cause the speeded responses typical of segmental form priming. For example, he found that hearing *lou2* 'hall' speeded identification of the identical word *lou2*. Hearing *lou3* 'hug,' however, did not speed responses to *lou2*, even though they are segmentally the same. He argues, in line with previous research (Cutler & Otake, 1999; Cutler and Donselaar, 2001; Cooper, Cutler, & Wales, 2002), that this is evidence for the online use of tonal information to constrain lexical activation. The difference in tone allows the subjects to quickly rule out incompatible candidates despite the similarity in segmental content. In a follow-up mediated priming experiment, Lee reduced the ISI from 250ms to 50ms and found that the minimal tone pairs did produce speeded responses. The facilitation of response times at a shorter ISI suggests that the processing

of tonal information may take place relatively late in lexical activation compared to that of segmental information.

In contrast, Yip (2001), in a shadowing study of Cantonese, found facilitation for segmentally identical monosyllabic words that have different tones. For example, hearing the prime /cho3/ resulted in faster responses to the target word /cho2/ compared to a prime that was unrelated in both segments and tone, such as /gwa1/. This leads him to conclude that Cantonese speakers are more sensitive to segmental information than suprasegmental information. He also found facilitation when the rime and tone of the prime and target syllables matched, but he attributes this to the effect of the rime and not the tone. Yip's findings differ from the findings of Lee, Cutler, and others. Is this difference specific to Cantonese or are the diverging results related to the difference in experimental task: shadowing in Yip's study versus lexical decision in Lee's? To address these questions and gain a better understanding of the effect of tone on lexical activation, we conducted a set of priming experiments with speakers of Mandarin. We manipulated the effects of tonal information by using primes and targets that were segmentally unrelated but that either matched or mismatch in lexical tone. We also compared the effects for words and pronounceable nonwords (syllables that follow the phonotactics of Mandarin, but have no meaning). This allowed us to test whether any effects observed for words were related to lexical or extra-lexical processing. Two experimental paradigms were employed (shadowing and lexical decision) to compare the effect of task on response time.

1. Experiment 1

The first experiment we performed was a shadowing experiment in which participants were asked to listen to a sequence of prime and target stimuli and then repeat the target as quickly and accurately as possible. Fourteen native Chinese speakers participated in this experiment (7 male). No participant reported any history of speech or hearing disabilities. Participants came from various regions in China, but they spoke Mandarin at home or school.

The target stimuli consisted 46 Mandarin words and 48 pronounceable nonwords. These were preceded by the prime syllables whose onset and rhyme segments were not related to those of the targets (*i.e.*, no segmental match). Each prime/target pair was presented twice, once with matching and once with non-matching tones. For example, the target syllable *ba* with Mandarin tone 3 (*ba3* ‘to hold’) was once preceded by prime syllable *mo3* ‘to wipe’ (tone match condition) and once by prime syllable *mo1* ‘to touch’ (tone non-match condition; see Fig.1). The time interval between the end of the prime and the beginning of the target was 250 ms.

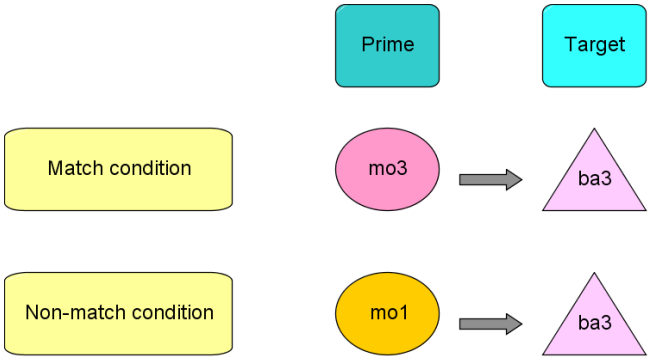

Figure 1.
An example of the match and non-match conditions. Only the lexical tone of the prime changes between the two presentations.

All tone/syllable combinations occurred only once, either as primes or as targets. The prime target sequences were arranged in two lists so that no prime or target syllable appeared more than once in a list. Items in each list were presented in randomized order and the sequence of the list was randomized across subjects.

Stimulus presentation was controlled by DMDX (K.I. Forster, Arizona State University) and participants listened to the stimuli sequences via headphones. They were instructed to ignore the first syllable of a stimulus pair and repeat the second syllable as quickly and accurately as possible. Vocalized responses and reaction times were recorded onto disk and after the experiments voice onset times were checked and if necessary corrected with with CheckVocal (A. Protopapas). Reaction times were calculated from the target sound offsets to account for variable target durations.

Statistical analysis shows a significant effect of the tone matching condition for words but not for non-words. In the by-subject ANOVA we obtained $F(2,13)=5.33$; $p=0.038$ for words and $F(2,13)=2.72$; $p=0.123$ for nonwords. The mean difference between the matching and non-matching condition was 10.01 ms for words and 9.08 ms for non-words. The by-item analysis did not show a significant effect $F(2,47)=3.46$; $p=0.07$ for nonwords and $F(2,5)=3.11$; $p=0.08$ for words. The mean difference between the matching and non-matching condition was 9 ms and 8.6 ms for nonwords and words, respectively). The mean RT difference between words and nonwords was 30.72 ms in the matching and 31.69 ms in the nonmatching condition and is highly significant.

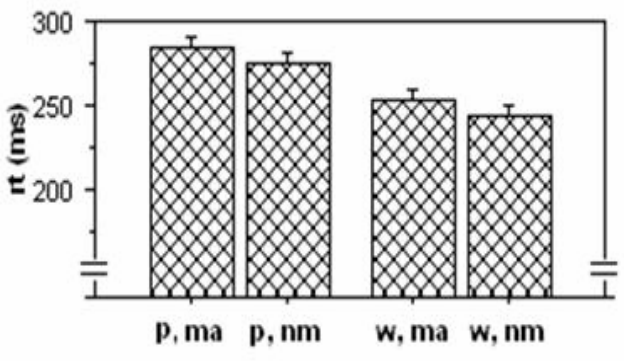

Figure 2.
Response time (rt) means and standard error for pronounceable nonwords (p) and words (w) compared for the match (ma) and non-match (nm) conditions in Experiment 1

Primes with matching tone and unrelated segments lead to a significant delay in the response to word targets but not to non-word targets. The lack of a significant effect for nonwords suggests that the delay maybe related to lexical processing rather than general auditory processing. The delay can be understood as inhibition in the case of tone match between primes and targets, and supports the view that tonal information plays a role in word recognition. In previous studies, inhibition in form priming has been taken as evidence of competition between activated lexical candidates (Slowiaczek & Hamburger, 1992; Monsell & Hirsh, 1998; Dufour & Peereman, 2003a/2003b). While these studies have looked at the influence of segmental information on lexical activation, we suggest that in our case it is possible that the tonal information creates a group activation of potential candidates that compete in selection.

2. Experiment 2

In order to assess the effect of the experimental task on the results from the first experiment, we used the same materials in a lexical decision task. Nineteen native Chinese speakers participated in this experiment (8 male). Prime and target stimuli were exactly the same as the Experiment 1, and stimulus presentation was similar to Experiment 1. All tone/syllable combination occurred only once, either as primes or as targets. The prime target sequences were arranged in two lists so that no prime or target syllable appeared more than once in a list. Items in each list were presented in randomized order and the sequence of the list was randomized across subjects. Stimulus presentation was controlled by DMDX (K.I. Forster, Arizona State University) and participants listened to the stimuli sequences via headphones. The participants were instructed to decide as quickly and accurately as possible whether the target sounds they heard were words or not by pressing a “Yes” or “No” button on a computer keyboard in

front of them. Reaction times were again calculated from the target sound offsets to account for variable target durations.

Again, we found a significant effect in the tone matching condition for words but not for nonwords. With the by-subject ANOVA we obtained $F(2,18)=7.64$; $p=0.013$ for words and $F(2,18)=1.04$; $p=0.32$ for nonwords. The mean difference between the matching and the nonmatching condition was 17.38 ms for words and -10.76 ms for nonwords. There was no significant difference between the overall reaction time for words and nonwords (-2.4 ms). The by-item analysis did not show significant effects ($F<1$ for both words and nonwords).

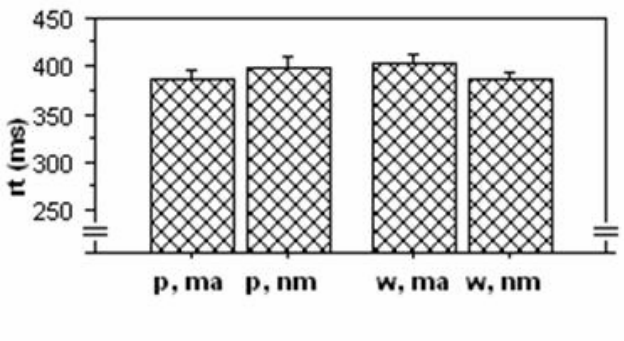

Figure 3.
Mean response times (rt) and standard errors for pronounceable nonwords (p) and words (w) compared for the match (ma) and non-match (nm) conditions in Experiment 2

The results of Experiment 2 are consistent with the results from Experiment 1. Again, inhibition was found for responses to words with primes that matched in tone, and no significant effect was for nonwords. This supports the view that independent of task, tone affects lexical processing and potentially activates a group of lexical candidates with the same tone that compete in selection.

Differences in the results between the two experiments demonstrate that task does have an effect on how subjects respond. In Experiment 1, there was a significant difference between the overall response times for nonwords versus words, perhaps related to the difficulty of pronouncing novel syllables. In the lexical decision task of Experiment 2, this difference in response times between words and nonwords does not appear since targets are not vocalized. The overall response time in Experiment 1 was faster by 184.5ms than that in Experiment 2, suggesting an additional effect of the task on responses. It is possible that the judgment of lexical status in the decision task requires additional processing time. These differences, however, do not interfere with the consistent inhibition found for the tone matching primes in the two experiments.

3. Discussion

Both of our experiments were designed to test the influence of tone on lexical selection. We manipulated the effect by using monosyllabic primes and targets that did not share any segmental phonology (i.e. consonants and vowels). Despite the different tasks performed by the subjects, a significant inhibition was found when words were primed by syllables that contained a matching tone. While the lack of significance in the by-item analysis must be addressed in future experiments, the significant by-subject effect is reinforced through replication in the two experiments. An effect was found for words only, not for nonwords, which supports the view that the observed effect is related to lexical processing. In line with previous studies of form priming, we view the inhibitory effect of primes with matching tones as indicative of lexical competition. We interpret this as a potential group activation of words with the same lexical tone that then compete during lexical selection. Unlike Yip (2001), we find that tone does affect lexical processing. This effect differs from the one described by Lee (2007) and others in which tone constrains lexical activation by inhibiting the activation of lexical candidates that shared the same segmental content but not the same tone.

While future experiments will be needed to better understand the sources of variance in our study and how the group activation of words based on shared tone might work, it is also true that behavioral studies cannot provide a complete understanding of lexical processing. Already, we have evidence from a series of EEG tests where stimuli that evoked similar response times in shadowing tasks evoke different ERPs. In a previous priming experiment (Will & Poss, 2008), matching and non-matching primes consisting of pitch contours without segmental content caused subjects to respond more quickly to words and non-words than primes consisting of unpitched noise. Despite these similar behavioral responses to both prime types, the ERPs show significant differences following matching and non-matching primes. Also, the differences show up early in the time course of the response, supporting the view that lexical tone is processed early in speech recognition. EEG versions of the experiment presented here are also underway to see if the differences found in the behavioral tests are reflected in the activity of the brain. Such methods will improve our understanding of how tone is processed and how it is represented in the mental lexicon.

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