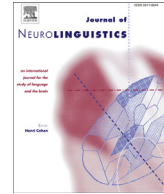




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## Second language experience modulates neural specialization for first language lexical tones



Benjamin D. Zinszer<sup>a, b, \*</sup>, Peiyao Chen<sup>c</sup>, Han Wu<sup>d</sup>, Hua Shu<sup>d</sup>,  
Ping Li<sup>a</sup>

<sup>a</sup> Department of Psychology, Center for Brain, Behavior, and Cognition, Pennsylvania State University, USA

<sup>b</sup> Department of Brain and Cognitive Sciences, University of Rochester, USA

<sup>c</sup> Department of Communication Sciences and Disorders, Northwestern University, USA

<sup>d</sup> State Key Laboratory for Cognitive Neuroscience and Learning, Beijing Normal University, China

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### ABSTRACT

Recent neuroimaging studies have revealed distinct functional roles of left and right temporal lobe structures in the processing of lexical tones in Chinese. In the present study, we ask whether knowledge of a second language (English) modulates this pattern of activation in the perception of tonal contrasts. Twenty-four native Chinese speakers were recruited from undergraduate and graduate students at Beijing Normal University, China. Participants listened to blocks of computationally manipulated /ba/ syllables which were varied to form within- and across-category deviants at equal acoustic intervals from a standard tone while their cortical blood oxygenation was measured by functional near-infrared spectroscopy (fNIRS). Blocks were analyzed for peak blood oxygenation (HbO) levels, and several linear models were estimated for these data, including effects of deviant tone type (within- or across-category), behavioral differences in tone identification, age of earliest exposure to English (spoken), and proficiency in English. Functional changes in HbO indicated a significantly greater response to within-category contrasts in right STG, consistent with previous findings. However, the effect of deviant type in left MTG was significantly modulated by the age of participants' earliest English exposure: Average across-category activation exceeded within-category activation only for participants exposed to English after 13 years of age. While previous research has established the importance of left MTG in the

\* Corresponding author. Department of Brain and Cognitive Sciences, University of Rochester, Rochester, NY 14627, USA.  
E-mail address: [bzinszer@gmail.com](mailto:bzinszer@gmail.com) (B.D. Zinszer).

categorical perception of lexical tones, our findings suggest that the functional specialization of this region is sensitive to second language experience, even in the processing of native language.

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## 1. Introduction

Categorical perception of speech is one of the basic, defining features that distinguish language from other forms of animal communication (Hockett, 1963). Native-like language comprehension is marked by categorical perception (hereafter, CP) at multiple levels, such that continuous variation in a speech signal (e.g., place of articulation or voice onset time in consonants) is treated by language users as transitions between discrete, linguistically meaningful units or categories. Early research demonstrated that native English speakers judge continuous variation of stop consonants categorically (Liberman, Cooper, Shankweiler, & Studdert-Kennedy, 1967), which is reflected as listeners' insensitivity to within-category variations but reliable discrimination of across-category variations of the same magnitude (two consonants on opposite sides of the categorical boundary).

### 1.1. CP and the functional hypothesis of tone processing

Suprasegmental features such as lexical intonation are also subject to these categorical perception effects (Gandour, 1983). Native speakers of Chinese, specifically, speakers of Mandarin in our study, perceive four linguistically salient pitch contours as distinct lexical tones. These contours are superimposed over an entire syllable and distinguish between minimal pairs that indicate meaning differences, just as phonemes do. Because of experiences with tonal categories, speakers of tonal languages such as Chinese and Thai, as compared with speakers of non-tonal languages, show an advantage at discriminating across-category contrasts like *dá* (Tone 2 – a rising pitch contour, meaning *arrive*) vs. *dà* (Tone 4 – a falling pitch contour, meaning *big*) in Mandarin Chinese but a disadvantage at discriminating within-category contrasts such as minor contour changes within the *dá* or *dà* categories (Xu, Gandour, & Francis, 2006).

Neurocognitive research in lexical tone processing has identified functional brain markers of CP. Native speakers of Thai (also a tonal language) and Chinese show lateralized mismatch negativity responses (MMN, a negative event-related potential at approximately 200 ms after the stimulus onset) to lexical tone contrasts from their native languages in an oddball paradigm (Kaan, Wayland, Bao, & Barkley, 2007; Xi, Zhang, Shu, Zhang, & Li, 2010; Yu, Wang, Li, & Li, 2014). Among native speakers of both Thai and Chinese, across-category contrasts elicit a left-lateralized MMN, and in native Chinese speakers, a greater right-lateralized MMN response for within-category contrasts (Xi et al., 2010). In a frequency domain analysis of electrophysiological responses, while non-native speakers showed greater alpha-band coherence in the right hemisphere when listening to Thai lexical tone contrasts, native Thai speakers showed this coherence bilaterally, suggesting differences in the involvement of left hemisphere for language-relevant vs. acoustic-only processing of the lexical tone contrasts (Kaan, Wayland, & Keil, 2013).

The lateralized response to acoustic vs. linguistic processing of lexical tones in native Chinese speakers has been further replicated and localized using fMRI. Zhang et al. (2011) showed that the hemodynamic response to across-category pairs of intonated syllables is greatest in the left middle temporal gyrus (MTG), consistent with left MTG's broader role in lexical retrieval, and the within-category contrast elicited a response in the right superior temporal gyrus (STG), suggesting acoustically based processing in the right hemisphere. Taken with the preceding electrophysiological evidence, this study presents a useful dissociative relationship for native-like CP of lexical tones: linguistically relevant contrasts (that is, discrimination between pitch contours across tone categories) elicits the greatest response in left hemisphere regions, specifically lexical-phonology processing areas

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