Brain and Language 180–182 (2018) 31–41

Contents lists available at ScienceDirect

Brain and Language

journal homepage: www.elsevier.com/locate/b&l

Are lexical tones musical? Native language's influence on neural response to pitch in different domains

Ao Chen[a,b,d,*], Varghese Peter[b,e], Frank Wijnen[a], Hugo Schnack[a,c], Denis Burnham[b]

[a] Utrecht Institute of Linguistics OTS, Utrecht University, Utrecht, The Netherlands
[b] MARCS Institute for Brain, Behaviour & Development, Western Sydney University, Sydney, Australia
[c] Department of Psychiatry, Brain Center Rudolf Magnus, University Medical Center Utrecht, Utrecht, The Netherlands
[d] School of Communication Science, Beijing Language and Culture University, Beijing, China
[e] Department of Linguistics, Macquarie University, North Ryde, NSW 2109, Australia

ARTICLE INFO

Keywords:
Lexical tones
Musical pitch
Mismatch negativity
Cross-domain correlation

ABSTRACT

Language experience shapes musical and speech pitch processing. We investigated whether speaking a lexical tone language natively modulates neural processing of pitch in language and music as well as their correlation. We tested tone language (Mandarin Chinese), and non-tone language (Dutch) listeners in a passive oddball paradigm measuring mismatch negativity (MMN) for (i) Chinese lexical tones and (ii) three-note musical melodies with similar pitch contours. For lexical tones, Chinese listeners showed a later MMN peak than the non-tone language listeners, whereas for MMN amplitude there were no significant differences between groups. Dutch participants also showed a late discriminative negativity (LDN). In the music condition two MMNs, corresponding to the two notes that differed between the standard and the deviant were found for both groups, and an LDN were found for both the Dutch and the Chinese listeners. The music MMNs were significantly right lateralized. Importantly, significant correlations were found between the lexical tone and the music MMNs for the Dutch but not the Chinese participants. The results suggest that speaking a tone language natively does not necessarily *enhance* neural responses to pitch either in language or in music, but that it does *change the nature* of neural pitch processing: non-tone language speakers appear to perceive lexical tones as musical, whereas for tone language speakers, lexical tones and music may activate different neural networks. Neural resources seem to be assigned differently for the lexical tones and for musical melodies, presumably depending on the presence or absence of long-term phonological memory traces.

1. Introduction

Speech and music are two unique products of the human brain that serve communicative purposes, and are present across all cultures (Patel, 2008). The specificity of, or the commonality between these two domains has received much attention in cognitive neuroscience, and there is evidence of both association and dissociation between the two (Bidelman, Hutka, & Moreno, 2013; Krishnan, Gandour, & Bidelman, 2010; Nan, Huang, Wang, Liu, & Dong, 2016; Peretz & Coltheart, 2003; Wong & Perrachione, 2007). The aims of this study are to examine (1) the effect of tone vs non-tone language experience on neural discrimination of pitch in speech and music, and (2) cross domain correlation of the event related potentials (ERPs) that indicate neural pitch change detection in music and speech, and whether any such correlation is influenced by tone/non-tone language experience.

Both speech and music experience modulate auditory perception, and there is perceptual attunement to ambient input in both domains in development. For example, newborn infants are able to discriminate both native and non-native speech sounds (consonants, vowels and lexical tones), but from about 4 months onward sensitivity to non-native sounds deteriorates while sensitivity to native sounds is maintained or improves (Kuhl et al., 2006; Kuhl, Williams, Lacerda, Stevens, & Lindblom, 1992; Mattock & Burnham, 2006; Mattock, Molnar, Polka, & Burnham, 2008; Werker & Tees, 1984). Once native phonetic categories are established, listeners perceive native phonemes categorically, whereas the non-native phonemes are perceived psycho-acoustically (Francis, Ciocca, & Ng, 2003; Hallé, Chang, & Best, 2004). Similar perceptual attunement has also been found in the music domain. Infants initially discriminate melodies from ambient and novel musical scales (Lynch, Eilers, Oller & Urbano, 1990), but this then becomes tuned to the structure of the ambient input (Lynch & Eilers, 1992; Trainor & Trehub, 1992) such that adults are less capable of discriminating non-

* Corresponding author at: Beijing Language and Culture University, No. 15 Xueyuan Road, 100083, Beijing, China.
E-mail address: irischen71@hotmail.com (A. Chen).

https://doi.org/10.1016/j.bandl.2018.04.006
Received 19 December 2017; Received in revised form 15 March 2018; Accepted 14 April 2018

native than native musical structures (Lynch et al., 1990; Schellenberg & Trehub, 1999; Trehub, Schellenberg, & Kamenetsky, 1999).

Over and above within-domain attunement, experience in one domain has been shown to enhance processing in the other. For example, speaking a tone language (i.e., a language in which pitch is used to distinguish lexical meaning) facilitates the discrimination of musical pitch (Bidelman et al., 2013; Chen, Liu, & Kager, 2016; Stevens, Keller, & Tyler, 2013). Conversely, musicianship enhances detection of lexical tone contrasts (Alexander, Wong, & Bradlow, 2005; Delogu, Lampis, & Belardinelli, 2006; Marie, Delogu, Lampis, Belardinelli, & Besson, 2011), and musicians more easily learn to pair pitch patterns and word meaning, an ability similar to learning lexical tones (Wong & Perrachione, 2007). In a recent study, Chen, Liu et al. (2016) showed that being a native tone-language speaker not only facilitates music perception, but engenders a dissociation of the processing of musical and lexical tone. Chen et al. tested native tone language (Chinese Mandarin) and non-tone language (Dutch) listeners on discrimination of Mandarin lexical tones and musical phrases. As expected, Chinese listeners outperformed Dutch listeners in the music tasks. Importantly, significant positive correlations were found between the discrimination of lexical tones and musical phrases among the Dutch listeners whereas such correlations were absent in Chinese listeners. Based on these findings, Chen et al. proposed the "split hypothesis", which holds that in perception, for tone language listeners, pitch variations that are used phonemically as lexical tones are split from other, non-lexical pitch variations, hence the absence of speech-music correlation among the Chinese listeners. For the Dutch listeners, as lexical tones do not play a phonemic role, tones and musical pitch are both perceived psychoacoustically in a unified process. Such cross-domain correlation has also been observed among native non-tonal language Turkish listeners (Chen, Roncaglia-Denissen, Roor, & Sadakata, 2016).

All these studies used behavioural methods. At the neural level, evidence has accumulated regarding plasticity induced by both language and music experience (Giuliano, Pfordresher, Stanley, Narayana, & Wicha, 2011; Krishnan et al., 2010; van Zuijen, Sussman, Winkler, Näätänen, & Tervaniemi, 2005). A component of auditory event-related potentials (ERP), the mismatch negativity (MMN), is commonly used to examine neural detection of auditory change. MMN can be elicited using a passive oddball paradigm, in which listeners are presented with a stream of 'standard' sounds conforming to a certain regularity punctuated occasionally by 'deviant' sounds, dissimilar in some relevant dimension from the standards. If the brain detects the change from standard to deviant, then on the difference waveform obtained by subtracting the response to the standard from that to the deviant, the MMN is visible as a negative peak between 100 and 300 ms from deviant onset (Bishop, 2007; Näätänen, Paavilainen, Rinne, & Alho, 2007).

There is some discrepancy with respect to the effect of tone language experience on MMN responses to linguistic and non-linguistic pitch change. When non-speech stimuli (harmonic or pure tones) are closely matched to lexical tones (identical amplitude information, duration, and fundamental requency (F0)), native tone language listeners have been shown to exhibit comparable MMNs to lexical tones and non-speech analogues (Gu, Zhang, Hu, & Zhao, 2013; Xi, Zhang, Shu, Zhang, & Li, 2010), suggesting common neural mechanisms for processing both speech and non-speech pitch contours. Different results have been found comparing tone and non-tone language listeners' MMN responses to pitch stimuli. Chandrasekaran, Krishnan and Gandour (2007a) found that Chinese listeners, compared to non-tone language listeners, showed larger MMNs in response to iterated ripple noises that capture the curvilinear characteristics of native lexical tones, but not for pitch contours represented by a linear rising slope which does not occur in real Mandarin Chinese speech. Chandrasekaran, Krishnan, and Gandour (2007b) found that whether Chinese listeners showed an enhanced MMN over English listeners depended on the acoustical salience of the tone contrasts. In Chandrasekaran, Krishnan, and Gandour (2009), non-speech homologues that were modelled on pitch differences within or between different Chinese tonal categories were presented to native Chinese speakers, native English musicians, and native English non-musicians. Regardless of the within- or between-category condition, the native Chinese listeners and the English musicians exhibited larger MMNs than the English non-musicians. In contrast, Kaan, Barkley, Bao and Wayland (2008) showed that although behaviorally English listeners discriminated Thai lexical tones less well than Chinese and Thai listeners, they showed a larger MMN compared to Chinese listeners. These inconsistent findings suggest that being a native speaker of a tone language modulates pitch MMN in a stimulus-specific way, and tone language speakers do not necessarily exhibit enhanced MMN compared to non-tone language speakers for lexical tones.

The above studies focused on the effect of language experience on neural responses to speech or non-speech pitch, but the non-speech stimuli lacked ecological validity and real-life function. As both language and music are universally used across human cultures to serve fundamental communicative purposes (Patel, 2008), it is crucial for understanding experience-dependent neural plasticity and the integration of high-level cognitive abilities that studies are conducted on the effect of language experience on neural processing of *music* – ecologically valid music stimuli, namely melodies that can occur in real life music. Therefore, in this study, as well as lexical tones, we used distinct three-note musical melodies with comparable pitch contours to the tones to investigate whether being a native speaker of a tone language or not modulates neural responses to lexical tones, and whether such modulation extends to the music domain.

How language experience may affect MMN lateralization is poorly understood. When presented with native lexical tones, MMN lateralization in tone language listeners differed across studies: some have found right lateralization (Luo et al., 2006; Ren, Yang, & Li, 2009; Xi et al., 2010); others no clear lateralization (Chandrasekaran, et al., 2007b); and yet others left lateralization (Gu et al., 2013). With regard to music, several studies report a frontal-central distribution of the MMN elicited by contour violation without clear lateralization (Trainor, McDonald, & Alain, 2002; Vuust, Brattico, Seppänen, Näätänen, & Tervaniemi, 2012). While scalp distribution of the MMN response does not necessarily reflect the location at which the MMN is generated, if the processing of lexical tones and musical pitch share neural resources, we would expect consistent manifestation of MMN lateralization across different conditions.

Besides MMN, several studies on pitch/tone discrimination report a negativity following MMN, likely to be the late discriminative negativity (LDN) (Cheour, Korpilahti, Martynova, & Lang, 2001). LDN is more frequently observed in children than adults, and tends to be more evident for speech than non-speech stimuli (Cheour et al., 2001). It has been suggested that, when presented with unfamiliar auditory stimuli, the LDN may reflect the transfer of the newly-encountered regularity into long term memory (Peter, Mcarthur, & Thompson, 2012; Zachau et al., 2005). Consistent with this hypothesis, Kaan et al. (2008) found an LDN in Chinese and English listeners presented with Thai tones, which decreased in amplitude after training, suggesting transfer of lexical tone information into long term memory. Whether LDN and MMN reflect the same change detection mechanism is still debated (Ceponiene et al., 2004; Čeponiene, Cheour, & Näätänen, 1998; Korpilahti, Krause, Holopainen, & Lang, 2001), and the cognitive function of LDN is not yet fully understood. Nevertheless, based on the research so far, we hypothesise that it is more likely to observe an LDN for lexical tones, if at all, in non-tone language speakers than in tone language speakers.

The aim of this study is to understand how language experience might shape neural responses to pitch change in different domains. We investigated Chinese and Dutch listeners' MMN to Chinese lexical tones and to simple musical melodies. If there is a tone language benefit in pitch perception in general, we expect Chinese listeners to show more pronounced MMN than the Dutch listeners for both the music and