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Effects of combination of linguistic and musical pitch experience on subcortical pitch encoding

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ABSTRACT

Musical experience and linguistic experience have been shown to facilitate language and music perception. However, the precise nature of music and language interaction is still a subject of ongoing research. In this study, using subcortical electrophysiological measures (frequency following response), we seek to understand the effect of interaction of linguistic pitch experience and musical pitch experience on subcortical lexical and musical pitch encoding. We compared musicians and non-musicians who were native speakers of a tone language on subcortical encoding of linguistic and musical pitch. We found that musicians and non-musicians did not differ on the brainstem encoding of lexical tones. However, musicians showed a more robust brainstem encoding of musical pitch as compared to non-musicians. These findings suggest that a combined musical and linguistic pitch experience affects auditory brainstem encoding of linguistic and musical pitch differentially. From our results, we could also speculate that native tone language speakers might use two different mechanisms, at least for the subcortical encoding of linguistic and musical pitch.

1. Introduction

Pitch is an important dimension that is relevant to both language and music perception (Plack, Oxenham, & Fay, 2005). For language, pitch is involved in signaling linguistic contrasts such as lexical tone and intonation (Ladefoged, 2003). For music, pitch is one of the central dimensions for arranging musical elements in a systematic manner (Patel, 2010). Given the important roles of pitch in both language and music, one of the intriguing questions is how the mechanisms of language and music perception interact. Previous studies show that musical experience facilitates linguistic perception (Alexander, Wong, & Bradlow, 2005; Gottfried & Riester, 2000; Gottfried, 2007; Gottfried, Staby, & Ziemer, 2004; Lee & Hung, 2008; Wong & Perrachione, 2007) and similarly,

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language experience facilitates music perception (Bidelman, Gandour, & Krishnan, 2011). However, recently, it has been found that the facilitation effect of musical experience on language perception is not straightforward (Cooper & Wang, 2012), especially when multiple types of pitch experiences (language or music) are involved. In the current study, we aimed to further understand the relationship between musical experience and linguistic processing, by comparing tone-language-speakers with and without musical pitch experience, on frequency following responses (FFR) elicited from lexical and musical pitch stimuli.

1.1. Relationship between music and language: behavioral studies

Several behavioral studies have found that musical experience enhances the perception of lexical tones (Alexander et al., 2005; Gottfried & Riester, 2000; Gottfried, 2007; Gottfried et al., 2004; Lee & Hung, 2008; Wong & Perrachione, 2007). For example, Gottfried and Riester (2000) found that individuals with music major had better identification for Mandarin tones than non-majors. Further, Gottfried et al. (2004) revealed that musicians discriminated (same/different) Mandarin lexical tones more accurately than non-musicians. Alexander et al. (Alexander et al., 2005) reported that English musicians were better at both discrimination and identification of lexical tones in terms of accuracy and reaction times. In sum, these findings reflect a considerable overlap of language and music, suggestive of a common perceptual substrate for the two.

While there are studies (Alexander et al., 2005; Gottfried & Riester, 2000; Gottfried, 2007; Gottfried et al., 2004; Lee & Hung, 2008; Wong & Perrachione, 2007) conducted on non-native speakers with (and without) musical experience revealing the overlap of music and language perception, there are also studies (Lee & Lee, 2010; Lee, Lee, & Shr, 2011) conducted on native tone language speakers (with musical experience) leading to inconclusive results. Lee and colleagues found a lack of correlation between language and music perception in both tone (Lee & Lee, 2010; Lee et al., 2011) and non-tone language speakers (Lee & Hung, 2008; Lee, Lekich, & Zhang, 2014). These findings led those authors to conclude that a lack of association between lexical and musical tone identification could be due to fundamental differences in the internal category structure of lexical and musical tones and whether or not they serve a linguistic function. Identification of musical pitch solely depends on pitch but in the case of lexical tones, other cues such as amplitude and duration also play important roles (Lee et al., 2011). However, the lack of correlation between language and music perception in their studies (Lee & Hung, 2008; Lee & Lee, 2010; Lee et al., 2011) does not allow drawing definite conclusions on the language-music association (Lee et al., 2011). Their studies reveal that in the presence of more than one type of experience, the language-music interaction gets more complex. Though their studies confirm that language-music interaction is not straightforward, the nature of interaction is still unclear.

In order to understand the interaction between language and music, Cooper and Wang (2012) compared tone-language-speaking musicians and non-musicians on their abilities to learn lexical pitch in a tone-word learning paradigm. They compared the Thai- and English-speaking musicians and non-musicians on Cantonese tone identification abilities. It was predicted that Thai musicians (TM) would identify Cantonese tones most accurately due to their combined tone language and music experience (two types of experience), followed by Thai non-musicians (TNM) who would not differ from English musicians (EM; both have one type of experience), but both groups were expected to outperform English non-musicians (ENM; no tone experience). This sequence of predictions was consistent with the findings of Wong and Perrachione (2007) who had previously observed that English musicians outperformed non-musicians in the learning of novel words differentiated by lexical tone contrasts. Thus, musical experience should enhance lexical tone perception abilities. However, Cooper and Wang (2012) found that combined language and music experience did not exert an additive effect on tone identification. In fact, Thai musicians did not exhibit the expected advantage over Thai non-musicians or English musicians, but rather, both Thai non-musicians and English musicians showed more accurate tone-word identification compared to Thai musicians. As expected, English non-musicians performed worst. Cooper and Wang (2012) accounted for these findings by explaining that due to musical experience, TM may make elaborate pitch mappings (as in the case of music) when learning other pitch contours. As a result, confusion may arise between language and music for TM resulting in poorer scores than EM (who do not possess lexical tone experience) or TNM (who lack musical experience). By extension, TNM, who lack the kind of pitch acuity possessed by the TM, would have learnt the pitch contours using principles of learning a tone language, thus resulting in better performance than TM.

1.2. Relationship between music and language: brainstem electrophysiological studies

Quite recently, pitch processing has been studied using FFR, an auditory evoked potential generated predominantly at the level of inferior colliculi of the brainstem (Krishnan, Xu, Gandour, & Cariani, 2005) that is also proposedly modulated from the cortex via corticofugal pathways (Chandrasekaran & Kraus, 2010). In addition, the auditory brainstem could be influenced by linear predictive coding (Chandrasekaran, Skoe, & Kraus, 2014) in a continuous online modulation loop (Chandrasekaran, Hornickel, Skoe, Nicol, & Kraus, 2009; Kraus & Chandrasekaran, 2010) that involves co-operation of both cortex and inferior colliculi. According to continuous online modulation model, cortex predicts the incoming input from the brainstem (inferior colliculi) and if there is a match between the two, the representation is more robust throughout the central auditory system. FFR represents the phase-locking abilities of the auditory system and thus, has been used as a metric of neural plasticity following language experience (Krishnan, Gandour, Bidelman, & Swaminathan, 2009; Krishnan et al., 2005; Swaminathan, Krishnan, & Gandour, 2008) and musical training (Wong, Skoe, Russo, Dees, & Kraus, 2007). Wong et al. (2007) observed more faithful FFR encoding of natural Mandarin tones in English musicians than non-musicians. Bidelman, Gandour, and Krishnan (2009) investigated cross-domain effects of music and language experience by studying brainstem encoding of synthetically generated musical and lexical tone contours. They found that both Chinese non-musicians and English musicians encoded both musical and lexical tones more robustly compared to English non-musicians. Importantly,