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Research Report

Effects of native language and training on lexical tone perception: An event-related potential study

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ABSTRACT

Tone languages such as Thai use pitch differences to distinguish lexical meaning. Previous behavioral studies have reported that naïve listeners can discriminate among lexical tones, but that native language background affects performance. The present study uses ERPs to determine whether native speakers of a tone language (Mandarin Chinese) and of a non-tone language (English) differ in their pre-attentive discrimination among Thai lexical tones, and whether training has a different effect in these two language groups. EEGs were obtained from 10 native Mandarin Chinese speakers, 10 English and 10 Thai speakers in an oddball paradigm: The Thai syllable [k^{h}a:] pronounced with a high rising or low falling tone, was presented as an infrequent deviant amidst a standard mid level tone [k^{h}a:] syllable, while participants watched a silent movie. Next, the Chinese and English participants completed a 2-day perceptual identification training on the mid level and low falling tones, and returned for a post training EEG. The low falling tone deviant elicited a Mismatch Negativity (MMN) in all participant groups before and after training; the high rising deviant elicited no, or a smaller, MMN, which became larger after training only in the English group. The high rising deviant also elicited a later negativity (350–650 ms) versus the mid level standard, which decreased after training in the Chinese group. These results suggest that non-Thai speakers can pre-attentively discriminate among Thai tones, but are sensitive to different physical properties of the tones, depending on their native language. English speakers are more sensitive to early pitch differences, whereas native speakers of Mandarin Chinese are more sensitive to the (later) pitch contour.

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1. Introduction

1.1. *Background*

Tone languages such as Thai use pitch differences to distinguish lexical meaning, that is the Thai syllable [k^{h}a:] pronounced with a low falling tone ("galanga, a kind of aromatic root"), means something completely different when it is pronounced with a tone that is low falling and then rising ("leg"), high falling ("I, servant"), high rising ("to do business in") or mid level ("to be lodged in"). Tone languages differ in their inventory of lexical tones. For instance, whereas Thai has five tones, Mandarin Chinese has four tones (high level, high rising, low dipping and high falling), and Yoruba three (low, mid, and high level). Because of these cross-linguistic differences, lexical tones provide a suitable means to investigate the effect of experience on speech perception, learning, and neural reorganization. Previous behavioral

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studies have reported that naïve listeners can discriminate among lexical tones, but that native language background affects performance. The present study uses ERPs to determine whether (a) native language background affects pre-attentive discrimination among Thai lexical tones, and (b) whether training has a different effect in native speakers of a tone versus non-tone language.

Behavioral research has shown that native speakers of a non-tone language (e.g., English) often have difficulty perceiving tones in a tone language like Chinese (Bluhme and Burr, 1971; Kiriloff, 1969; Wang et al., 1999), whereas native experience with a tone language appears to facilitate the perception of tones in another tone language (e.g., Wayland and Guion, 2004; Wayland and Li, in press). This may be related to the difference in the way native and non-native speakers of tone languages process lexical tones. Gandour and Harshman (1978), for example, found that native speakers of a tone language (Thai and Yoruba) placed more emphasis on the linguistic tone dimensions, i.e., direction and slope of the fundamental frequency (F_0), while native speakers of a non-tone language (American English) placed more emphasis on the non-linguistic tone dimensions of average pitch and extreme endpoints. Similarly, Gandour (1983) found that, when compared to speakers of tone languages, native speakers of English paid more attention to the average F_0 and less to the F_0 contour information when identifying tones. Moreover, Lee and Nusbaum (1993) found that Mandarin Chinese, but not English listeners, were slowed down by an irrelevant change in pitch level when making a segmental classification. These findings suggest that Mandarin listeners, but not English listeners, perceive pitch and segmental information in an integral manner.

Speakers of tone and non-tone languages have also been found to employ different neural mechanisms in perceiving lexical tones. In a dichotic perception experiment, Wang et al. (2001) found that Mandarin tones were predominantly processed in the left hemisphere by native Mandarin speakers, but bilaterally by American English speakers with no prior tone experience. Similar results were found for Thai by Van Lancker and Fromkin (1973, 1978). Brain imaging studies report increased left hemisphere activation in native speakers processing lexical tones in their native language compared to non-native speakers (left frontal operculum, Gandour et al., 2000; left frontal, parietal and parietal–occipital areas, Klein et al., 2001). Non-native speakers show increased activation of the inferior frontal area in the right hemisphere (Klein et al., 2001), which has been shown to be more sensitive to non-linguistic pitch differences compared to the left (Zatorre et al., 2002).

The ability to perceive lexical tones has been shown to improve with experience. For example, Wang et al. (1999) showed that the ability of native English learners to correctly identify Mandarin tones increased from 69% before, to 90% after extensive auditory training. More recently, Wayland and Guion (2004) found that discrimination of Thai tones by native speakers of Chinese improved significantly after training. In addition, an improvement in tone identification has been found to be related to an improvement in tone production (Wang et al., 2003a). Training has also been shown to induce neurophysiological changes in native speakers of a non-tone language. English speakers who were trained to distinguish among lexical tones in Chinese showed a more extensive left hemisphere activation, and additional activation in the right inferior frontal gyrus after compared to before training, as measured by fMRI (Wang et al., 2003b).

It is important to note, however, that most of the existing data on tone perception have been obtained by having participants consciously compare or classify tone stimuli. This may have led to potential confounds due to attention, working memory or other factors. In the present study, we use ERPs to investigate how native speakers of Mandarin Chinese and native speakers of English process the distinctions between Thai lexical tones pre-attentively, that is, without paying conscious attention or performing an active discrimination task, and what effect training has on tone perception at this pre-attentive level.

One tool to investigate pre-attentive auditory discrimination is the Mismatch Negativity (MMN), or its magnetic equivalent, the MMNm or MMF (Mismatch field). The MMN is elicited to infrequent stimuli that are discriminated from frequent standard stimuli in pitch, duration, voice onset time (VOT) or other acoustic or phonetic properties. The MMN can be elicited even when participants are engaged in a different activity such as watching a movie or reading a book, or when they are asleep, which suggests that the MMN is an index of auditory discrimination at the pre-attentional level (see Näätänen, 2001, for an overview).

The MMN has been shown to increase in amplitude and, in some cases, to have a shorter peak latency as behavioral discrimination performance improves (Kraus et al., 1995; Menning et al., 2002; Näätänen et al., 1993; Tremblay et al., 1997, 1998). These changes in the MMN can even precede behavioral improvement during training (Tremblay et al., 1998). Moreover, an increased MMN can be observed for new contrasts that have not been trained on, that is, if the contrast is related to the contrast trained on and is relatively easy to discriminate (Gottselig et al., 2004; Tremblay et al., 1997).

Numerous studies have applied the mismatch negativity to study the adult perception and acquisition of non-native language contrasts (e.g., Kraus et al., 1995; Peltola et al., 2003; Tremblay et al., 1997, 1998; Winkler et al., 1999). For example, Tremblay et al. (1997) trained English speakers on the discrimination of a pre-voiced labial stop, which is not part of the English consonant inventory. ERPs after training showed an increased and longer lasting MMN. In addition, the effects of training were shown to carry over to the perception of an untrained pre-voiced alveolar stop (also not used in English). Using MEG, Menning et al. (2002) trained adult German speakers on durational contrasts of Japanese mora, showing an increase in discrimination performance as well as an increase in MMF amplitude and decrease in MMF latency after training. The MMN is therefore a fruitful tool to study perceptual discrimination at the pre-attentive level and the effects of training.

1.2. *The present study*

In the current study, we used an MMN oddball paradigm to investigate whether (a) there is a difference between native speakers of Thai, native speakers of a different tone language (Mandarin Chinese), and native speakers of a non-tone

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