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Dialectal differences in hemispheric specialization for Japanese lexical pitch accent

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ABSTRACT

Language experience can alter perceptual abilities and the neural specialization for phonological contrasts. Here we investigated whether dialectal differences in the lexical use of pitch information lead to differences in functional lateralization for pitch processing. We measured cortical hemodynamic responses to pitch pattern changes in native speakers of Standard (Tokyo) Japanese, which has a lexical pitch accent system, and native speakers of 'accentless' dialects, which do not have any lexical tonal phenomena. While the Standard Japanese speakers showed left-dominant responses in temporal regions to pitch pattern changes within words, the accentless dialects speakers did not show such left-dominance. Pitch pattern changes within harmonic-complex tones also elicited different brain activation patterns between the two groups. These results indicate that the neural processing of pitch information differs depending on the listener's native dialect, and that listeners' linguistic experiences may further affect the processing of pitch changes even for non-linguistic sounds.

1. Introduction

A native speaker of a language possesses an intricate knowledge of that language's phonological system, including its unique set of phonemic categories, phonological rules and prosodic structures. Recent advances in brain imaging studies have begun to reveal the neural processes involved in processing certain types of phonological information. In particular, it has been shown that the left and right cerebral hemispheres work differently for processing segmental and prosodic aspects of phonology: the left hemisphere is more heavily involved in processing segmental contrasts while the right hemisphere typically processes prosodic cues including affective prosody (Buchanan et al., 2000; Jacquemot, Pallier, LeBihan, Dehaene, & Dupoux, 2003; Näätänen et al., 1997; Ross, 1981; Schirmer & Kotz, 2006; Tervaniemi et al., 1999; van Lancker, 1980; Zatorre, Evans, Meyer, & Gjedde, 1992).

The neural processing of language, however, can be substantially altered by one's experience with a language, such as the age that one acquires it, and how much one uses it (c.f., Dehaene et al., 1997; Perani et al., 1998). Behaviorally, it is well established that as a consequence of learning one first language (L1), discrimination of segments in a non-native language (L2) becomes more difficult (e.g., English /r/ and /l/ by Japanese listeners; Goto, 1971; Miyawaki et al., 1975). Electrophysiological studies have shown that when native and non-native phonemic contrasts are compared, contrasts in one's native language typically produce larger responses in the left auditory area, while non-native contrasts do not produce such responses (Buchwald, Guthrie, Schwafel, Erwin, & Van Lancker, 1994; Dehaene-Lambertz, 1997; Näätänen et al., 1997; Rivera-Gaxiola, Csibra, Johnson, & Karmiloff-Smith, 2000).

The effects of language experience on hemispheric lateralization have been most clearly demonstrated with lexical-level prosody, such as tones in Thai or Chinese, and lexical pitch accent in Japanese. That is because acoustic cues that are prosodic (e.g., pitch changes), a characteristic that is generally associated with bilateral processing or a right-hemisphere advantage, are used to distinguish lexical meaning, which is associated with a left-hemisphere advantage. In Japanese, for example, a pair of homophones with two syllables may be distinguished by a pitch accent contour of high-to-low (HL) vs. low-to-high (LH): ha'shi (HL: "chop stick") vs. ha-shi' (LH: "bridge"). Brain activation for these stimuli seems

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to be functionally determined. That is, when the pitch cues for lexical prosody are processed as a part of one's native language phonology, left-lateralized activations are found, and when the same cue is processed either as a non-linguistic or non-native stimulus, no left-dominant activation is seen (Gandour, Wong, & Hutchins, 1998; Gandour et al., 2000; Klein, Zatorre, Milner, & Zhao, 2001; Sato, Sogabe, & Mazuka, 2007; Sato, Sogabe, & Mazuka, 2010; Wang, Sereno, Jongmen, & Hirsch, 2003).

Sato et al. (2010) demonstrated that the effect of language experience emerges during infancy for L1 learners. Using near infrared spectroscopy (NIRS), they found that Japanese infants showed left-lateralized responses to the lexical pitch accent changes in lexical items at 10 months of age, while no such laterality was observed when the same pitch changes were presented in a pure tone stimulus. At 4 months of age, however, no left-hemisphere advantage was found in response to either lexical or pure tone stimuli. Infants are able to discriminate the stimuli behaviorally at either age. Thus, the results show that Japanese infants, as a consequence of learning the sound system of their language, begin to show a left-lateralized response by 10 months. Adult L1 learners of Japanese are like 10-month-olds, showing a left-lateralized response to the lexical pitch accent (Sato et al., 2007).

Minagawa-Kawai, Mori, Sato, and Koizumi (2004), Minagawa-Kawai, Mori, and Sato (2005) tested the differences between L1 and L2 learners using a duration-based phonemic contrast. Like lexical-level prosody, the acoustic cues for distinguishing long vs. short vowels are prosodic (i.e., durational changes). Yet, in languages like Japanese, Finnish and Estonian, they are used to distinguish lexical meaning. Minagawa-Kawai et al. found that L1 learners of Japanese show left-dominant responses to the vowel duration changes. Highly proficient L2 learners of Japanese, in contrast, did not show left-dominant brain activations for this contrast. Although the durational contrast is non-distinctive in their native language (Korean), the participants in the study had no trouble discriminating them. Taken together, these studies suggest that the processing of lexical-level prosody (or a similar distinction in vowel duration) is associated with left-hemisphere advantage only when it is acquired as part of the listener's L1.

Differences in phonological systems are found not only across languages but also across dialects within a language. The distinction between languages and dialects is not always clear, yet there are important differences between the two. As a general rule, different dialects of one language are closer to each other than different languages are, and dialectal differences are often concentrated at the phonological level. Different dialects of one language typically share most of the same syntax and lexical items, such that speakers of different dialects can comprehend one another. Given these differences, we investigated whether within-language dialectal differences in sound contrasts influence the processing of such contrasts in the same way that cross-language sound contrasts would. At the segmental level, dialectal differences were found in event-related potential (ERP) responses to merger vowel stimuli between merged and unmerged dialect speakers (Conrey, Potts, & Niedzielski, 2005), suggesting that a dialect difference can cause different brain responses between two dialect groups.

Dialectal differences in phonology can occur at the lexical level of prosody as well, and such differences are ideally suited to investigate how the experience of learning a dialect affects one's processing and representation of language in his/her brain. Functional lateralization is a natural indicator of these functions. As described above, Standard (Tokyo) Japanese utilizes lexical pitch accent to distinguish lexical meaning, while 'accentless' dialects do not use pitch at the lexical level at all (Uwano, 1999). Both dialects use pitch specifications at the phrasal level of intonation (Igarashi, in press; Yamaguchi, 1998).

An important advantage of comparing cross-dialectal differences, vs. cross-linguistic differences, is that the effect of linguistic experience on lexical-level prosody is easier to isolate from confounding influences of syntactic, semantic and segmental properties, which are unavoidable in cross-linguistic studies. It should be noted, however, that there is an asymmetry between speakers of standard and non-standard dialects of a language. Speakers of non-standard dialects are typically exposed to the standard dialect extensively through media and education by the time they are adults, whereas speakers of the standard dialect may not have been exposed to non-standard dialects at all. Thus, while speakers of a standard dialect may speak only the standard dialect, speakers of non-standard dialects are often highly proficient in the standard dialect as well.

In the case of Japanese, the standard dialect utilizes a lexical-level prosody distinction, while non-standard, accentless dialects do not. Speakers of both dialects are familiar with the lexical-level prosody of the standard dialect. The difference is that standard dialect speakers learned it as a part of their primary dialect while accentless dialect speakers learned it as a part of their secondary dialect. In the opposite pattern, where the lexical-level prosody that is utilized in a non-standard dialect is not used in the standard dialect, as in the lexical pitch accent of the Korean Southeastern dialect vs. the standard (Seoul) dialect, the standard dialect speakers are mostly unfamiliar with the lexical-level prosody of the non-standard dialect, and unable to distinguish a pair of lexical items on the basis of lexical-level prosody per se. Consequently, the speakers of the two dialects differ not on how or when they learned it, but on whether or not they know it at all.

The tonal dialect of Roermond Dutch is of the latter type. Fournier, Gussenhoven, Jensen, and Hagoort (2010) investigated the speakers of this dialect on their processing of lexical tonal contrasts and intonation contrasts (statement vs. interrogation) and found that Roermond Dutch speakers show a left dominance for lexical pitch and a right dominance for intonational pitch. Speakers of a tonal dialect, who are likely to have learned the local dialect as their first language, process lexical level prosody in a left-dominant manner, on par with mono-lingual native speakers of tonal ∗languages (Gandour et al., 1998; Gandour et al., 2000; Klein et al., 2001; Sato et al., 2007).

A logical question that follows from this is whether speakers of a non-tonal dialect, who learn it as their secondary dialect, would process it like a native language (i.e., like Roermond Dutch speakers) or like an L2 leaner would (i.e., L2 learners of Chinese). Note that since the standard Dutch speakers are not exposed to the Roermond dialect in any substantial way, they are simply not familiar with the Roermond lexical tonal changes. Therefore, it is still unclear how the lexical tonal changes are processed by the speakers who acquired it as a phonological repertoire in a secondary dialect. Japanese is a language that allows us to address this question directly. Unlike Dutch or Korean, it is the standard dialect that utilizes lexical pitch accent, while a non-standard, accentless dialect does not. While the two dialects are different in the lexical use of pitch information, they are similar in the phrasal level intonation for question and statement, that is, rising and falling pitch.

We will consider two ways Japanese accentless dialect speakers may process the lexical pitch accent of Japanese. First, it is possible that the accentless dialect speakers process the lexical-level prosody of standard Japanese (i.e., lexical pitch accent) like an L1 native speaker. Accentless dialect speakers have been exposed to the standard dialect since a young age, and they show sensitivity and knowledge to lexical pitch accent, as demonstrated by their performance in simple discrimination or identification of pitch accent that is similar to that of Standard speakers (Utsugi, Koizumi, & Mazuka, 2010a). Dialectological studies have reported that a change from 'accentless' to pitch accent dialects is in progress,