Cortical magnetic responses for native and non-native speech sounds: MMNm induced by English /r/ and /l/  
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Abstract
Native Japanese-speaking adults have difficulty perceiving the English /r/ and /l/ distinction since these exact sounds are not included in the Japanese phonetic system. To investigate the neural correlate of this phenomenon we recorded cortical magnetic responses (Magnetoencephalography, MEG) from American English (AE) and Japanese (J) speakers using /ra/ and /la/ sounds. A passive oddball paradigm was used to record MMNm, an electromagnetic index of acoustic change detection. Contrary to general expectation from previous findings, MMNm was larger for J than AE speakers. Moreover, a second component identifiable as P3a peaked approximately at 250 ms, was observed only for AE not for J speakers.

1. Introduction
Linguistic experience affects speech perception [1]. Adults have difficulty perceiving differences among sounds not used to distinguish words in their native language. For example, native Japanese speaking adults are usually unable to perceive the /r/ and /l/ distinction in English [2]. Although such perceptual difficulty for adult second language learners is common across all native languages, the underlying neural mechanisms remain unresolved.

In order to investigate neural correlates of this phenomenon, we recorded cortical magnetic responses (MEG) to speech sounds, /ra/ and /la/. In MEG studies, weak magnetic fields produced by electric currents flowing in neurons are measured by multi-channel SQUID (Superconducting Quantum Interference Device)[3]. Sites in the cerebral cortex activated by a stimulus can be calculated from the detected magnetic field distribution.

We used an oddball task where a deviant stimulus occasionally embedded in a sequence of repetitive standard stimuli. The MMNm, a magnetic counterpart of Mismatch Negativity (MMN), observed specifically for the deviant sound has been regarded as a manifestation of automatic detection of acoustic stimulus change [4]. When speech sounds are used as stimuli, MMN/MMNm has also been shown to be sensitive to whether the sounds are native to the individual undergoing the experiment [5].

2. Method
Thirteen monolingual American English (AE) speakers (6 females and 7 males) and 13 Japanese (J) speakers (6 females and 7 males) participated in the study. Parents of AE speakers were both monolingual AE speakers. All of the subjects were right-handed by self-report. None of the subjects had any hearing loss or neurological abnormalities. Each gave informed written consent.

Stimuli (http://www.his.atr.co.jp/slap/report/) and experimental procedures were identical to the previous study [2][6]. Stimuli consisted of synthesized /ra/ and /la/ sounds with a duration of 110 ms (short-duration stimuli) and 150 ms (long-duration stimuli). They were clearly perceived as either /ra/ or /la/ by all the AE speakers. In general, the sound pressure level of vowels is much higher than that of consonants. Thus the short-duration stimuli are assumed to have less backward masking effects from the vowel parts [6]. The stimulus-onset asynchrony was 600 ms. During the experiment subjects watched a self-selected silent film and were directed not to pay attention to the sounds.

Magnetic responses were measured with dual 37-channel gradiometers (Magnes, Biomagnetic Technologies Inc, USA). They were placed over the left and right temporal lobes. The responses to the standard were subtracted from those to the deviant sounds to determine MMNm.

3. Results
A clear MMNm was observed only for the short-duration stimuli not for the long-duration stimuli for both AE and J speakers regardless of the speech sounds (the duration effect). The MMNm amplitude was larger for J than AE speakers.
No hemispheric difference was observed for AE or J speakers in MMNm amplitude elicited by the short-duration stimuli. The latency of the MMNm was comparable between the AE and J speakers (170 ms). A second peak (P3a) following the MMNm was observed only for AE, but not for J speakers. This peak also showed the duration effect, i.e., diminished peak amplitude for the long-duration stimuli. No hemispheric difference was observed for this component.

4. Discussion
The duration effect was observed for both AE and J speakers. This result indicates that the masking effect occurs even in native speakers. The native speakers can understand/recognize speech sounds in spite of such masking effects. The present finding might thus be related to the phonemic restoration effect in which listeners “hear” the parts of the words that are not really there [7].

This finding might be related to the warping of perceptual space seen in the perceptual magnet effect, in which Kuhl et al (1992) showed discrimination is better between vowel sounds far from a prototype than those nearer a prototype [1]. Moreover they showed that even 6 month-old infants have more difficulty discriminating between stimuli near a prototypical vowel from their native language than between stimuli near a prototypical vowel in the non-native language. The perception of acoustic differences within a native category could therefore be subject to suppression. The larger MMNm for J group may reflect “suppression free” responses attributable to acoustic differences between the sounds. Consistent with this interpretation, recent animal studies have shown that cortical sensory representations normally shrink in response to normal sensory exposure, but not in the condition of sensory deprivation [8][9].

For J speakers, MMNm was observed in all subjects. However, P3a was not consistently observed for J speakers. Little attention has been paid for P3a compared with MMNm but this finding is consistent with a recent study reporting that autistic children under speech therapy had reduced P3a amplitudes, while their MMN amplitudes were normal [10]. This is also consistent with a finding that P3a was larger for identifiable (e.g., the sound of a bell) than for non-identifiable natural sounds [11].

5. Conclusions
Cortical magnetic responses to speech sounds were different between AE and J speakers. The present finding provides further evidence that native language exposure affects responses from auditory cortex.

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7. References