A study on nonlinguistic feature in singing and speaking voices by brain activity measurement

Tomohiko Nakamura (0710053)

School of Information Science,
Japan Advanced Institute of Science and Technology

February 5, 2009

Keywords: Nonlinguistic information, Neuroimaging, Singing, Speaking, fMRI.

Singing voice has unique acoustical features that are different from those of speaking voice. In this study, we investigate brain activities that elicited by the stimuli concerning singing and speaking voices. We analyze differences of those brain activities to investigate human voice perception.

Speech has linguistic information and nonlinguistic information. Humans perceive both information from speech. Linguistic information is what speaker said, and nonlinguistic information is related to speaker's gender and feelings, etc. Although a large number of studies have been done on investigating perception of linguistic information, few focuses on perception of nonlinguistic information. It is known that humans can perceive and distinguish singing and speaking voices by using the differences of nonlinguistic information. In this study, we investigate acoustic features that humans capture to perceive speaking voice and singing voice to examine the perception mechanism of nonlinguistic information by measuring the brain activity.

Callan *et al.* researched the activity of brain when humans listened to both singing voices and speaking voices of Japanese lyrics. The analyzed results showed that brain activity when subjects listened to the singing voice was different from that when listening to speaking voice. Brown *et al.* conducted brain measurement experiments in which subjects listened

to the stimuli that altered melody and harmony. As the results, some brain regions were elicited by the complexity and harmony of the song. However, they could not analyze the brain activities only related to the special nonlinguistic information because the presented stimuli included linguistic information. We attempt to study the perception of nonlinguistic information because it is important to perceive and distinguish singing and speaking voices.

Therefore, we conducted experiments that were not affected by linguistic information. In our study, to investigate what acoustic features elicit brain activities, we conducted brain activity measurement experiments using the stimulus sounds that have the same linguistic information and different nonlinguistic information. The linguistic information was the same as /a/, and the duration of all stimuli was about 1.7 seconds. Stimuli were synthesized using the high-quality analysis-synthesis system STRAIGHT (Speech Transformation and Representation using Adaptive Interpolation of weiGHTed spectrum). Moreover, to investigate singing voice perception, we need to evaluate "Singing-ness", and to examine whether the stimuli are perceived as human voice, we need to evaluate "Natural-ness". Then, we discuss the relation between the results of psychoacoustic experiments and the results of brain activities.

In this study, we conducted two brain activity measurement experiments to examine brain activities. In experiment I, to investigate acoustic features that elicit similar brain activities by singing voice, we used six stimulus sounds. Those stimuli include real (actual) singing and speaking voices that were vocalized professional tenor singer, and synthesized voice with the singer's formant (formant peak at about 3kHz) and vibrate. The parameters of the formant and vibrato were decided according to Saito's research result.

In experiment Ⅱ, to investigate which acoustic features were more important for perception of singing voices, we used six stimulus sounds. The acoustic features include spectrum shape, fundamental frequency and amplitude envelope. Those stimuli were synthesized from actual singing voice and speaking voice. We extracted spectrum shape, fundamental frequency and amplitude envelope from those two actual human voices. Next, we synthesized six stimuli based on extracted acoustical features.

The results of brain activity measurement experiments showed that certain brain activity regions are elicited by the singing voice stimulus. The brain regions include LOrG (lateral orbital gyrus), MOrG (medial orbital gyrus) concerning the emotion system. Moreover, the results of the experiment Ⅱ showed that brain activities were different because of the difference of the acoustical features. Those brain regions were inside regions of brain.

We examined relations between the results of psychoacoustic experiment and the results of brain activity experiments. The results showed that the stimulus with large "Natural-ness" elicited larger brain activities than the stimulus with small "Natural-ness". There was no region that was more elicited by rising of the evaluation of "Singing-ness".

It is necessary for future work to increase the number of subjects so that the activity difference may appear even if the threshold of the analysis is made more severe.