Extraction of Brain Cortical Activities Related to Auditory Impressions Induced by HVAC Sound Using Nonnegative Tensor Factorization

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***Abstract*— The linear model that predicts subjective coolness/preference induced by HVAC (heating, ventilation, and air conditioning) sound from brain cortical activities was constructed. Time-frequency components of brain cortical activities were extracted from magnetoencephalographic (MEG) data using the time-frequency analysis and nonnegative tensor factorization (NTF). Brain cortical activities related to subjective coolness/preference induced by HVAC sound were extracted from rank-1 components of NTF and from the weight vector of the predictive model.**

I. Introduction

To create a neurophysiological index for evaluation of subjective impressions, relationships between subjective impressions and brain activities have been investigated in recent years [1, 2]. Although these studies have indicated the possibility of evaluating impressions using neurophysiological indices, they have not yet led to practical indices.

In this study, we focused on an evaluation of automotive HVAC (heating, ventilation, and air conditioning) sounds, which affect comfortableness in a car largely because they continuously make loud noise. We extracted some of the components of brain cortical activities while the subjects were hearing automotive HVAC sounds. These components were extracted from the multi-channel time-frequency features of magnetoencephalographic (MEG) data using nonnegative tensor factorization (NTF) [3]. The linear model that predicts subjective coolness/preference induced by HVAC sound from components of NTF, and the brain cortical activities related to subjective coolness/preference were extracted.

II. Method

A time-invariant HVAC sound and six amplitude-modulated HVAC sounds were generated by changing the modulation frequency from 0 to 3.2 Hz as stimuli. Eight participants (6 males and 2 females, 21-24 years old) took part in the MEG measurements. Four stimuli, including the most- and least-cooled/preferred stimuli in subjective evaluation tests prior to MEG measurement, were selected for each subject. Each subject heard pairs of stimuli and reported which of the stimuli he/she felt was cooler/preferred for each pair.

The continuous wavelet transform (CWT) was performed on the MEG raw data of each channel, at each time (0-5000 ms by 20 ms), for each frequency (4-100 Hz by 1 Hz). Because the time-frequency feature was expressed as a 4-way tensor that has indices of frequency, time, channel, and epoch, it was decomposed into some rank-1 components that express brain cortical oscillations using NTF.

The linear predictive model is constructed using the support vector machine framework [4] for each subject. It classifies the difference between paired feature vectors into two classes corresponding to paired-comparative judgment. To evaluate performance of the predictive model, prediction accuracies of paired-comparative judgments were calculated.

III. Results and Discussion

The mean prediction accuracies of paired-comparative judgments on coolness and preference were 55.4% and 55.5%, respectively. Fig. 1 shows an example of a weight vector of the predictive model and frequency components extracted by NTF. Because the linear weight is a contribution of each component for the prediction of impressions, it is considered that components with a higher absolute value of weight indicate brain cortical activities related to subjective coolness/preference induced by HVAC sound.

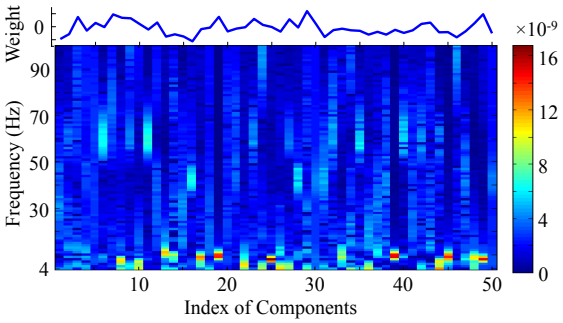

Figure 1. An example of weight vector and frequency components extracted by NTF (Subject 5, coolness). Number of components was 50. The prediction accuracy of this model was 66.7%. For instance, the weight vector shows that the 16th and 49th components (7-10 Hz and 38-48 Hz activities, respectively) significantly affect the prediction of subjective coolness.

References

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