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A study on compensatory action of speech production for Transformed Auditory Feedback.

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1 Introduction

Humans acquire new languages including their mother language by learning from the interaction between speech production and perception process. In such a learning process, a channel of information exchange between speech production and perception, named the speech chain, has been created. To describe the mutual communication of speech production and perception processes in the brain, Liberman et al. proposed the motor theory of speech perception. This theory emphasizes that there exists a strong link between speech production and perception.

The role of auditory feedback in speech production has been studied to understand the interaction between speech production and perception since the early ages. Many experiments with various points of view have been carried out to investigate interactions between speech production and perception for an ongoing speech. However, they did not investigate the interaction effects directly from the movement of articulators. In this study, we focus on the short-time interaction between speech and perception based on Transformed Auditory feedback (TAF) method. To obtain reliable evidences, the physiological observation by means of Electro Magnetic Articulography (EMA) is adopted in this experiments as well as the acoustic analysis.

2 Transformed Auditory feedback (TAF) experiment

This study attempts to explore the effects of real-time changes of vowel formants on speech production process. For the TAF experiment, it is important to feedback sounds in real time by maintaining personal characteristics of the subjects. Therefore, we did the experiments using a real time transformed feedback system by keeping the personal characteristics of the tested subjects.

For formant transform, F1 and F2 of /e/ were changed into those of /a/, /i/ and /u/ respectively with transform rate at 20 %, 40 %, 60 %, 70 %, 80 %, and 100 %. Only at the transformation rate 100 %, the feedback sound is transformed from /e/ to /a/, /i/ or /u/ completely. The formant frequencies (F1 and F2) of /a/, /i/, /u/ and /e/ were measured for each subject before the experiments. The transformed sound was presented to the subject through a headphone. In perturbed feedback trial, the subject received a normal (non-perturbed) feedback sound during the first 2 or 2.5 seconds, and then the subject received the formant-transformed feedback sound for 2 seconds. The normal feedback sound was reset in the last 0.5 or 1 second. Each set of the speech material consisted of three trials with an interval of 3 seconds between the trials. The subject was asked to successively perform 10 sets (30 trials) for each transformation ratio.

In this study, with an EMA, we examined compensatory action of articulators (tongue and lips) of a subject. We confirmed that the compensatory action took place when the subject was given a perturbed feedback sound.

3 Results

Earlier study gave equal transform ratio for both the first two formants (F1 and F2) during transformed perturbation. And we found that the compensatory action took place with a probability between 60 % ~ 70 % in all experimental trials using the acoustic sound analysis alone. In this study, we gave non-equal perturbation ratios for the first two formants to investigate the compensatory effects. Based on our acoustic analysis results, we found that the compensatory action probability in all experimental trials was low, and only increased a little when the transformed perturbation rate getting close to 100 %. In addition, Principal Component Analysis (PCA) was used to analyze the EMA data when the perturbation utterance /i/ or /u/ was given. Based on the analysis results, we found that when perturbation utterance /i/ was given, the subject was induced to utter the perturbed sound /i/ in many trials. Only using the not induced experimental trials, the compensatory action probability was about 56 % among all experimental trials which was higher than that of the probability from acoustic analysis (31.7 %). Since the compensatory action probability was only a little higher than 44.0 %, it may be caused

by chance For perturbation sound /u/ case, we got a probability of 61.7 % compensatory action in all experimental trials based on the acoustic analysis, but got a probability of 79.4 % compensatory action which was a higher probability than that of our earlier studies. In addition, our results showed that the probability of compensatory action using PCA analysis of EMA data was higher than that of using acoustic data analysis. This is one of the advantages of using EMA than only using acoustic analysis.

4 Conclusion

In this study, we investigated the compensatory actions of a subject during speech production when auditory feedback was a transformed sound with non-equal transform ratio for F1 and F2. we got the following conclusions:

1. Only using acoustic sound analysis, we found low compensatory action probability for all experimental trials. And, the probability of compensatory action increased a little when the perturbation transform rate close to 100 %. Compared with our early study, we could conclude that human beings have more compensatory action for perturbation sound with equal transformed ratio for F1 and F2. However, this conclusion needs to be further investigated.
2. Using principal component analysis of EMA data, we got high probability of compensatory action than using acoustic analysis only. That is to say, using EMA data, the compensatory action may be more easily to be captured which is one of the advantages of using EMA for analyzing the real time compensatory actions during speech production.