# Investigation of compensatory action to the transformation ratio for the Transformed Auditory Feedback

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## 1 Introduction

The role of auditory feedback in speech production has been studied to understand interaction between speech perception and production since the early ages. Examples of the auditory feedback include the Lombard's effect under which utterance becomes louder than usual under the noisy environment and the basic frequency is increased. Lee et al. proposed the delayed speech feedback(DAF). However, these experiments destroy human's normal utterance. Therefore, they are inadequate to explain the interaction between auditory perception and speech production. For this reason, Kawahara et al. introduced a transformed auditory feedback (TAF) in their experiments. Their study revealed some important role of auditory feedback regarding the fundamental frequency during phonation. However, the influence of the formant was not clear. Matsuoka et al. focused on the short-time interaction between speech production and perception based on the TAF method. To obtain a reliable evidence, physiological observation by means of electromyography (EMG) was adopted as well as the acoustic analysis. The results revealed that both EMG observation and acoustic

analysis showed compensations for the changes when perturbed sound was feedback to the subject during utterance. However, Saitoh et al. did not confirm the compensatory action when they used a Japanese vowel for the TAF. Their results also suggested the compensatory action of two or more coarticulation points. However, dependence of the compansatory action on the transformation ratio and phonemic difference was not quantitatively measured. In this study, we investigate dependence of compensatory action on transformation ratio for the transformed auditory feedback on Japanese vowel.

## 2 Transformed Auditory Feedback(TAF)

This study attempts to explore effects of real-time changes in 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 subject. During the experiment, the feedback sound was transformed from /e/ to /a/, /i/ and /u/ at the rate of 20, 40, 60, 70, 80 and 100 %. In the transformed sound, F1 and F2 of /e/ were changed into those of /a/, /i/ and /u/ respectively. Only in the case that the transformation ratio is 100 %, the feedback sound is transformed from /e/ to /a/, /i/ and /u/ completely. To do the transformation in real time, the formant information of /e/, /a/, /i/ and /u/ were measured for the subject before the experiments.

The transformed sound was presented to the subject through a headphone. In perturbed feedback trial, the subject receives a normal (non-perturbed) feedback during the first 2 or 2.5 seconds, and then the subject receives the formant-transformed sound for 2 seconds. The normal feedback sound was reset in the last 0.5 or 1 seconds. 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.

## 3 Results and Conclusion

The compensatory action showed a different tendency when the feedback sound was transformed from /e/ to /a/, /i/ and /u/. The ratio of the compensatory action also has decreased as the transformation ratio has increased. Therefore, it was understood that the compensatory action didn't take place easily when the transformation ratio was large. It was shown that the most active compensatory action takes place when the transformation ratio is about 60 %. When transformation ratio was small, the compensatory action didn't take place because the change in the phoneme was not perceived. But, when transformation ratio was large, the compensatory action took place, because the change in the phoneme was perceived. The ratio when the compensatory action took place for F1 was larger than that for F2. A separate articulation organ works respectively for F1 and F2. F1 can be changed easily because it is easy to move in the lower jaw and lip. On the contrary, it becomes difficult to change of F2 because it deeply relates to the movement before and behind the tongue.

## 4 Summary and problem in the future

In this study, we have confirmed the conpensatory action for the transformed auditory feedback by using Japanese vowels. The compensatory action depended on the transformation ratio and on the phoneme to which the formants were shifted.

To further investigate movement of the articulatory organs which control F1 and F2, it is necessary to employ the electromagnetic articulographic (EMA) system and electromyography (EMG) system.