Title	歌唱における気導・骨導の聴覚フィードバックに関する調査研究 [課題研究報告書]
Author(s)	鳥谷，輝樹
Citation	
Issue Date	2016-09
Type	Thesis or Dissertation
Text version	author
URL	http://hdl.handle.net/10119/13747
Rights	
Description	Supervisor:鵜木　祐史，情報科学研究科，修士

Study on Effects of Auditory Feedback by Air-Conducted and Bone-Conducted Speech on Singing

Teruki Toya (1410031)

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

August 4, 2016

Keywords: singing, auditory feedback, air-conduction, bone-conduction.

Singing, as well as speaking, is a kind of human speech communications and a popular activity all over the world. However, it is a fact that some people with no speaking disorder cannot produce proper singing voice, and such people are called "poor-pitch singers." In order to help such people to sing properly, investigations of human production mechanisms for singing are important. Previously, both auditory perception systems and speech production systems in humans during singing have been investigated. In addition, interaction between perception and production during singing has also been focused.

Speakers perceive their own voice as "auditory feedback" during speech production. Auditory feedback is one of the important factors to maintain their singing voice properly because it integrates their perception systems and production systems. Based on this perspective, previous studies have investigated effects of auditory feedback on one's speaking/singing. However, these studies have focused on only air-conducted (AC) auditory feedback and ignore the effect of bone-conducted (BC) auditory feedback. It still has not been clarified whether/how bone-conducted (BC) auditory feedback contributes to maintenance of the singing voice.

The goal of this report is to discuss the characteristics of AC/BC auditory feedback. This report surveys and summarizes previous studies related to the features of the speaking/singing voice, and that related to auditory feedback during speaking/singing. The findings from this report will be used for revealing the perception–production process of singing activity.

Firstly, this report surveyed the previous studies about acoustic features of speech sound, particularly singing voice. These studies, using acoustical and psychophysical analyses, found that temporal changes in intensity, fundamental frequency (F0) and spectral information are the important features in speech sound. Moreover, they also found that singing voice has stronger intensity, longer vowel-duration, discrete changes in F0 contour, dynamic fluctuation in F0 (e.g. vibrato), and spectral peak in high frequency range ("singer's formant") as characteristic features. The findings indicated that these features are related to singing-voice perception and they provide "singing-ness."

Secondly, this report surveyed the previous studies about auditory feedback (focusing on AC speech) during speaking/singing. The initial studies found that speech intensity and F0 of speaker's voice increase when the surrounding sound level increases ("Lombard effect"). Later, several techniques of feeding speaker's delayed/transformed voice back to themselves have been taken. The studies using delayed auditory feedback (DAF) indicated that the mismatch of the temporal relationships between perception and production leads to speech disruption. The studies using transformed auditory feedback (TAF) in F0 found that F0 of the speaker's voice changes when F0 of the feedback sound is perturbed a little. These studies reported that, with some latency, speaker's F0 opposes in most cases but sometimes it follows the perturbed F0. They simultaneously reported that the latency of the opposing response is a little lower than that of the following response. Moreover, the other studies found that such opposing changes are observed also in the first (F1) and second formant frequency (F2). The studies about singing with a target signal indicated that F0 of the singer's voice follows the signal's F0 (called "pitch-matching") due to auditory feedback. The other studies indicated that auditory feedback is also related to vibrato, by using feedback stimuli with F0 periodic fluctuation. Then, some other studies indicated that singer's F0 deviation from intended F0 becomes larger under presence of feedback-masking noise as AC sound. In contrast, another study reported that such deviation becomes smaller under presence of masking noise as AC sound. In this survey, no studies about auditory feedback related to singer's formant have been found. From these findings, this report pointed out, as a remaining issue, that whether/how AC and BC auditory feedback contributes to the accurate pitch-matching, vibrato creation, and singer's formant creation during singing.

Finally, this report surveyed the previous studies about transmission pathways and acoustical features of BC speech, in order to focus on BC auditory feedback as well as AC. Several physiological studies indicated that there are five main pathways of BC hearing. Several acoustical studies indicated that BC speech contains F0 information enough, and that it contains less components of higher frequency than AC speech. Several psychological studies indicated that BC hearing overall dominates speaker's perception in the range of 0.7–2 kHz. At the same time, a related study indicated that vibrotactile-auditory combined feedback affect F0 of one's produced voice more strongly than auditory feedback only. It indicated also that vibrotactile latency of F0 response is a little lower than auditory latency. Based on the findings above, this report inferred that AC and BC singing voice might have different properties (e.g. gain or latency) each other as auditory feedback.

In conclusion, as the discussions from previous findings, this report inferred that BC as well as AC auditory feedback might contribute to singer's pitch-matching and F0 dynamic flactuation, and that AC more than BC auditory feedback might contribute to singer's formant. In order to clarify them, this report considered following things as important points; investigation of recording/presentation devices for BC speech, and investigation of physical/perceptual differences between AC and BC speech.