

Effects of background sound on the volume and fundamental frequency of a singing voice

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ABSTRACT

Background

Singers often perform with musical accompaniment or the voices of other singers. These background sounds can mask a singer's own voice, whereas they can be a reference for the fundamental frequency (F0). Ternström and Sundberg (1988) reported that the precision of F0 in choir singers deteriorated both when the sound from other singers was too loud and when the reference sound was too small, and concluded that the difference in intensity between the external reference and the airborne auditory feedback affects a singer's control of F0. However, they required subjects to keep the volume of their voice constant using visual feedbacks. Therefore, the effect of the intensity of background sound on the volume of their voices remains unclear.

Aims

To investigate the effect of the level of the chorus and musical accompaniment on the volume and F0, singing voice under the condition that singers can change their singing volume freely was recorded. Variations of the volume and F0 were compared among the levels and types of the background sounds.

Method

Five Japanese adults (3 females and 2 males, 38 ± 9.3 years), who have no history of hearing and speaking diseases, participated in the following experiment. One female subject was an experienced choir singer, and others had not experienced professional training of singing. Necessary information regarding the experiment was given to the subjects, and informed consent was obtained from each subject prior to the experiment. The experiment was approved by the Institutional Review Board on Ergonomic Research of AIST.

The subjects were requested to sing a song (Japanese children's song *Donguri korokoro*) a cappella or with background sound of a piano accompaniment, choir singing, or multi-talker noise. The intensity of the background sound was set at 40, 50, 60, 70, or 80 dB(A). The piano accompaniment was made using MIDI synthesizer (Microsoft GS Wavetable Synth), and the choir singing was mixed from solos of eight singers (4 females and 4 males). The multi-talker noise produced by Tanaka (1989) was used.

The background sounds were generated by a personal computer at a sampling frequency of 44.1 kHz and fed to a circumaural open-back headphone (Senheiser 650) via a 24-bit digital-to-analog converter (Echo Digital Audio

AudioFire 12), an digital mixer (Roland EDIROL M-16DX), a programmable attenuator (Tucker-Davis Technologies PA-5), and a distributor (PreSonus HP4). Singing voices of the subjects were detected by a headset microphone (SHURE BETA54) and recorded in the same personal computer at a sampling frequency of 44.1 kHz via the same digital mixer and the same digital-to-analog converter. All the experiments were carried out in a anechoic room. Through the headphone, the subjects heard the background sound and also their own singing voice as picked up by the microphone.

Before actual test session began, each subject had a practice session. In the practice run, each subject was requested to sing with background sound of a piano accompaniment at 60 dB (A) and adjust the intensity of his/her voice so that the subject perceived his/her auditory feedback with "preferred" or "natural" loudness. The subjects were also requested to keep the intensity of their voice constant through all run of the experiment.

In the test session, the piano accompaniment of 60 dB (A) and the test background sound were presented sequentially. 16 conditions (3 sound types \times 5 intensity levels and quiet condition) were randomly applied. Three runs were carried out for each condition.

Results

The results show that the volume of the singing voice increased as the intensity of background sound increased, regardless of the type of sound. Meanwhile, F0 precision (the difference between frequencies notated on the score ($A = 440$ Hz) and extracted from the recorded signal) of the singing voice was not affected by the intensity of background sound. However, F0 precision deteriorated more under the multi-talker noise condition than under a cappella and other background sound conditions.

Discussions and Conclusions

The variation in singing volume in accordance with the intensity of background sound was similar to that for speech production in noise (i.e., the Lombard effect; Lane & Tranel, 1971, Summers et al., 1988). That is, the subjects tried to keep the auditory feedback constant subconsciously against the background sound even in singing tasks, and consequently obtained high F0 high precision over all tested intensities of background sound.

Under the condition of multi-talker noise, there was no reference and the feedback was strongly disturbed, whereas there was sufficient feedback with no reference in a cappella condition and sufficient reference with insufficient feedback under the other background sound. It is indicated that the

intensity of background sound does not directly affect F0 precision while the existence of sufficient auditory feedback or the external reference is important to maintaining F0 precision.

Keywords

singing voice, musical accompaniment, choir singing, reference, masker, intensity, fundamental frequency, auditory feedback

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