Acoustic effect of face shield and mouth mask on speech and vocal music

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Abstract

In addition to its direct impact on the life and health of infected people, Covid19 [1], [2] has disrupted several aspects of society via measures that have been taken to halt the spreading of the disease. Cultural activities, which, almost by definition, are bringing people together, are among the most affected, and in particular, people singing together, due to the accompanying heavy breathing and possibility for far-carrying droplet exhalation, is occupying a high position in the list of activities that are suspect to be considered as super-spreading events.

Based on experimental demonstrations, it is generally believed that horizontal droplet spreading during talking or breathing can be substantially reduced by wearing a mouth mask [3], [4] or face shield [5]. In the framework of enabling choir and other group singing together without unacceptable risks for droplet spreading related infection risks, putting on a face shield and somewhat extending the distance with neighboring singers might be a mitigating measure with limited discomfort involved.

By performing laboratory recording tests, we have addressed the question on the extent to which choir singers wearing a face shield would affect the quality of the choir sound. Each of the six non-professional volunteers singers was asked to sing (solo) in a karaoke setting with text provided by a tablet screen and background music supplied by open-back headphones (HD 650 Sennheiser®) at moderate sound pressure level, an English version of the Christmas song ‘Silent night’. Every singer was singing the song twice: once with and once without a plexiglass face shield. The face shield was visually set for all participants to ensure consistency between recordings and protection efficiency regardless of the head geometry of the tested person.

A similar experiment was conducted to assess the impact of face mask on speech quality by reading a text with and without facemask, at normal speech level. The text was extracted from the Master thesis of one of the authors’ students. None of the participants had rehearsed the text prior to the recording.

The setting was realized in a semi-anechoic chamber of the Laboratory of Acoustics of KU Leuven in Heverlee, Belgium (background noise level L_p<0dB). The participants were positioned at 1.3 m in front of an omnidirectional microphone (RTA-M dBX®) via a soundcard (Focusrite Scarlett 8i6 3rd Gen®) making use of open-source recording software (Audacity®). The experiments were guided by researchers from the Department of Physics and Astronomy and the Faculty of Architecture of KU Leuven. Recordings were also made in the Acoustics Laboratory at Slovak Technical University (STU) in Bratislava, Slovakia.

Figure 1. Photo of the measurement apparatus during a session of speech recordings without facemask within the semi-anechoic room of the Laboratory of Acoustics at KU Leuven

After removing silences, the spectra of the recordings were compared between the two scenarios. The removal of the silences was made using a numerical noise gate algorithm with a detection threshold set 10 dB higher than the electronic noise and only applied to silent episodes of at least 50 ms long, in order not to affect between-word silences. A summary of the spectral modifications caused by the acoustic shielding of the face shield for the different singers is shown in Figure 2 (right side) below. Also a summary of spectral modifications of different tissue and surgical mouth masks is shown in Figure 2 (left side). These transfer functions were computed by 3rd-octave band for each participant, and averaged.

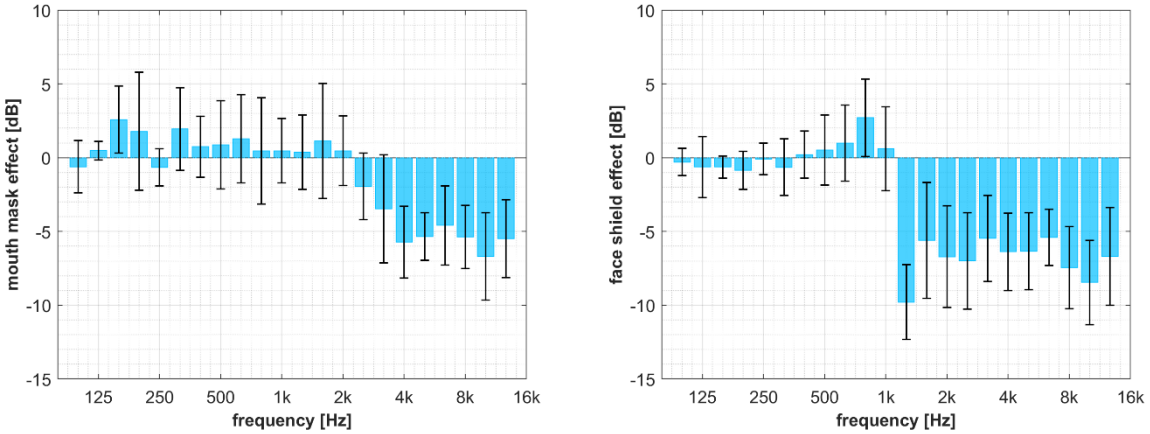

Figure 2. Spectral transfer functions of the facemask (left side) and the face shield (right side) respectively recorded during text reading and singing on 6 non-experienced singers. The error bars represent the standard deviation of the third-octave band recorded magnitudes within the tested population.

Although there are variations among different singers, it is clear that below 1kHz, the effect of the face shield is quite limited, while for 1kHz and above, the acoustic shielding effect of the Plexiglas screen reduces those sound components with 3-12dB. The effect of this "low-pass filtering" effect on the acoustic quality of choir music can be assessed by comparing the original and synthetically filtered version of choir music performed by Leuvens Universitair Koor (LUK) in the audio made publicly available online [6]. The effect is distinctively audible. This is not surprising: the well audible part of the spectrum of choir sound extends from about 100Hz to about 5000Hz. Frequencies above 1kHz are responsible for the brightness of the sound. A reduction of the sound pressure level with 3dB and 12dB is analogous to reducing the number of singers with respectively a factor 2 and a factor 16. The observed low-pass filtering effect is somewhat analogous to the effect of hearing the choir at some distance. Whether this is "acceptable", is a matter of subjective perception. The effect can be assessed by comparing original recordings of LUK with their synthetically filtered version based on our laboratory recordings.

Similar filtering characteristics were observed in the face mask experiment, where the frequencies above 2.5kHz were significantly attenuated by between 2-10dB. Overall, the absorption of the high frequencies was lower for the face mask than for the face shield and shifted to a higher frequency range. The observations are consistent with other studies regarding the assessment of the speech quality with facemasks [7]–[9]. Despite the small population sample, the speech rhythm, i.e. the words and inter-words duration, of the participants was found to be not significantly affected by wearing a facemask. By subjective perception, listening to the recordings in a silent environment, it was qualitatively assessed that within the recorded samples, the speech intelligibility remained quasi unaffected, all words remaining understandable despite the acoustic filtering effect of the face mask.

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