How voice production of singers is influenced by room acoustics

Paul Luizard[1]*, Silvain Gerber[2], Nathalie Henrich Bernardoni[2]

[1]Audio Communication Group, Technische Universität Berlin, Einsteinufer 17c, Berlin, D-10587, Germany
[2]Univ. Grenoble Alpes, CNRS, Grenoble INP, GIPSA-lab, 38000 Grenoble, France

Keywords: singing voice, singer adaptation, electroglottography, room acoustics

Introduction

Performers, whether instrumentalists or singers, tend to develop rather individual adaptation patterns across room acoustical conditions [1,2]. While instrumentalists mostly adapt in terms of tempo [1], singers tend to emphasize variations of loudness and timbral colour in conjunction with related room-acoustical parameters, namely Stage Support and Bass Ratio [2]. Adaptation to room acoustics has also been investigated on talkers in terms of vocal effort, explicitly mentioned by participants and correlated to voice intensity [3]. Vocal effort while talking was found to be larger in rooms that lack early reflections.

Such adaptation should be reflected on glottal-source parameters. Electroglottographic measurements enable to non-invasively assess several features of glottal behaviour, such as contact quotient (duration of glottal contact over a cycle) or its counterpart, open quotient [4]. In speech, contact quotient was found to be correlated to vocal effort [5]. In singing, it was found to be strongly related to vocal intensity in laryngeal mechanism 1, and to fundamental frequency in mechanism 2 [6].

The present study aims at investigating the singing adaptation process in rooms with various acoustics, by assessing voice production by means of acoustical and electroglottographical in-situ measurements.

Methods

Singing-voice features (sound intensity I, fundamental frequency F0, contact quotient CQ) were compared with room acoustical parameters (early decay time EDT, early stage support ST_{early}, bass ratio BR, late interaural cross-correlation $IACC_{late}$, speech transmission index STI). Eight room acoustics were tested to find correlates between singing-voice parameters and room-acoustics ones which would reveal adaptation patterns. Four singers (soprano, mezzo-soprano, tenor, baritone) were asked to sing exercises (glissandi, crescendi) and excerpts of lyrical musical pieces in each room. Both near-field acoustical signal and electroglottography (EGG) were recorded, synchronised, and calibrated.

The statistical analysis of the data was based on the linear-mixed-models (LMM) framework. This approach can take advantage of the data nested structure and account for random factors, such as different singers and different musical pieces.

Results and discussion

Descriptive statistics showed tendencies, such as an influence of ST_{early} variation (sound level of the room response) across rooms on voice-range profile for two singers, as depicted in Fig. 1 for Singer 3. These results were confirmed and generalized by the LMM analysis. Singers adapted particularly well in terms of vocal intensity when performing singing exercises. The musical pieces yielded larger correlation with room acoustics, namely the proportion of variance in voice production that could be explained by room acoustics, on average across singers: 30% for I, 6% for CQ, and 4% for F0. It should be noted that the variance across singers is large, e.g. for I: 70% for Singer 3 and 2% for Singer 2, indicating that they were not sensitive to room acoustics in a similar manner, each singer having an individual adaptation pattern.

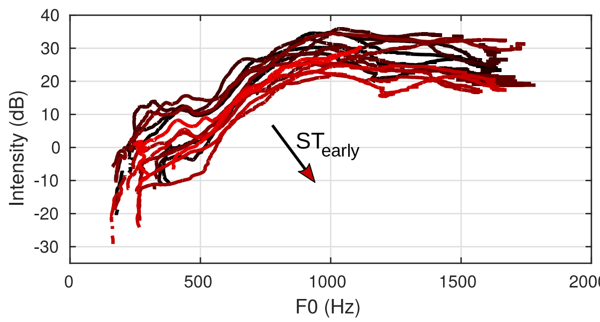

Figure 1: Voice-range profile of Singer 3 for increasing (black to red) room acoustical parameter ST_{early}

Acknowledgements

This work was partially funded by the A. von Humboldt Foundation. The authors would like to thank the singers, the room managers, and E. Brauer for his help with the recordings.

References

[1] Luizard *et al*, Proc. Conf. AES on Immersive and Interactive Audio, 2019.
[2] Schärer Kalkandjiev *et al*, Psychomusicology: Music, Mind, and Brain, 25(3), 2015.
[3] Bottalico *et al*, J. Acoust. Soc. Am., 139(5), 2870-2879, 2016.
[4] Henrich *et al*, J. Acoust. Soc. Am., 115(3), 1321-1332, 2004.
[5] Huang *et al*, J. Voice, 9(4), 429-438, 1995
[6] Henrich *et al*, J. Acoust. Soc. Am., 117(3), 1417-1430, 2005

*paul.luizard@campus.tu-berlin.de