

## Effects of Historical Recording Technology on Spectral Measurements of Modern-Day Opera Singers

**Objective:** The fields of vocal pedagogy and voice performance often debate about the “state of the art of singing,” but such debates often center around subjective analyses of singers who were recorded with limited recording technology. This study attempts to understand what remains of the original voices of historical singers on wax cylinder recordings by analyzing and comparing spectral characteristics of wax cylinder and microphone recordings of modern-day professional opera singers.

**Method/Design:** This study recorded 20 professional opera singers with an Edison Home Phonograph onto brown-wax cylinder replicas and, simultaneously, with a flat-response omnidirectional microphone. Spectral moments,  $L_1$ - $L_2$  difference, and harmonic-to-noise ratio measurements were extracted from two tasks: a *messa di voce* on C4/C5 on the vowel [a] and a short phrase from “Caro mio ben.” Broadband noise was recorded to compare the frequency responses of both systems.

**Results:** There was attenuation of the sound intensity level below 440 Hz which was confirmed by a significant decrease in the  $L_1$ - $L_2$  difference across all tasks for all participants. HNR significantly decreased across all tasks; indicating increased noise in cylinder recordings. There were significant differences in spectral moments between the two recording technologies, although the effects differed between tasks. Simulated wear on the cylinders by period equipment caused an increase in the noise floor and deterioration above 3 kHz, which may contribute to auditory masking.

**Conclusion:** The results from this study show that significant spectral distortions are caused by the wax cylinder phonograph system; however, further perceptual testing is required to understand how such spectral differences limit what the listener hears. The effects of the wax cylinder phonograph system depended on the task. Therefore, a primary conclusion of this study is that there is not a consistent restoration technique that can be used to mitigate the distortions caused by the recording technology.