Acoustical exploration on the role of the audiophonatorical feedback in professional female classical singing

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Introduction

Singers must learn to take care of their kinaesthetic feedback always, but especially in acoustical dry conditions. Singers study their music at home, and in a concert hall there are other acoustical conditions.

This study aims to proof or disproof a general consensus among singers that singing is mainly controlled using kinaesthetical sensations, although many singers would tell us from experience that the environment can also influence their singing too. Is it possible to estimate the extent of the influence of acoustic feedback given by the acoustic environment for classical female singing?

Experimental setting

Five singers were asked to sing the first verse of the song "Heidenröslein" by Franz Schubert in an anechoic chamber. One microphone was placed in front of the singer at a distance of 2m and the signal was recorded and altered with a hall generator. The singer received the signal from the latter through a set of headphones. In addition, a headset with a microphone placed at a distance of 5cm from the singer's mouth was used. For reference recordings, three other microphones were used: one was placed inside the headphones, and two to the right and left in front of the singer at a distance of 2.4m. The microphone signals were amplified and recorded. Different settings were used on the hall generator and this, when fed through the headphones, gave the singer the acoustical impression of being in a different environment. The settings used were R1 and H2 and the reverberation times were 1.5s and 4.2s respectively. The signal that the singer heard through the headphones had no delay.

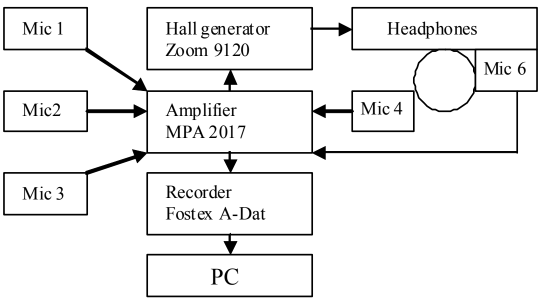

Fig. 1: **Experimental setting**

Results:

The results presented in this paper correspond to graphs of one word ("Knab", sung in the first period) and one singer. The following plots show the means of the parameters specified on each figure. 22 recordings were taken for each of the two acoustical environment simulations. The spectra and the derived functions RMS, normalized spectral centroid and vibrato are calculated with the pvan program [1] that comes with the package SNDAN, and the formants with the LPC function with MATLAB.

The statistical evaluation was calculated using a two-sided t-test with a significance level of 0.05. If the test result was significant then a mask was drawn to non-zero values.

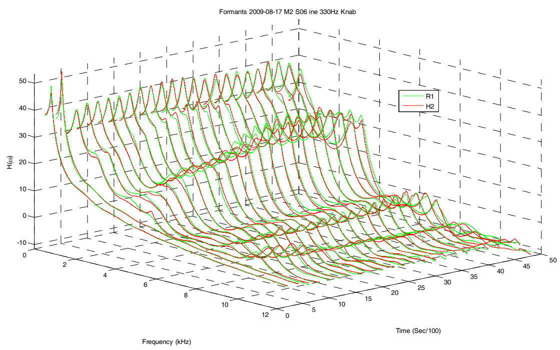

Fig. 2: **Waterfall diagram for the formants of „Knab"**

The time dependency of the spectra can be seen on the changing of the intensity levels of the partials over time, the time-dependant structure of the formants (fig. 2), and on all qualities derived from the spectral characteristics (fig. 5, 6 and 7), if they are calculated time dependant. The singer never has his jaw or lips in a constant position while singing.

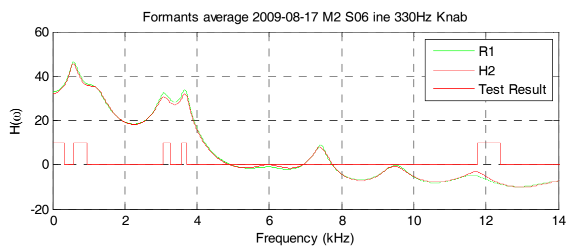

Fig. 3: **Means of formants**

Fig. 3 shows the average over time of the formant intensities corresponding to recordings of "Knab" with the hall generator settings R1 and H2. The intensities of the partials were calculated and a t-test was carried out for each point of time. The formant-plots show differences mainly in frequency-regions whereas the partials show a statistical significant statistical difference at many points of time. The distribution of the partials in the formant graph is shown in fig. 4

A rise of formant-energies around 2 kHz can be seen starting at around 250 ms (fig. 2). In this time-region the RMS (fig. 6) and the normalized spectral centroid (fig. 5) show a significant difference.

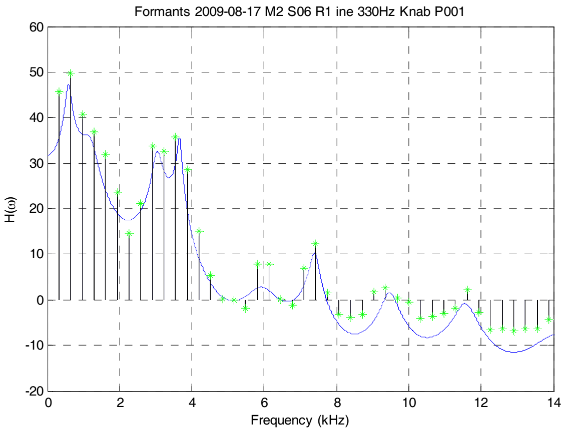

Fig. 4: **Formant and spectrum of “Knab”, Pass 001**

The time varying characteristics of the partials (not shown here) show results similar to those shown for the RMS (fig. 6) and normalised spectral centroid (fig. 5).

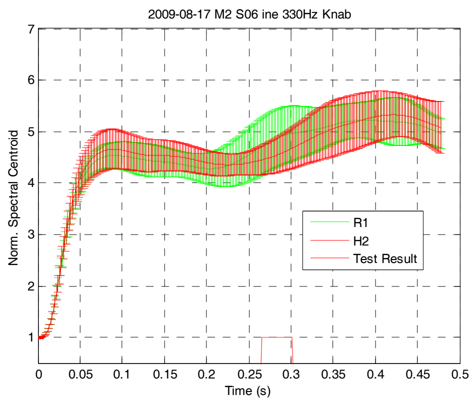

Fig. 5: **Normalised spectral centroid over Time**

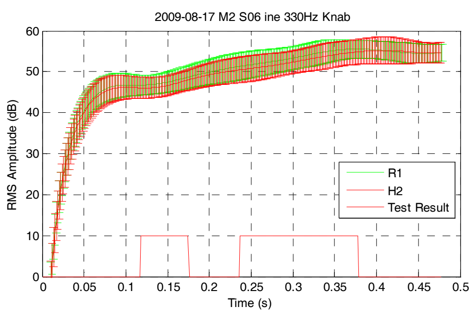

Fig. 6: **RMS over time**

The frequency vibrato amplitude was calculated as the absolute value of the deviation from the mean frequency of the tone, and always has a tendency to get higher, as the time-distance to the onset of the tone increases. Fig. 7 shows the confidence interval of the vibrato differences and the mask with the regions of statistical significant differences.

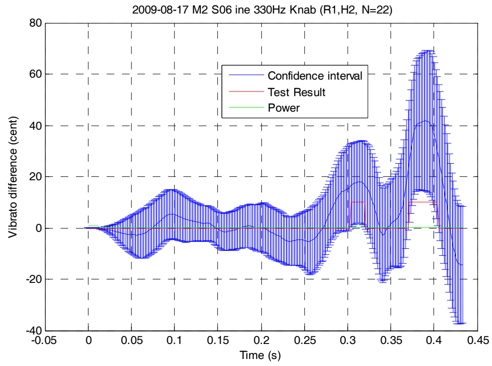

Fig. 7: **Vibrato difference over time**

Listening test

For the listening test, the first musical period of “Heidenröslein” was used. The extracted part was taken from a former recording and in this case, additional settings were used on the hall generator - H1 and R2, with reverberation times of 3.3 and 1.3s respectively. The parts of the recorded signal (Mic. 1) were first extracted and then altered with the hall generator setting R1 to give a more natural impression for the listeners. The listeners got offered 100 examples in a pairwise arrangement. 12 pairs recorded with auditory feedback from different rooms, and 3 with auditory feedback from the same rooms, were used. Listeners should answer whether the music was sung in the same room or in different rooms. They had only two possibilities for their answers – same or different. 39 people were the subjects for judging. All of them were choir-singers, 3 of them were professional singers. 46% of the subjects did not recognize the effect of the room-dependant deviations. Their answers were “same” (p=0.41) or randomly (p=0.5), and they were dropped out. The residual subjects had scores of 41% correct answers.

The comparison of physiological parameter-values for Shimmer, Jitter, HNR, Inverse filter parameters and spectral tilt (H1-H2, H1-A1, H1-A2, H1-A3) calculated from the data of mic. 5 did not show statistical significant differences.

Conclusion

Significant statistical differences in RMS, normalised spectral centroid, spectra and vibrato were found at a few points of time in the recordings of the singer. To make any sort of generalisatoin regarding whether differences in acoustic feedback and reverberation-time alter the musical quality, physiological behaviour or acoustics of the professional singing voice more research needs to be done.

It seems that professional singers fit the creation of their singing tone according to their imagination.

[1] Beauchamp, J. W.: Analysis, Synthesis and Perception of Musical Sounds. New York, 2007