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Vocal adaptation of singers to room acoustics

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Purposes

Characterize the **influence** of the **acoustics** of a room on the **vocal production** of a singer

Determine which **strategies** are used by the singers to adapt to the room

Estimate the **preference** of room acoustics to various singing styles, for a **singer** and a **listener**

[1] Previous studies

Mostly based on
- Instrumentalists, not singers
- Singers in unrealistic environments

1. *Schärer Kalkandjiev et al, 2013*
- 1 cellist in 7 rooms, same program
- Music recordings and room acoustic measurements
- Multivariate statistics : 4 components could explain 97% of the music variance

2. *Kato et al, 2015*
- 4 instrumentalists and 1 singer in virtual rooms
- Sound rendering through 6 surrounding speakers in an anechoic chamber
- Most acoustical features were varied beyond the corresponding just noticeable difference
- Audio features and questionnaires showed that musicians consciously adjust their interpretation style

3. *Marshall et al, 1985*
- Choir singers and soloists in an anechoic chamber
- Virtual sound field based on time delays and relative amplitudes of reflections and reverberation
- Reverberation controls the comfort of singers
- Early reflections are appreciated if they are short (< 40 ms)

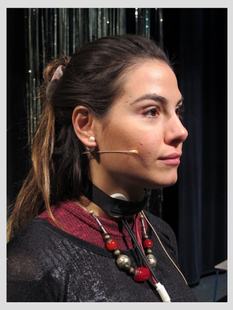
2. Noson *et al, 2000*
- 2 to 4 singers ensembles in a church
- Artificial early reflections added by means of couples microphone – speaker
- Fast-tempo singing requires strong early reflections whereas slow-tempo singing not significantly impacted

[2] Methodology

1. <u>The experiments</u>
- Real rooms : recordings of singers through microphones and electroglottography (EGG, used to observe the activity of the vocal folds).
  As well, measurements of mono- and binaural room impulse responses
- Virtual rooms : replication of the experiment through dynamic binaural auralization based on measured and simulated impulse responses

2. <u>The analysis</u>
- Analysis of the variance in the performance of singers regarding the variation of estimated room acoustic parameters, in terms of musical features and vocal quality
- Verbal analysis of the questionnaires filled by the singers after each recording
- Listening tests to estimate the preference of listeners

[3] Singers



- 4 different vocal ranges (soprano, alto, tenor, baritone)
- Different singing styles (opera, coloratura, lied) within classical repertoire
- Recordings : exercises (glissando from lowest to highest note, crescendo for 3 different notes), 3 different musical excerpts (variation of tempo, rhythm, dynamics), one common tune (*Happy birthday*)

<u>The measurements</u>
- Acoustics : musical features (tempo, dynamics, articulation)
- EGG signal : vocal mechanism, vocal fold behavior

[4] Real rooms

- Classical room acoustic measurements (ISO-3382) for room acoustical parameters estimation
- Binaural room measurements for dynamic auralization

Numerical values for the 1 kHz octave band

Church (V = 9360 m³)
T20 = 4.7 s, EDT = 4.6 s, C80 = -5.3 dB

Philharmonie Berlin (V = 22000 m³)
T20 = 2.0 s, EDT = 2.0 s, C80 = 2.4 dB

Joseph Joakim Saal (V = 3660 m³)
Without banners
T20 = 2.2 s, EDT = 2.1 s, C80 = -1.3 dB
With banners
T20 = 1.5 s, EDT = 1.6 s, C80 = 0.9 dB

Chamber music room (V = 590 m³)
T20 = 1.2 s, EDT = 1.0 s, C80 = 4.5 dB

Cabaret theater (V = 1700 m³)
T20 = 0.7 s, EDT = 0.7 s, C80 = 8.1 dB

Recording studio (V = 420 m³)
Without banners
T20 = 0.7 s, EDT = 0.7 s, C80 = 6.7 dB
With banners
T20 = 0.5 s, EDT = 0.5 s, C80 = 9.8 dB

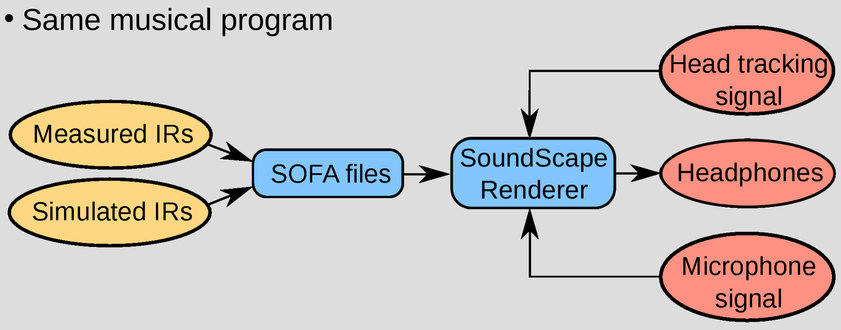
Anechoic chamber
V = 640 m³
Cutoff frequency = 70 Hz

[5] Virtual rooms

Aim of this step: provide the singers with real-time auralization so that they can sing in virtual rooms

In each real room, impulse responses measured with a Neumann dummy head and a speaker at the mouth position, both placed on a rotating table
Samples in the horizontal plane from -40° to +40°, 5° step

Based on the monaural impulse response measurements (ISO-3382) in each real room, simulations calibrated within the RAVEN software
Replication of the whole circular binaural measurements through simulations
- 8 real rooms
- 8 simulated rooms
- Same musical program



[6] Perspectives

- Perform the statistical analysis on the acoustical and physiological data
- Perform a verbal analysis on the questionnaires of the singers
- Run a listening test to estimate which combination {singing ; acoustics} is preferred
- Compare the performances in virtual conditions based on measured vs. simulated impulse responses

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