A Spatial Audio Quality Inventory for Virtual Acoustic Environments (SAQI)

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How to perceptually evaluate Virtual Acoustic Environment?

- Assessment of selected singular auditive qualities[1,2]
- Assessment of overall perceptual accuracy[3,4]
- Assessment according to differentiate sensory catalogues[5,6]
- *Ad-hoc* vocabularies vs. empirically substantiated elicitation approaches

## Prior Research

<table>
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</tbody>
</table>


Methods for creating consensual sensory vocabularies

- Verbal vs. non-verbal
- Stimulus-based vs. non-stimulus-based
- Individual vs. group-based
- Laymen vs. experts

Nominal Group method, Delphi method, Focus Group method
Discussion Guideline

“Create a consensus vocabulary …
“Create a consensus vocabulary covering all auditive qualities that may arise when comparing virtual acoustic environments …
“Create a consensus vocabulary covering all auditive qualities that may arise when comparing virtual acoustic environments of all types and in all stages of development…”
“Create a consensus vocabulary covering all auditive qualities that may arise when comparing virtual acoustic environments of all types and in all stages of development with each other, or with respect to a given or imagined reference (e.g., the corresponding reality).”
Discussion Guideline

“Create a consensus vocabulary covering all auditive qualities that may arise when comparing virtual acoustic environments of all types and in all stages of development with each other, or with respect to a given or imagined reference (e.g. the corresponding reality).”

Quality names:

- Describe perceptual process
- Complete but still practically relevant
- Formulated clearly and unambiguously
- Non-overlapping
Dual-moderator, two-way Focus Group
Dual-moderator, two-way Focus Group
Dual-moderator, two-way Focus Group
Dual-moderator, two-way Focus Group
Dual-moderator, two-way Focus Group
Dual-moderator, two-way Focus Group

Moderated group discussion

Observers
Dual-moderator, two-way Focus Group

Moderated group discussion
Dual-moderator, two-way Focus Group

Moderated roundtable discussion
Dual-moderator, two-way Focus Group
Validation

1. Internal post-check of semantic consensus
2. *External* post-check of understandability
3. Semantic analysis
4. Resolved by 5 experts

Final German vocabulary
Translation GER → EN

- Translation guidelines by Hambleton (2001)

- Translation by 5 bilingual experts (two natives, 3 non-natives)
  - Individual translations of German quality names
  - Finalized in online group meeting

- Back-translation by 3 German experts working abroad

### Spatial Audio Quality Inventory (SAQI-EN)

<table>
<thead>
<tr>
<th>Category</th>
<th>Auditory Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Timbre (8)</strong></td>
<td>Tone color bright-dark, High-/Mid-/Low-frequency tone color, Sharpness, Roughness*, Comb filter coloration*, Metallic tone color</td>
</tr>
<tr>
<td><strong>Tonalness (3)</strong></td>
<td>Tonalness, Pitch, Doppler effect</td>
</tr>
<tr>
<td><strong>Geometry (10)</strong></td>
<td>Horizontal/Vertical direction, Front-back position, Distance, Depth, Width, Height, Externalization, Localizability, Spatial disintegration</td>
</tr>
<tr>
<td><strong>Room (3)</strong></td>
<td>Reverberation level, Reverberation time, Envelopment by reverberation</td>
</tr>
<tr>
<td><strong>Time behavior (7)</strong></td>
<td>Pre-/Post-echoes, Temporal disintegration, Crispness, Speed, Sequence of events, Responsiveness</td>
</tr>
<tr>
<td><strong>Dynamics (3)</strong></td>
<td>Loudness, Dynamic range, Dynamic compression effects*</td>
</tr>
<tr>
<td><strong>Artifacts (7)</strong></td>
<td>Pitched/Impulsive/Noise-like artifact, Alien source, Ghost source, Distortion, Tactile vibration</td>
</tr>
<tr>
<td><strong>General (7)</strong></td>
<td>(Overall) Difference, Clarity, Speech intelligibility, Naturalness, Presence, Degree-of-Liking, Other</td>
</tr>
</tbody>
</table>

* Illustrative audio examples have been created.
Exemplary SAQI Test Procedure
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Exemplary SAQI Test Procedure

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Exemplary SAQI Test Procedure

- Test Stimulus
- Imagined Reference
  or
- Reference Stimulus

No Difference?

Yes

Overall Difference?

Upper Scale Label
Lower Scale Label

Unipolar Rating Scale

End of Test

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Exemplary SAQI Test Procedure

Overall Difference?

- No
- Yes (optional)

Upper Scale Label
Lower Scale Label
Unipolar Rating Scale

Modifications I
- A
- B1
- B2
- C1
- C2
- F2

Modifications II

Check Boxes

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Exemplary SAQI Test Procedure

- Test Stimulus
- Imagined Reference
- Reference Stimulus

Overall Difference?

- No
  - Upper Scale Label
  - Lower Scale Label
  - Unipolar Rating Scale

- Yes
  - Modifications I
  - Modifications II
  - Assessment entities
  - Check Boxes

End of Test
Exemplary SAQI Test Procedure

1. Test Stimulus or Imagined Reference
2. Overall Difference?
   - Yes: Upper Scale Label
     - Modifications I (optional)
       - Check Boxes
       - Assessment entities
         - A
         - B
         - C
         - D
         - E
         - F
         - Other:
   - No: Lower Scale Label
     - Unipolar Rating Scale
     - Difference Quality 1?
       - "Circumscription ..."
3. End of Test

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Exemplary SAQI Test Procedure

1. Test Stimulus or Imagined Reference

2. Overall Difference?
   - No
   - Yes

3. Difference Quality 1? “Circumscription …”
   - Yes
   - No

4. End of Test

Modifications I
- A
- B1
- B2
- C1
- C2
- F2

Modifications II
- A
- B
- C
- D
- E
- F

Assessment entities
- Other: [ ]

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Exemplary SAQI Test Procedure

Overall Difference?
- Yes
  - Upper Scale Label
  - Modifications I
  - Assessment entities
  - Check Boxes
  - Modifications II
  - Assessment entities
  - Check Boxes
- No
  - Upper Scale Label
  - Modifications I
  - Assessment entities
  - Check Boxes
  - Modifications II
  - Assessment entities
  - Check Boxes

Difference Quality 1?
- Yes
  - Upper Scale Label
  - Modifications I
  - Assessment entities
  - Check Boxes
  - Modifications II
  - Assessment entities
  - Check Boxes
- No
  - Bipolar Rating Scale
  - Check Boxes

Difference Quality N?
- Yes
  - Upper Scale Label
  - Modifications I
  - Assessment entities
  - Check Boxes
  - Modifications II
  - Assessment entities
  - Check Boxes
- No
  - Bipolar Rating Scale
  - Check Boxes

Other Differences?
- Other:
- End of Test
Exemplary SAQI Test Procedure

1. **Overall Difference?**
   - **Yes**:
     - **Upper Scale Label**
     - **Lower Scale Label**
     - **Modifications I**
       - **A**
       - **B1**
       - **B2**
       - **C1**
       - **C2**
     - **Modifications II**
       - **F2**
     - **Assessment entities**
       - **A**
       - **B**
       - **C**
       - **D**
       - **E**
       - **F**
       - **Other:**
   - **No**:
     - **Difference Quality 1?**
       - **Yes**:
         - **Upper Scale Label**
         - **Lower Scale Label**
         - **Modifications I**
           - **A**
           - **B1**
           - **B2**
           - **C1**
           - **C2**
         - **Modifications II**
           - **F2**
         - **Assessment entities**
           - **A**
           - **B**
           - **C**
           - **D**
           - **E**
           - **F**
           - **Other:**
       - **No**:
         - **Difference Quality N?**
           - **Yes**:
             - **Upper Scale Label**
             - **Lower Scale Label**
             - **Modifications I**
               - **A**
               - **B1**
               - **B2**
               - **C1**
               - **C2**
             - **Modifications II**
               - **F2**
             - **Assessment entities**
               - **A**
               - **B**
               - **C**
               - **D**
               - **E**
               - **F**
               - **Other:**
           - **No**:
             - **Other Differences?**
               - **Yes**:
                 - **Other:**
               - **No**:
                 - **End of Test**
Exemplary SAQI Test Procedure

1. **Overall Difference?**
   - Yes: Imagined Reference
   - No: Unipolar Rating Scale

2. **Difference Quality 1?**
   - Yes: Circumscription
   - No: Bipolar Rating Scale

3. **Difference Quality N?**
   - Yes: Circumscription
   - No: Bipolar Rating Scale

4. **Other Differences?**
   - Yes: Imagined Reference
   - No: Unipolar Rating Scale

      **End of Test**

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**Modifications**

- Modifications I
- Modifications II

**Assessment entities**

- A
- B
- C
- D
- E
- F

**Check Boxes**
Resources

- SAQI-EN/GER in free Matlab® listening test toolbox WhisPER 1.8.0
  - DOI 10.14279/depositonce-31

- SAQI Test Manual v.1.0
  - DOI 10.14279/depositonce-1
  - Explanations, practical guidelines
  - Audio examples
  - Test data from real SAQI tests
  - Functions for plotting and convenient data import to SPSS
First Applications – Non-individual dynamic binaural synthesis
First Applications – Non-individual dynamic binaural synthesis
Focus Group Members

Fabian Brinkmann, Benjamin Bernschütz, Clemens Büttner, Diemer de Vries, Vera Erbes, Alexander Fuß, Matthias Geier, Martin Guski, Michael Horn, Stefan Klockgether, Steffen Lepa, Alexander Lindau, Hans-Joachim Maempel, Johannes Nowak, Rob Opdam, Zora Schärer, Frank Schultz, Sascha Spors, Michael Vorländer, Stefan Weinzierl and Hagen Wierstorf.

Validation of German SAQI

Matthias Frank, Markus Noisternig, Sönke Pelzer, Andreas Silze, and Franz Zotter.

English SAQI

Jude Brereton, Kees de Visser, Brian Gygi, Charalampos Saitis, and Steven van de Par

English-German back-translation

Frank Melchior, Nils Peters and Ulrich Reiter.
Thank you!

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