LISTENERS’ RESPONSE TO STRING QUARTET PERFORMANCES RECORDED IN VIRTUAL ACOUSTICS

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Virtual Acoustics

- An active acoustic system alters the acoustics of a room by imposing responses synthesized from pre-recorded impulse responses of another space
- Offers flexibility to tailor the acoustics of a multi-purpose concert venue for the demands of a specific event
- The purpose is to provide an environment that is more enjoyable both to the performers and the audience
Haydn’s Study

Photo by Tom Beghin
Music Room at Esterhaza

Photo by Tom Beghin
Motivation

(Virtual)Space

Performer

Audience
Motivation

Ko, Woszczyk, Chon (2012)

(Virtual)Space

Performer

Audience
Motivation

Recorded performances → Audience
Recording Setup

<table>
<thead>
<tr>
<th></th>
<th>Condition 1</th>
<th>Condition 2</th>
<th>Condition 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>$T_{30}$ (seconds)</strong></td>
<td>1.38</td>
<td>1.74</td>
<td>2.08</td>
</tr>
<tr>
<td><strong>Level (dBC)</strong></td>
<td>88.2</td>
<td>88.2</td>
<td>88.3</td>
</tr>
<tr>
<td><strong>C80 (dB)</strong></td>
<td>14.4</td>
<td>13.7</td>
<td>13.1</td>
</tr>
<tr>
<td><strong>ST1 (dB)</strong></td>
<td>-13.8</td>
<td>-13.2</td>
<td>-13.1</td>
</tr>
<tr>
<td><strong>IACC</strong></td>
<td>0.46</td>
<td>0.43</td>
<td>0.41</td>
</tr>
<tr>
<td><strong>LF (125-500Hz)</strong></td>
<td>0.208</td>
<td>0.214</td>
<td>0.223</td>
</tr>
</tbody>
</table>
Experiment

Trial 1 of 9

Sample1  Sample2  Sample3

What sample sounds the most natural?
What sample sounds the least natural?
What sample sounds the closest?
What sample sounds the farthest?
What sample sounds the biggest room?
What sample sounds the smallest room?
What sample sounds the most clear?
What sample sounds the least clear?
What sample sounds the loudest?
What sample sounds the quietest?
What sample sounds the best?
What sample sounds the least?

NEXT
## Experiment

<table>
<thead>
<tr>
<th><strong>Criterion</strong></th>
<th><strong>Question</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Naturalness</td>
<td>1. Which sample sounds the most natural?</td>
</tr>
<tr>
<td></td>
<td>2. Which sample sounds the least natural?</td>
</tr>
<tr>
<td>Source distance</td>
<td>3. Which sample sounds the farthest?</td>
</tr>
<tr>
<td></td>
<td>4. Which sample sounds the closest?</td>
</tr>
<tr>
<td>Room size</td>
<td>5. Which sample sounds like the biggest room?</td>
</tr>
<tr>
<td></td>
<td>6. Which sample sounds like the smallest room?</td>
</tr>
<tr>
<td>Clarity</td>
<td>7. Which sample sounds the most clear?</td>
</tr>
<tr>
<td></td>
<td>8. Which sample sounds the least clear?</td>
</tr>
<tr>
<td>Loudness</td>
<td>9. Which sample sounds the loudest?</td>
</tr>
<tr>
<td></td>
<td>10. Which sample sounds the quietest?</td>
</tr>
<tr>
<td>Preference</td>
<td>11. Which sample sounds the best?</td>
</tr>
<tr>
<td></td>
<td>12. Which sample sounds the worst?</td>
</tr>
</tbody>
</table>
Data Analysis

Participant response → Response matrix (9x12) → Probability
## Result

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Question</th>
<th>$F$ (2, 24)</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naturalness</td>
<td>1. most natural?</td>
<td>0.046</td>
<td>.955</td>
</tr>
<tr>
<td></td>
<td>2. least natural?</td>
<td>0.769</td>
<td>.475</td>
</tr>
<tr>
<td>Source distance</td>
<td>3. farthest?</td>
<td>25.246</td>
<td>&lt; .001*</td>
</tr>
<tr>
<td></td>
<td>4. closest?</td>
<td>11.997</td>
<td>&lt; .001*</td>
</tr>
<tr>
<td>Room size</td>
<td>5. biggest room?</td>
<td>49.017</td>
<td>&lt; .001*</td>
</tr>
<tr>
<td></td>
<td>6. smallest room?</td>
<td>62.715</td>
<td>&lt; .001*</td>
</tr>
<tr>
<td>Clarity</td>
<td>7. most clear?</td>
<td>16.529</td>
<td>&lt; .001*</td>
</tr>
<tr>
<td></td>
<td>8. least clear?</td>
<td>13.658</td>
<td>&lt; .001*</td>
</tr>
<tr>
<td>Loudness</td>
<td>9. loudest?</td>
<td>3.729</td>
<td>.039*</td>
</tr>
<tr>
<td></td>
<td>10. quietest?</td>
<td>4.458</td>
<td>.023*</td>
</tr>
<tr>
<td>Preference</td>
<td>11. best?</td>
<td>3.465</td>
<td>.048*</td>
</tr>
<tr>
<td></td>
<td>12. worst?</td>
<td>3.239</td>
<td>.057</td>
</tr>
</tbody>
</table>
Naturalness

Acoustic Condition

Average Probability

most natural
least natural
Source Distance

Average Probability

Acoustic Condition

farthest

closest
Source Distance

Average Probability

Acoustic Condition

---

farthest

closest
Room Size

Average Probability

Acoustic Condition

biggest

smallest
Room Size

Average Probability vs. Acoustic Condition

- Red square: biggest
- Blue triangle: smallest
Room Size

Acoustic Condition

Average Probability

biggest

smallest

1

2

3

1

0.2

0.4

0.6

0.8

0.2

0.4

0.6
Clarity

![Graph showing Clarity](image)

- Average Probability
- Acoustic Condition

- Red squares: most clear
- Blue triangles: least clear
Clarity

Acoustic Condition

Average Probability

most clear
least clear
Clarity

Acoustic Condition

Average Probability

most clear

least clear
Loudness

Average Probability

Acoustic Condition

loudest

quietest
Loudness

Average Probability

Acoustic Condition

loudest

quietest
Preference

Average Probability

Acoustic Condition

0.2
0.4
0.6
0.8

best
worst

1
2
3
Summary

Acoustic Condition vs. Average Probability

- Farthest vs. Closest
- Biggest vs. Smallest
- Most Clear vs. Least Clear
- Loudest vs. Quietest
Summary

Acoustic Condition vs Average Probability

- **Most natural**
- **Least natural**

- **Best**
- **Worst**
Summary

• Listening experiment with excerpts performed in virtual acoustic conditions
• Data showed no systematic effect of music (or string quartet groups)
• Listeners perceived differences in room acoustics in recorded samples
  – Source distance, room size, clarity, loudness
• Listener data showed no difference in naturalness
  – Implies a virtual acoustic system can improve the perception of space and performance while maintaining naturalness
• While performers strongly preferred enhanced acoustics (Conditions 2 and 3), this pattern was not found in the listener data
  – In need of more participants?
Caveat

• Stimuli were recorded samples and not live performances
  – Listeners’ experiences were probably different from performers’
• Cannot verify listener consistency
• Music in diverse styles
  – Difficult to judge the effect of virtual acoustics on different musical styles
Future Works

• Repeat experiment
  – With musicians without experiences with virtual acoustics
  – With general audience
  – In a different system setup (e.g. multichannel surround)

• Musical analysis to extract parameters that would best predict the effect of acoustic conditions on performance
  – Such as micro-timing, (a)synchronicity, pitch accuracy

Understanding how performers and listeners perceive different acoustic conditions will help fine-tune virtual acoustics systems for everyone’s pleasure.
Thanks for your attention!
Questions? Comments?