Assessment of Room Size and Position of the Listener by Normal Sighted Persons Based on Acoustic Response of the Room

M. Horvat, K. Jambrošić, J. Francetić, H. Domitrović, M. Rychtarikova, V. Chmelik
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Introduction

• auditory information -
  – supplement to visual info
  – often enough on its own
  – for a blind or a visually impaired person, a crucial source of information

• experiments - normal-sighted persons
  – self-localization in a room and room size assessment
  – auditory cues of virtual acoustic environments
  – recreation by a multichannel loudspeaker system (Ambisonics)
Experimental setup

- stimuli - impulsive
  - hand claps
  - footsteps

- acoustic conditions
  - hard reflexive floor, all other surfaces treated
  - absorption - $\alpha =$
    - 0.1
    - 0.2
    - 0.4
  - diffusion - $s =$
    - 0.05 on all surfaces
    - 0.9 on the ceiling (0.05 on other surfaces)
    - 0.9 on the left wall (0.05 on other surfaces)
Experimental setup

• 36 listeners
  – age range 21-28
  – no hearing impairment
  – variable knowledge on acoustics/music

• test procedure
  – reproduction - 2\textsuperscript{nd} order 3D Ambisonics
  – 9 different acoustic treatments
  – self-localization - three positions in a room (A, B and C)
  – room size assessment - four rooms (1, 2, 3 and 4)
  – task: listen to three (or four) recordings for each acoustic treatment and put the positions (ABC, CBA, BCA,... 6 possible) or rooms (1234,4132,2143,...24 possible) in correct order
Rooms - 1

- self-localization - hand claps (own)
- room size assessment - central position - hand claps (own)
- 12 m x 7 m x 3 m = 252 m$^3$ - medium size
Rooms - 1

- self-localization - footsteps (of someone else)
- room size - footsteps (own)
- $12 \text{ m} \times 7 \text{ m} \times 3 \text{ m} = 252 \text{ m}^3$ - medium size
Rooms - 2

- room size assessment
- $35 \text{ m} \times 2.4 \text{ m} \times 3 \text{ m} = 252 \text{ m}^3$ - hallway
Rooms - 3

- room size assessment
- $4 \text{ m} \times 3 \text{ m} \times 2.5 \text{ m} = 30 \text{ m}^3$ - small
Rooms - 4

- room size assessment
- 24 m x 14 m x 6 m = 2016 m³ - large
## Results - $X^2$-statistics

<table>
<thead>
<tr>
<th>Hand claps</th>
<th>Scattering coefficient ( )</th>
</tr>
</thead>
<tbody>
<tr>
<td>$df = 5$</td>
<td></td>
</tr>
<tr>
<td>all 0.05</td>
<td></td>
</tr>
<tr>
<td>ceiling 0.9</td>
<td></td>
</tr>
<tr>
<td>wall 0.9</td>
<td></td>
</tr>
<tr>
<td>0.1</td>
<td>$\chi^2 = 23.18$</td>
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<tr>
<td></td>
<td>$p &lt; 0.001$</td>
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<tr>
<td>0.2</td>
<td>$\chi^2 = 0.94$</td>
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<td>$p = 0.967$</td>
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<td>0.4</td>
<td>$\chi^2 = 7.65$</td>
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<td>$p = 0.177$</td>
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<table>
<thead>
<tr>
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<td>$df = 5$</td>
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<tr>
<td>wall 0.9</td>
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<tr>
<td>0.1</td>
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<td>$\chi^2 = 2.41$</td>
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<td>$p = 0.790$</td>
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### self-localization

<table>
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<td>$df = 23$</td>
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</tr>
<tr>
<td>all 0.05</td>
<td></td>
</tr>
<tr>
<td>ceiling 0.9</td>
<td></td>
</tr>
<tr>
<td>wall 0.9</td>
<td></td>
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<tr>
<td>0.1</td>
<td>$\chi^2 = 197.3$</td>
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<td>$p &lt; 0.001$</td>
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<td>0.2</td>
<td>$\chi^2 = 32.00$</td>
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<tr>
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<td>$p = 0.100$</td>
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<tr>
<td>0.4</td>
<td>$\chi^2 = 120.0$</td>
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<td></td>
<td>$p &lt; 0.001$</td>
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### room size assessment

<table>
<thead>
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</thead>
<tbody>
<tr>
<td>$df = 23$</td>
<td></td>
</tr>
<tr>
<td>all 0.05</td>
<td></td>
</tr>
<tr>
<td>ceiling 0.9</td>
<td></td>
</tr>
<tr>
<td>wall 0.9</td>
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<tr>
<td>0.1</td>
<td>$\chi^2 = 119.2$</td>
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<td>$p &lt; 0.001$</td>
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<td>0.4</td>
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<td>$p &lt; 0.001$</td>
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Results - self-localization - handclaps

Percentage of answers vs. different parameters.
Results - room size assessment - handclaps

![Bar chart showing percentage of answers for different conditions.](chart.png)

- **Conditions**
  - $s = 0.05$, $0.9$ ceiling, $0.9$ wall
  - $s = 0.05$, $0.9$ ceiling, $0.9$ wall
  - $s = 0.05$, $0.9$ ceiling, $0.9$ wall
  - $s = 0.05$, $0.9$ ceiling, $0.9$ wall

- **Parameters**
  - $a = 0.1$
  - $a = 0.2$
  - $a = 0.4$

- **Horizontal axis**
  - Percentage of answers

- **Vertical axis**
  - Conditions and parameters

**Note:**
- Date: 08.05.2014
- Location: ATF 2014, Vienna, Austria
- Event: May 6-7, 2014
Results - room size assessment - footsteps

Percentage of answers

s = 0.05, 0.9 ceil, 0.9 wall
a = 0.1

s = 0.05, 0.9 ceil, 0.9 wall
a = 0.2

s = 0.05, 0.9 ceil, 0.9 wall
a = 0.4
Results - self-localization - absorption

![Bar graph showing percentage of correct hits for different values of parameter a.]

- For $a = 0.1$, hand claps have a higher percentage of correct hits compared to footsteps.
- For $a = 0.2$, both hand claps and footsteps have similar percentages of correct hits.
- For $a = 0.4$, hand claps still have a higher percentage of correct hits compared to footsteps.

ATF 2014, Vienna, Austria
May 6-7, 2014
Results - self-localization - diffusion

![Bar chart showing percentage of correct hits for different conditions.]

- **s = 0.05 all**
- **s = 0.9 ceil**
- **s = 0.9 wall**

Legend:
- **Blue** = hand claps
- **Red** = footsteps
Results - room size assessment - absorption

![Bar chart showing percentage of correct hits for different values of absorption (a).](chart.png)

- **a = 0.1**
  - Hand claps: 45%
  - Footsteps: 25%

- **a = 0.2**
  - Hand claps: 30%
  - Footsteps: 30%

- **a = 0.4**
  - Hand claps: 25%
  - Footsteps: 25%

**08.05.2014**
**ATF 2014, Vienna, Austria**
**May 6-7, 2014**

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Results - room size assessment - diffusion

![Bar chart showing percentage of correct hits for different scenarios.](chart.png)

- **s = 0.05 all**
- **s = 0.9 ceil**
- **s = 0.9 wall**

Legend:
- Blue: hand claps
- Red: footsteps
Conclusions

• ability of self-localization - not well developed (no need)
  – already obtained visually
  – increase of absorption further reduces this ability (0.4 too much, expected in studios and control rooms only)
  – diffusion on the ceiling makes it more difficult

• ability to assess room size - more pronounced
  – develops from everyday experience (use of different spaces)
  – reduced with increased absorption
  – stable with changes in diffusive properties
  – medium-sized room often confused with others

• future work
  – redo the experiments with blind (visually impaired persons)
Thank you for your attention!