Noise control to improve employee satisfaction in offices - What should we measure and how should we promote better design?

Valtteri Hongisto
Senior research scientist, FIOH @ Turku
Adjunct professor, Aalto University @ Helsinki
+358405851888 valtteri.hongisto@ttl.fi
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Effects of bad acoustics and excessive noise in offices

- Lack of speech privacy
  - feeling of being overheard
  - feeling of disturbing someone
- Concentration difficulties →
- Reduction of cognitive performance
- Communication difficulties
- Bad ambience (relationships)
- Reduced environmental dissatisfaction
- Stress, distress
- Sick-leaves
- Increased turnover
- Use of various coping methods
- Work management problems
- Excess of remote work
Noise levels in open-plan offices

- Trompette & Chatillon 2012 J Occup Env Hyg
- Noise levels can vary significantly between open-plan offices
- 54 … 86 dB $L_{eq,8h}$ (France)
- 21 offices, 117 operators

**FIGURE 5.** Distribution of noise exposure levels for 117 operators.
Performance vs. STI

Jahncke, Hongisto, Virjonen 2012 Appl Acoust
Hongisto 2005 Indoor Air
Is my talking noise then?

- Employee ratings were collected before and after the relocation
  1. First in private room office,
  2. Thereafter in an open plan office
- The same noise levels in both office types (50-52 dB $L_{Aeq7h}$)
  - Variability of noise $L_{A1\%}-L_{A99\%}$ was larger in 1
- Environmental satisfaction ($p<0.05$) and acoustic satisfaction ($p<0.01$) better in 1

- Noise level meter cannot determine when the sound is noise
- Acousticians’ way of coping with this philosophical problem:
  - Focus on room & building acoustic design
  - Forget the people, because you cannot know how they behave.
  - Expect that conversations (not noise) takes place with short distances
ISO 3382-3:2012

- All distances
- STI
- SPL of speech
- Normal effort of speech
- Empty room
- Make the outcome simple to be understood by architects and users
- Forget frequencies
- Create target values
ISO 3382-3:2012 Quantity 1: Radius of distraction, $r_D$

- STI depends on
  - Signal-to-noise ratio
  - Early Decay time
- Work performance improves when Speech Transmission Index, STI, is less than 0.5
- The distance from a speaker at which STI falls below 0.5
- $r_D$ in metres which is very convenient
- very sensitive to masking, so that it cannot be used alone as a room acoustic descriptor
ISO 3382-3:2012 Quantity 2: Spatial decay rate of A-weighted speech, DL₂

- A-weighted level of speech at 4 metres
  - Interpolated
- Reduction of A-weighted SPL of speech per distance doubling
  - Fitted

![Graph showing the spatial decay rate of A-weighted speech, with key points and fitted line.](image)
ISO 3382-3 data

- 16 offices with varying
  - Absorption
  - Screen height
  - Room size
  - Background noise
- Huge potential for improving the acoustic privacy by design
ISO 3382-3 excluded reverberation time

Reverberation time describes the temporal decay of sound in selected point.

Workers desire strong spatial decay of sound from different directions of the office.

RT and DL2 does not work as a primary design parameter!

(N=15)

Finnish standard, SFS 5907

Virjonen et al. 2009 Acta Acust united Ac
ISO 3382-3 lacks suggestions for recommended values

<table>
<thead>
<tr>
<th>Class</th>
<th>Acoustic classification</th>
<th>$r_D$ [m]</th>
<th>$DL_2$ [dB]</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Excellent</td>
<td>5 or less</td>
<td>11 or more</td>
</tr>
<tr>
<td>B</td>
<td>Good</td>
<td>5 to 8</td>
<td>8 to 11</td>
</tr>
<tr>
<td>C</td>
<td>Fair</td>
<td>8 to 11</td>
<td>5 to 8</td>
</tr>
<tr>
<td>D</td>
<td>Poor</td>
<td>11-15</td>
<td>3-5</td>
</tr>
</tbody>
</table>

Class E: Values do not fulfill Class D

Normal voice level (59 dB at 1 m) shall be used in $r_D$ determination
**ABC of Acoustic Privacy**

**Absorb**  Maximize absorption in ceiling, walls and screens

**Block**  Use high screens where privacy is needed

**Cover**  Use artificial speech masking

*Figure: Cambridge Sound Management*
Noise control by layout – Activity-based offices
Activity-based office - Case

- Good results
- Fixed workstation for all in open space
- Anonymous work rooms available nearby
  - One room per three workstations
Furniture ensembles

- The sales is exploding
- ISO standard for determining the acoustic performance is lacking

All figures are taken from the Internet
Furniture ensembles

- Standard reverberation room
- Noise reduction in 125-4000 Hz
- Speech reduction index $D_S$

\[
DL_W = L_{W,1} - L_{W,2}
\]

\[
D_S = L_{W,S,A,1} - L_{W,S,A,2}
\]

$D_S = 2.6 \text{ dB}$
Furniture ensembles

$L_{W1}$  $L_{W2}$

Hongisto et al. 2015
Accepted to Acta Acust united Ac
# Furniture ensembles

<table>
<thead>
<tr>
<th>Specimen</th>
<th>$D_s$ [dB]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.0</td>
</tr>
<tr>
<td>2</td>
<td>0.2</td>
</tr>
<tr>
<td>3</td>
<td>0.6</td>
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<tr>
<td>4</td>
<td>1.0</td>
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<td>5</td>
<td>1.5</td>
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<td>6</td>
<td>0.6</td>
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<tr>
<td>7</td>
<td>1.8</td>
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<td>8</td>
<td>2.6</td>
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<td>4.0</td>
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<td>10</td>
<td>0.8</td>
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<td>11</td>
<td>3.9</td>
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<td>12</td>
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<td>13</td>
<td>2.8</td>
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<tr>
<td>14</td>
<td>18.5</td>
</tr>
<tr>
<td>15</td>
<td>22.4</td>
</tr>
<tr>
<td>16</td>
<td>19.8</td>
</tr>
</tbody>
</table>

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Hongisto et al. 2015
Accepted to Acta Acust. united Ac
Furniture ensembles – in the eyes of ISO 3382-3

- Example: $D_S = 6 \text{ dB}$

<table>
<thead>
<tr>
<th></th>
<th>$r_D$ [m]</th>
<th>$D_{2S}$ [dB]</th>
<th>$L_{PA4m}$ [dB]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without furniture</td>
<td>5</td>
<td>9</td>
<td>44</td>
</tr>
<tr>
<td>With furniture</td>
<td>0</td>
<td>9</td>
<td>35</td>
</tr>
<tr>
<td><strong>CHANGE</strong></td>
<td><strong>-5</strong></td>
<td><strong>0</strong></td>
<td><strong>-9</strong></td>
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Holistic approach: Acoustics as a part of design process

Physical factors
1. Spatial density (m²/person)
2. Architectural layout & functionality
3. Acoustics
4. Air conditioning
5. Window view, natural light
6. Lighting
7. Ergonomics at the workstation
8. Interior design
9. Environment

Psychological factors
- Ask the employees about the factors of environmental dissatisfaction
- Focus on these factors during the office design
- Involve of employees during change design
- Management of change
- Personal control of physical factors
Sonera case

- Open-plan office 2500 m²
- Number of physical factors were improved at once
  - acoustics, lighting, interiors, activity based design
- Most psychological factors were well taken into account
- Quasi-field experiment (N=40)
  - Questionnaire before & after the refurbishment
- Large improvement in nearly all subjective measures related with the perception of the office and environmental factors

Hongisto et al. 2015 Under Review in Journal X
<table>
<thead>
<tr>
<th>ABCDEFG of Acoustic Design</th>
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<tbody>
<tr>
<td><strong>Absorb</strong></td>
</tr>
<tr>
<td><strong>Block</strong></td>
</tr>
<tr>
<td><strong>Cover</strong></td>
</tr>
<tr>
<td><strong>Distance</strong></td>
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<tr>
<td><strong>Etiquette</strong></td>
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<tr>
<td><strong>Floor</strong></td>
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<tr>
<td><strong>Group</strong></td>
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<tr>
<td><strong>Holism</strong></td>
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<tr>
<td><strong>Isolation</strong></td>
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<tr>
<td><strong>J</strong></td>
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