



Finnish Institute of
Occupational Health

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

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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

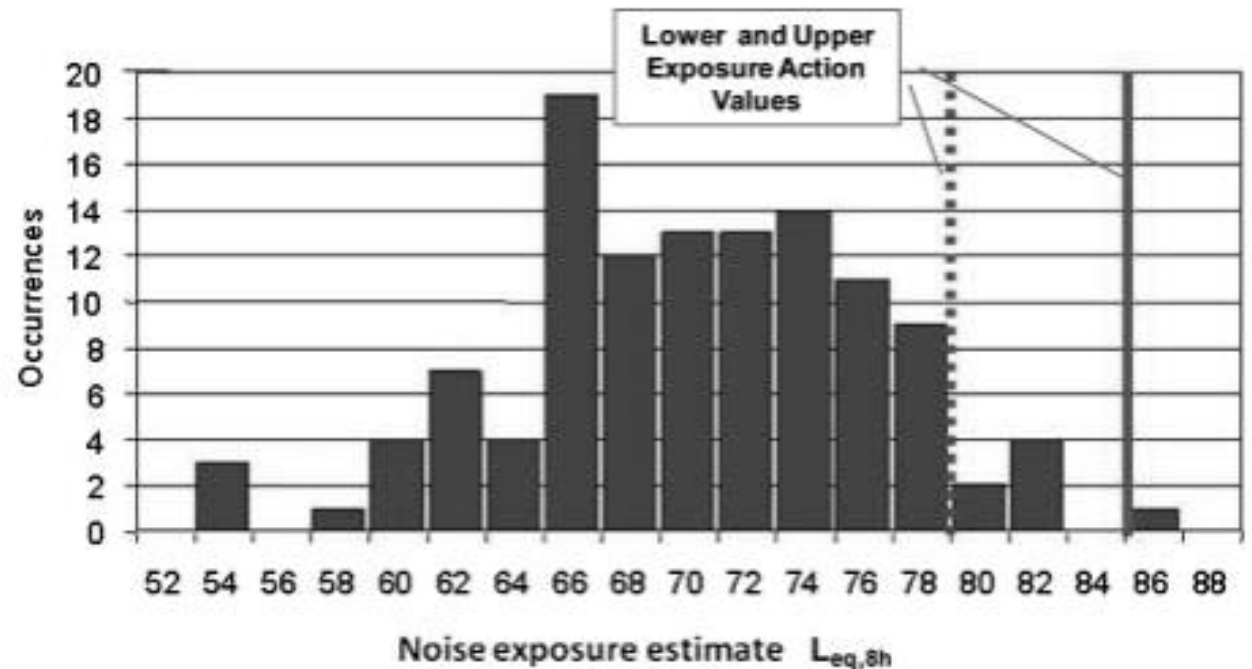


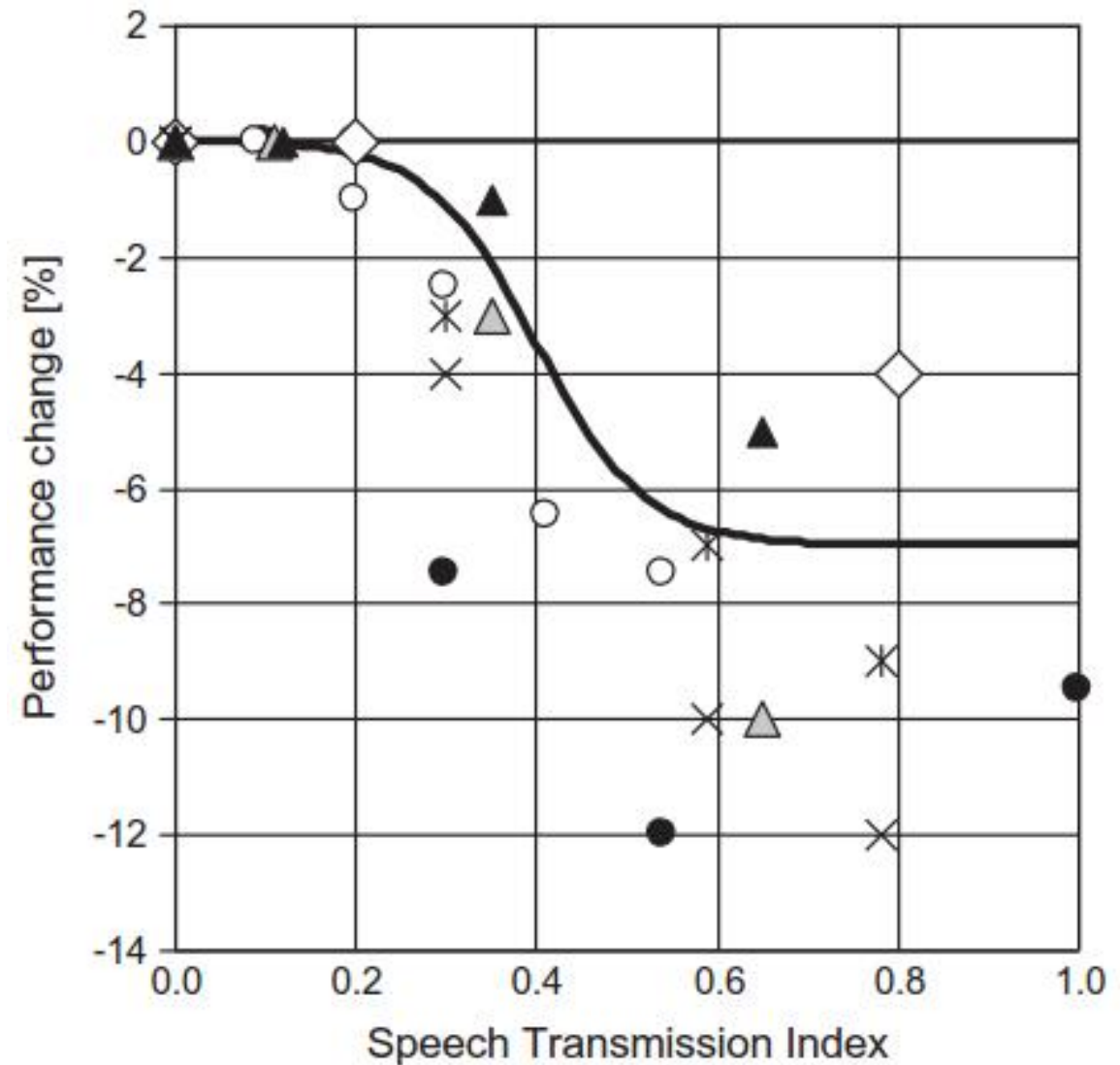
FIGURE 5. Distribution of noise exposure levels for 117 operators.

Performance vs. STI

Jahncke, Hongisto, Virjonen 2012 *Appl Acoust*

Hongisto 2005 *Indoor Air*

- Ellermeier and Hellbrück (1998) Exp. 2A [12]
- Ellermeier and Hellbrück (1998) Exp. 2B [12]
- ◇ Venetjoki et al. (2006) [13]
- △ Haka et al. (2009) Task1 [14]
- ▲ Haka et al. (2009) Task2 [14]
- × Schlittmeier et al. (2008) Exp. 1 [15]
- * Schlittmeier et al. (2008) Exp. 2 [15]



Is my talking noise then?

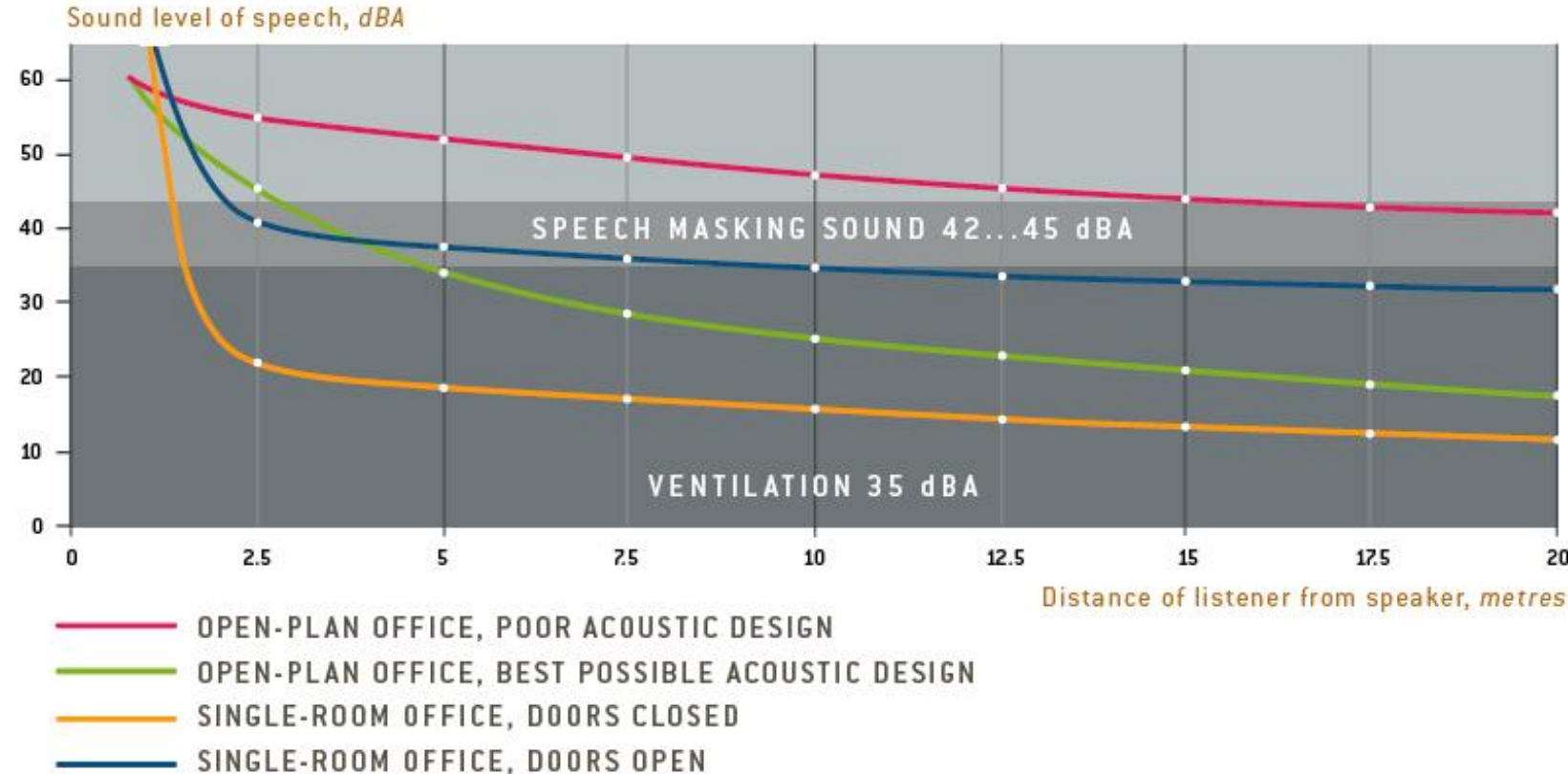
Kaarlela-Tuomaala et al. 2009 Ergonomics

- 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

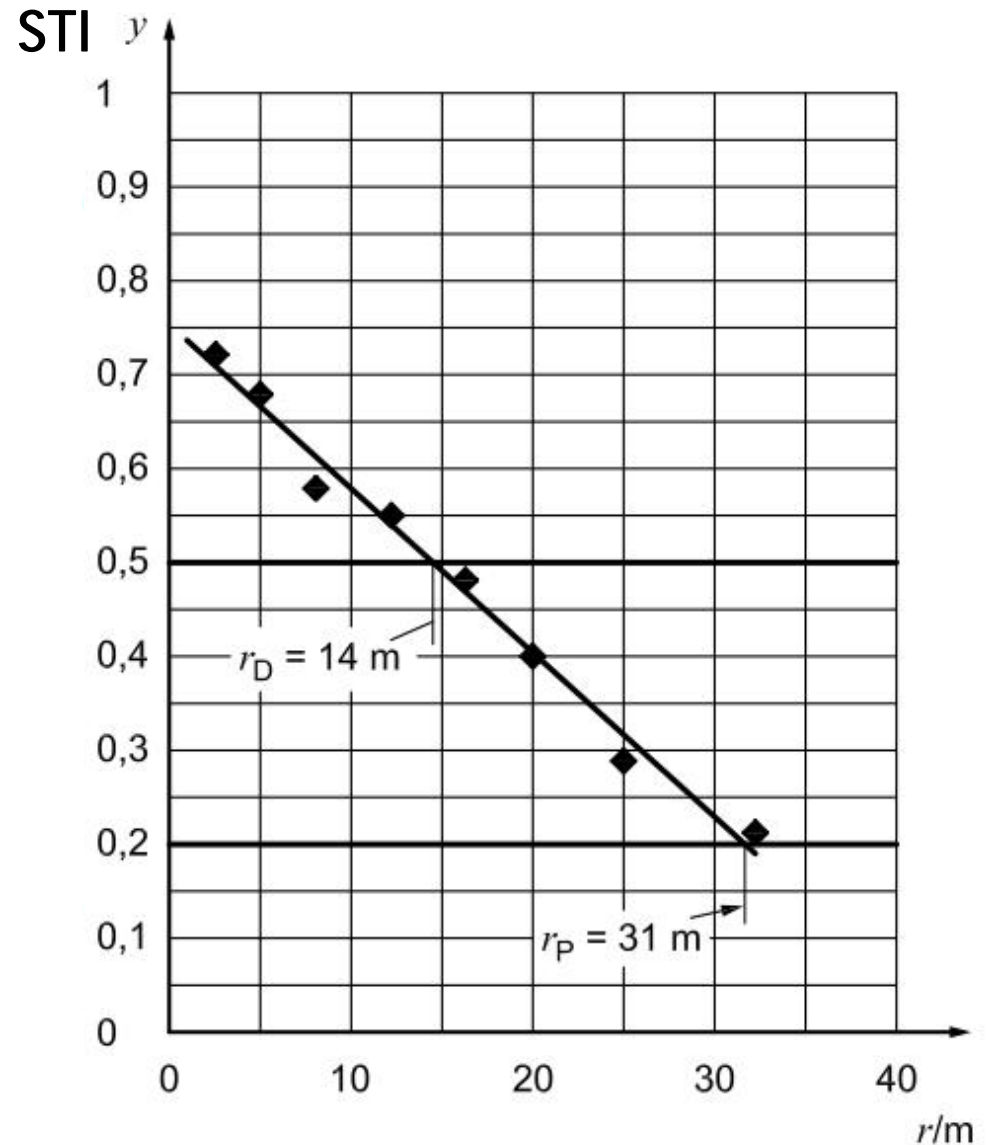
- All distances
- STI
- SPL of speech
- Normal effort of speech
- Empty room
- Make the outcome simple to be understood by architects and users
- Forget frequencies
- Create target values



ISO 3382-3:2012 Quantity 1: STI

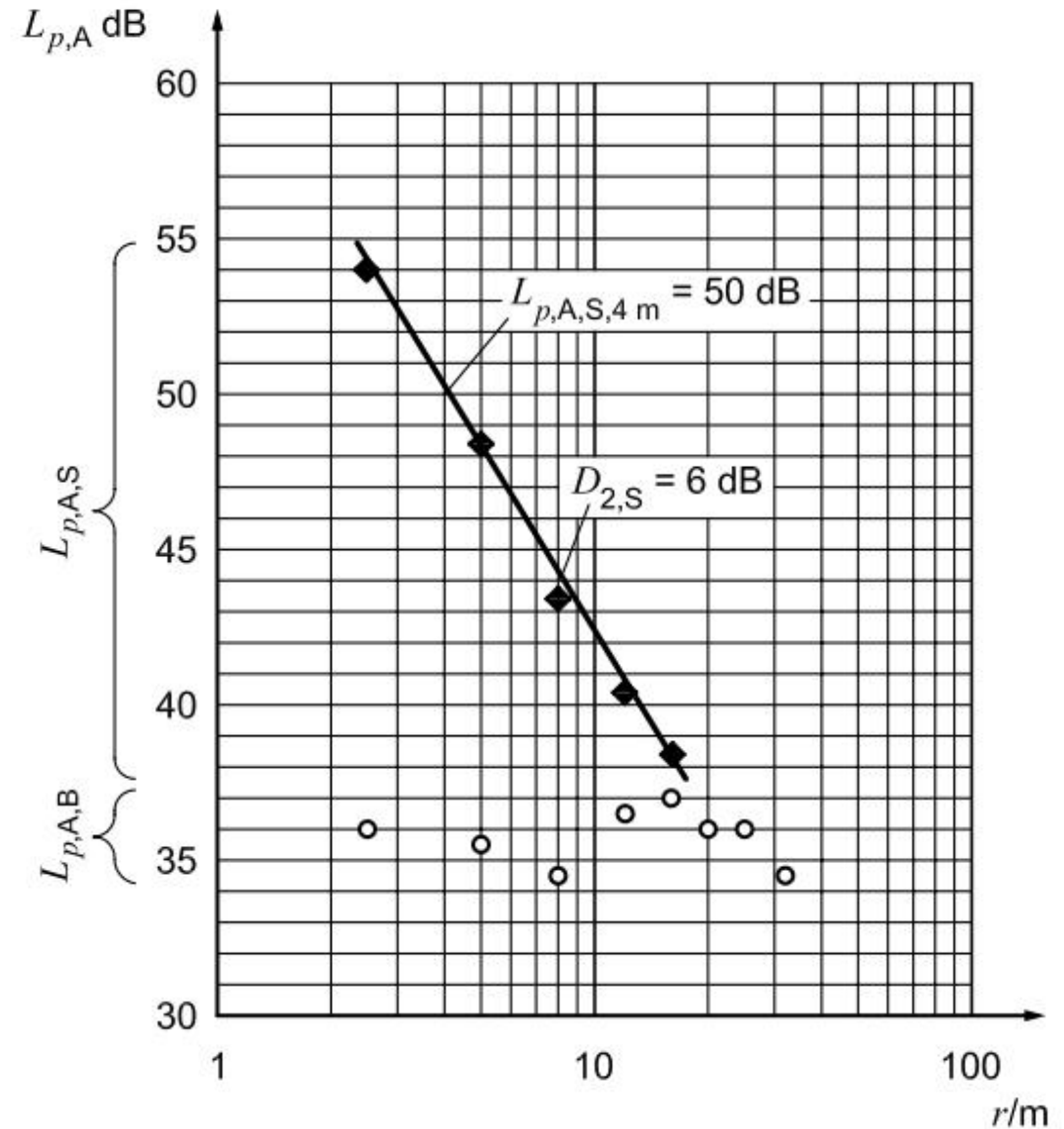
Radius of distraction, r_D

- 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, DL_2

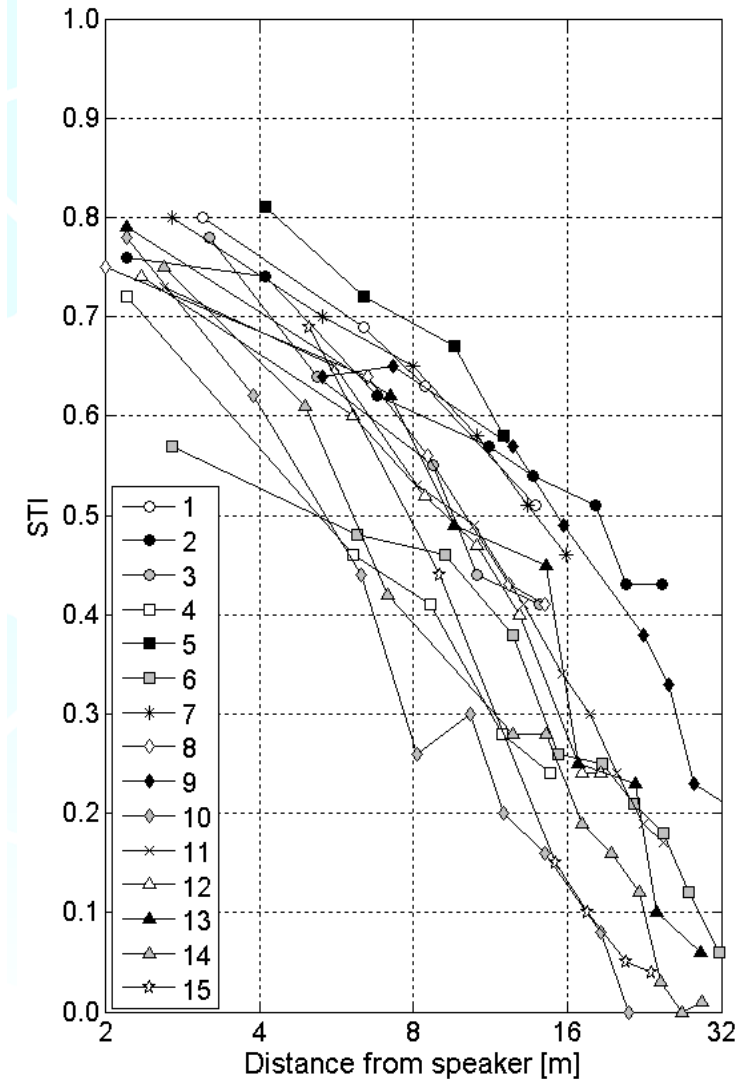
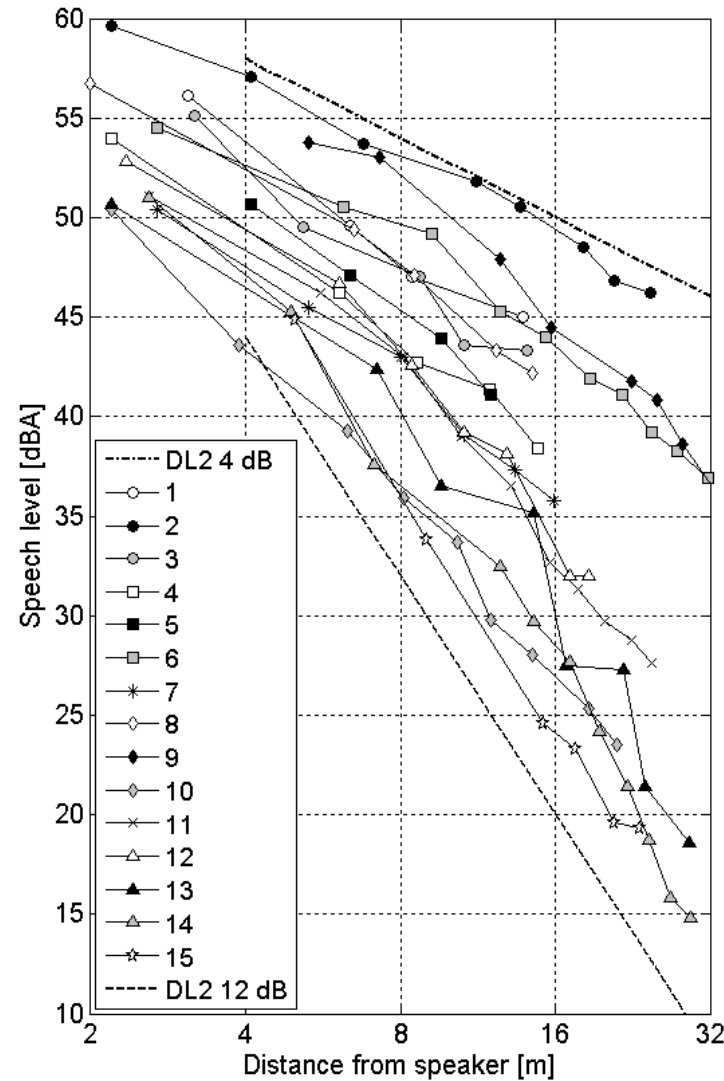
- A-weighted level of speech at 4 metres
 - Interpolated
- Reduction of A-weighted SPL of speech per distance doubling
 - Fitted



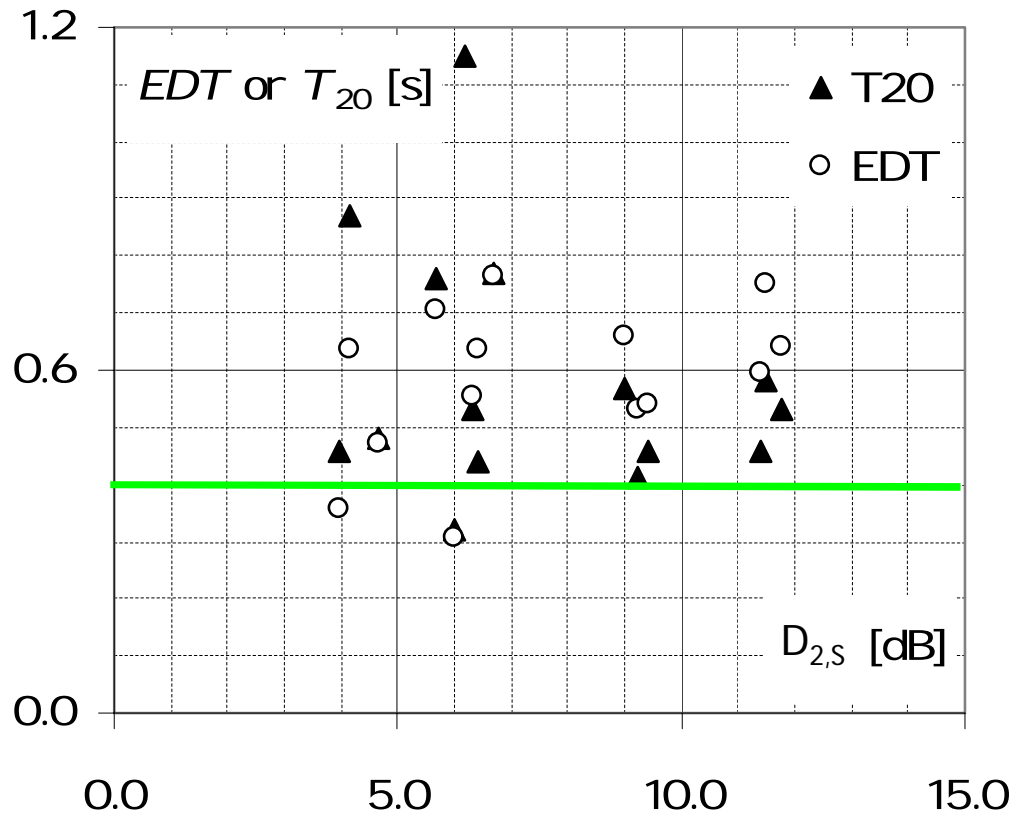
ISO 3382-3 data

- 16 offices with varying
 - Absorption
 - Screen height
 - Room size
 - Background noise
- Huge potential for improving the acoustic privacy by design

Virjonen et al. 2009 Acta Acust united Ac



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

ISO 3382-3 lacks suggestions for recommended values

Virjonen et al. 2009 Acta Acust united Ac

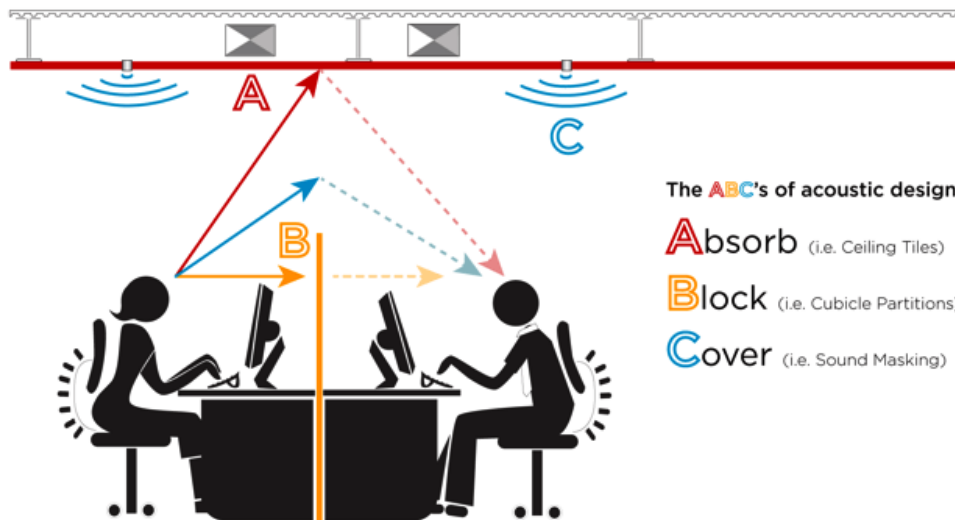
Class	Acoustic classification	r_D [m]	DL_2 [dB]
A	Excellent	5 or less	11 or more
B	Good	5 to 8	8 to 11
C	Fair	8 to 11	5 to 8
D	Poor	11-15	3-5

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



The ABC's of acoustic design

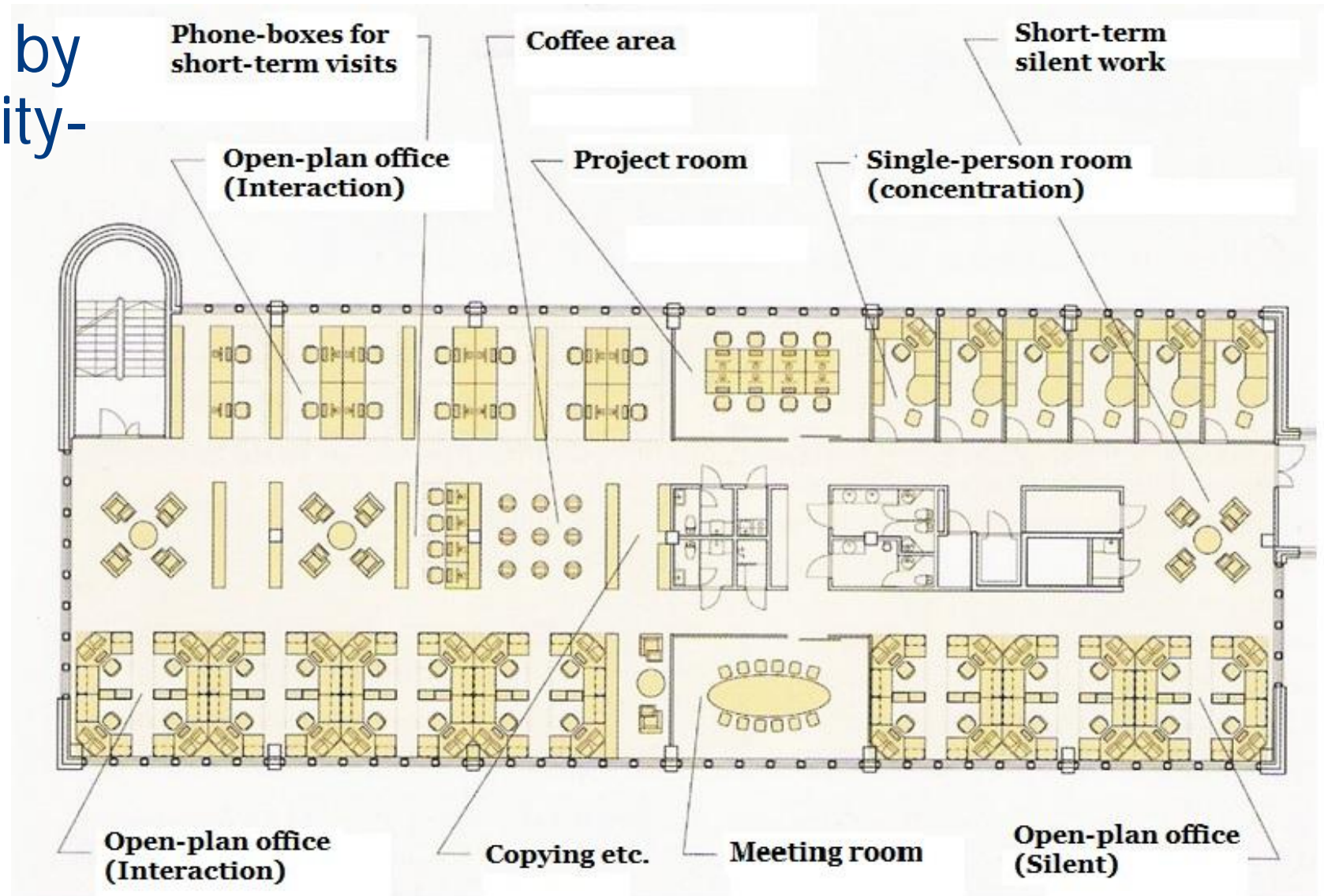
Absorb (i.e. Ceiling Tiles)

Block (i.e. Cubicle Partitions)

Cover (i.e. Sound Masking)

Figure: Cambridge Sound Management

Noise control by layout – Activity-based offices



Furniture ensembles

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



www.3dmodels.com



Furniture ensembles

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

Hongisto et al. 2015
Accepted to Acta Acust united Ac

$$DL_W = L_{W,1} - L_{W,2}$$

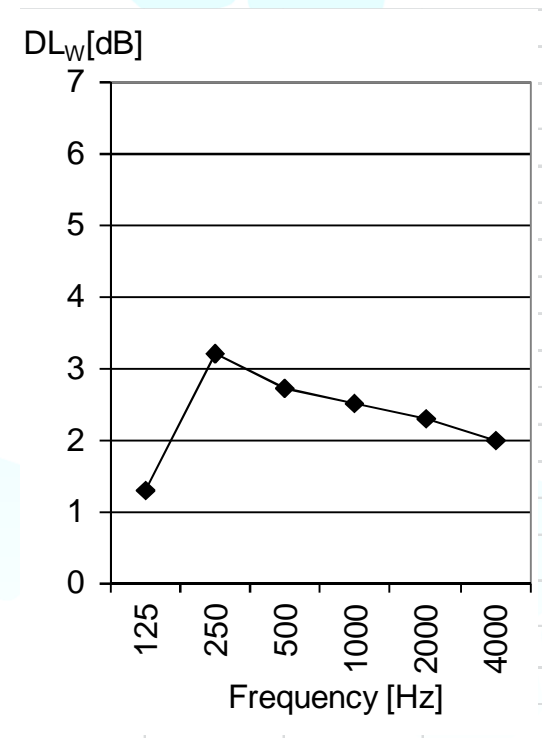
$$D_S = L_{W,S,A,1} - L_{W,S,A,2}$$



L_{W1}



L_{W2}



$D_S = 2.6$ dB

Furniture ensembles

Hongisto et al. 2015
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L_{W1}

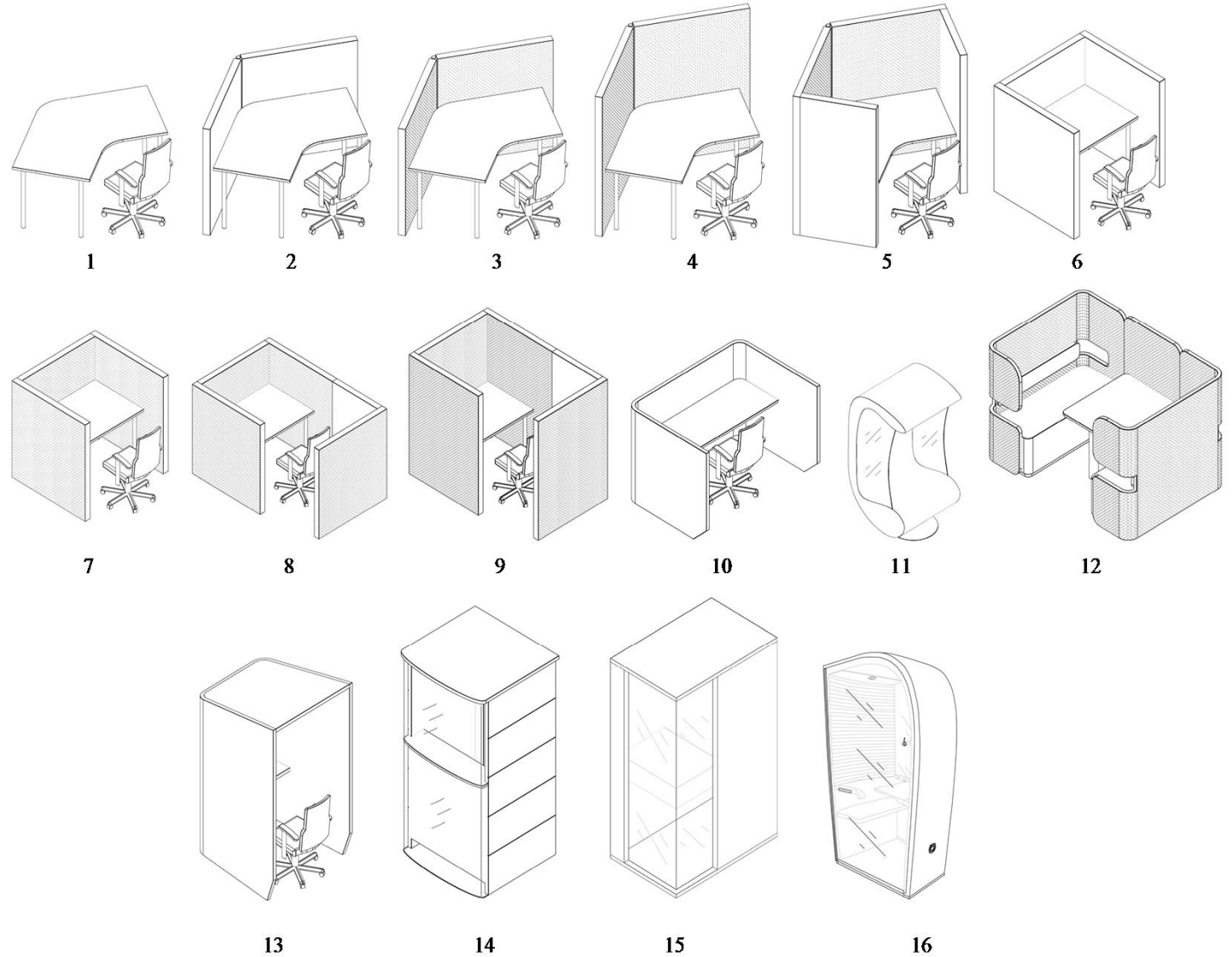


L_{W2}

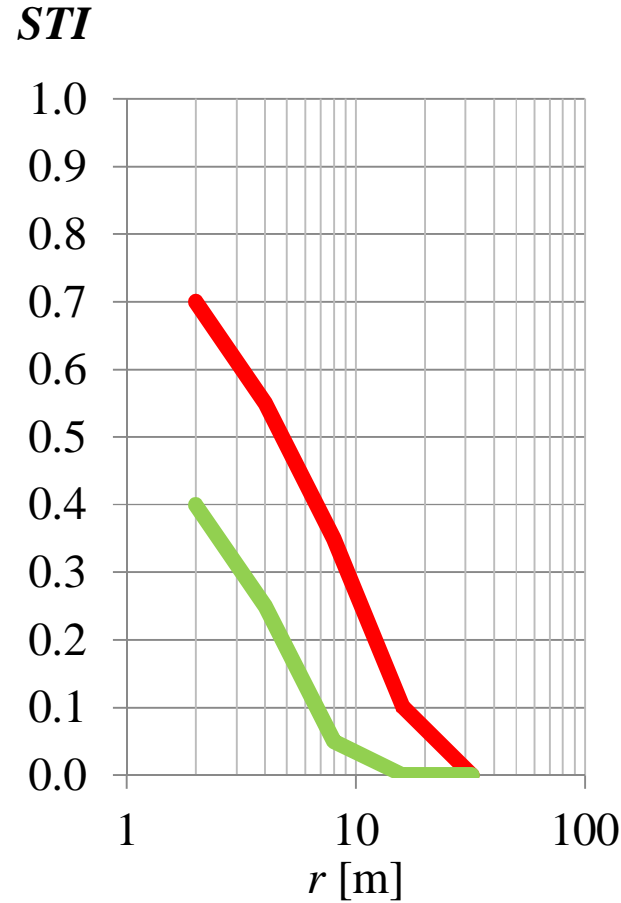
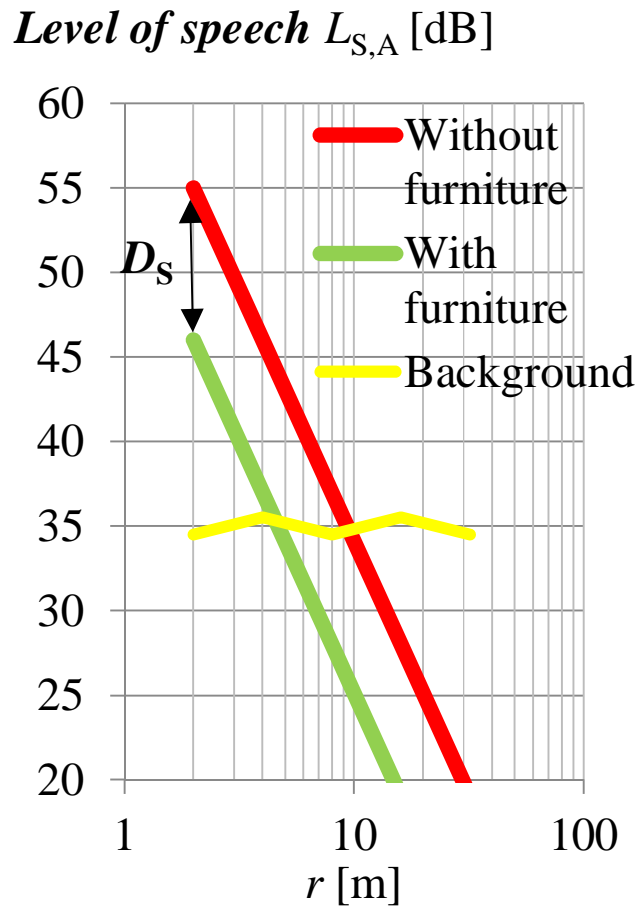
Furniture ensembles

Hongisto et al. 2015
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Specimen	D_s [dB]
1	0.0
2	0.2
3	0.6
4	1.0
5	1.5
6	0.6
7	1.8
8	2.6
9	4.0
10	0.8
11	3.9
12	1.9
13	2.8
14	18.5
15	22.4
16	19.8



Furniture ensembles – in the eyes of ISO 3382-3



- Example: $D_S=6$ dB

	r_D [m]	D_{2S} [dB]	L_{pA4m} [dB]
Without furniture	5	9	44
With furniture	0	9	35
CHANGE	-5	0	-9

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

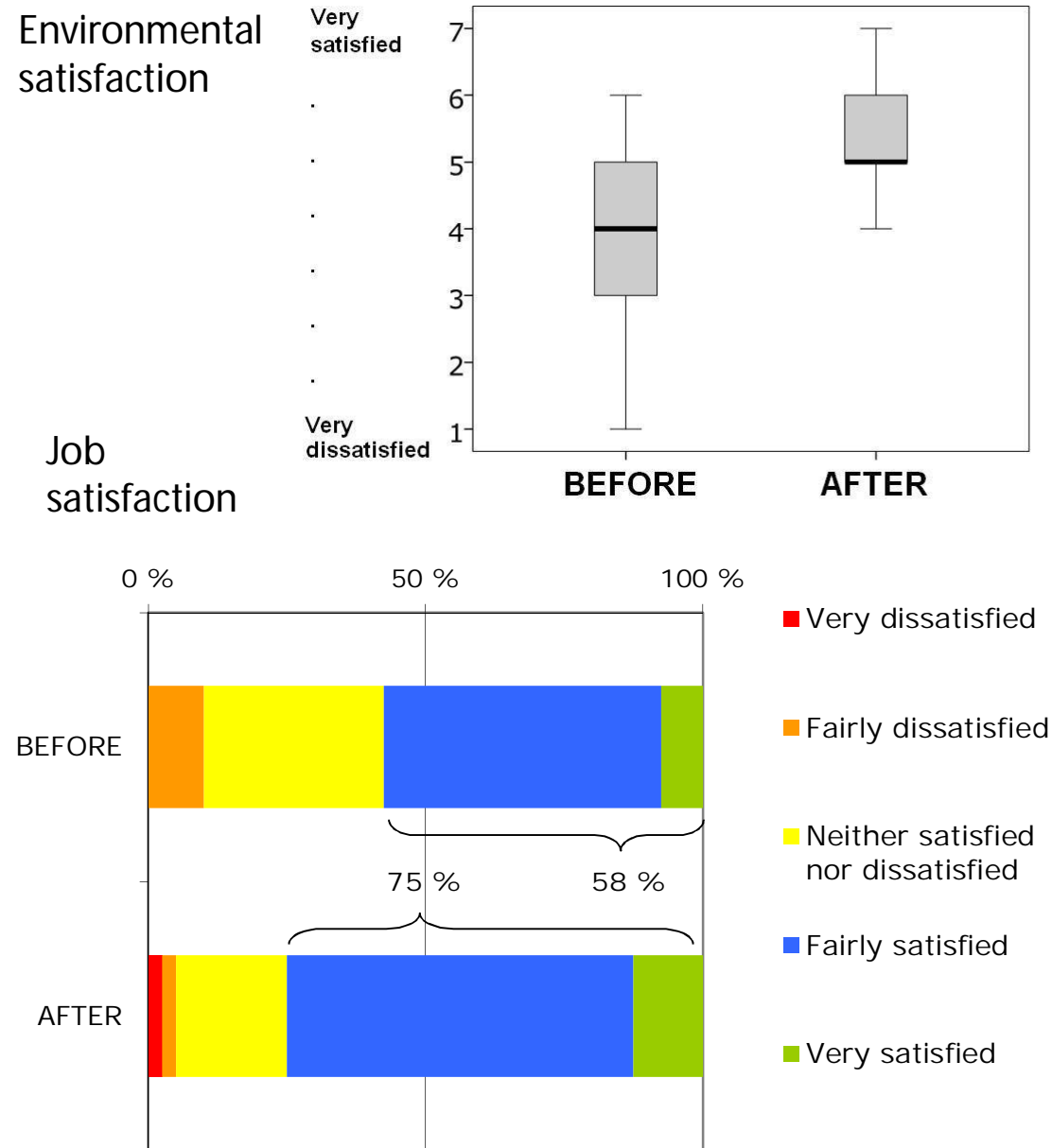
Psychological factors

- 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*



ABCDEFGG of Acoustic Design

- A**bsorb Maximize absorption in ceiling, walls and screens
- B**lock Use high screens where privacy is needed
- C**over Use artificial speech masking
- D**istance Avoid desk-to-desk distances less than 2.5 m
- E**tiquette Agreement about the use of the space and behaviour in the space
- F**loor Soft floor coverings
- G**roup Group the teams for efficient communication
- H**olism Remember the entirety: $1+1+1=10$
- I**solation Sufficient sound insulation to achieve privacy in pods, rooms, booths
- J** ?