Danish Sound Cluster seminar - *Acoustics in Open Plan Offices* - Copenhagen, 23 March 2023

Acoustical parameters for open-plan offices according to ISO 3382-3 and how to make sense of them

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Abstract

- The international standard ISO 3382-3:2022 (2nd revised edition) defines a number of measurable room acoustic parameters for the objective evaluation of the acoustics of open plan offices.
- The main challenge is, that the acoustics cannot be handled as a simple noise control problem, and the reverberation time is not particularly useful.
- In the talk, the relevance of the various ISO parameters will be discussed and room acoustic parameter studies are used to through light on the combined effect of background noise, screens and sound absorbing surfaces.

Outline

- Results of early projects
- Acoustic parameters
- Noise from human activities
- Disturbance by speech noise
- Simulations with background noise from speech
- Comparison with suggested target values
- Summary concerning the ISO parameters

Open-plan office, investigations 2004

Real office

Figure 2: Office layout in the right wing.

Computer model

Figure 4: The computer-simulated open-plan office (version with no screens).

Early research projects (DTU)

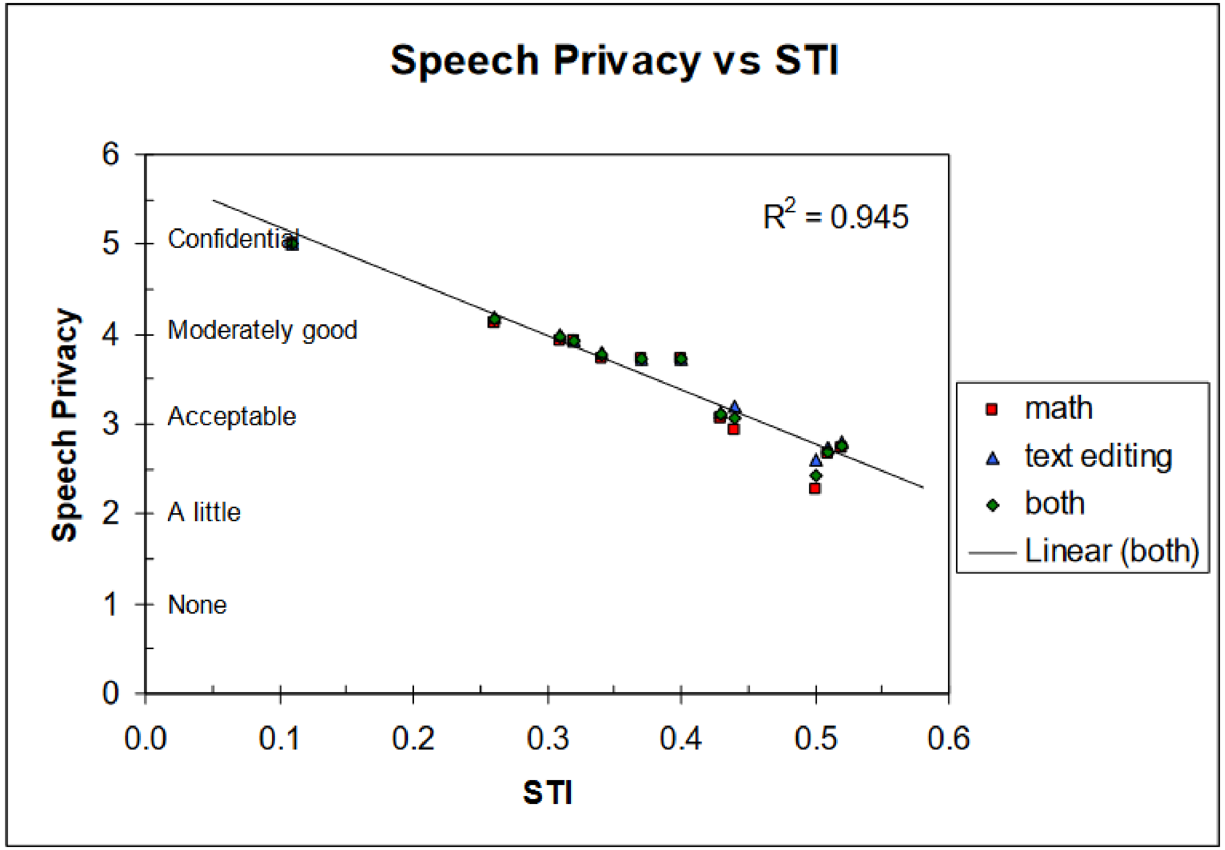


Figure 6: Subjective rating of speech privacy versus Speech Transmission Index (STI).

Claudio Pop (2004)

MSc project

- Listening tests (12 conditions)
- Binaural sound presentation
- Four room versions (with/without screens, more/less absorption)
- Three distances to source (speech)
- 15 test subjects
- Acceptable speech privacy: STI < 0.45 and DL_2 > 4 dB

Popp & Rindel 2007

Findings in early research projects (DTU)

No.	Acoustical environment	Description	Average sound level dB(A)	Operative temperature ºC
1	Cellular office	No recording played - the acoustic environment created by background noise and by noise caused by the work of the exposed subjects	48	23 28
2	Open-plan office I	Recording from the model based on the parameters obtained by the in-situ measurements – replica of the real office (Pop and Rindel, 2005)	52	23
3	Open-plan office II	Recording from the model (I) with a longer reverberation time. Very reflective ceiling	54	23
4	Open-plan office III	Recording from the model (I) with a shorter reverberation time by adding sound baffles below the ceiling and sound screens between desks	49	23 28

Ivana Balazova (2007)

PhD project

- Work in simulated office environment
- Lab. with 7+1 surround sound
- Four acoustical conditions
  - Cellular office
  - Open plan office, real and with more/less sound absorption
- 15 test subjects

Balazova et al. 2007

Findings in early research projects (DTU)

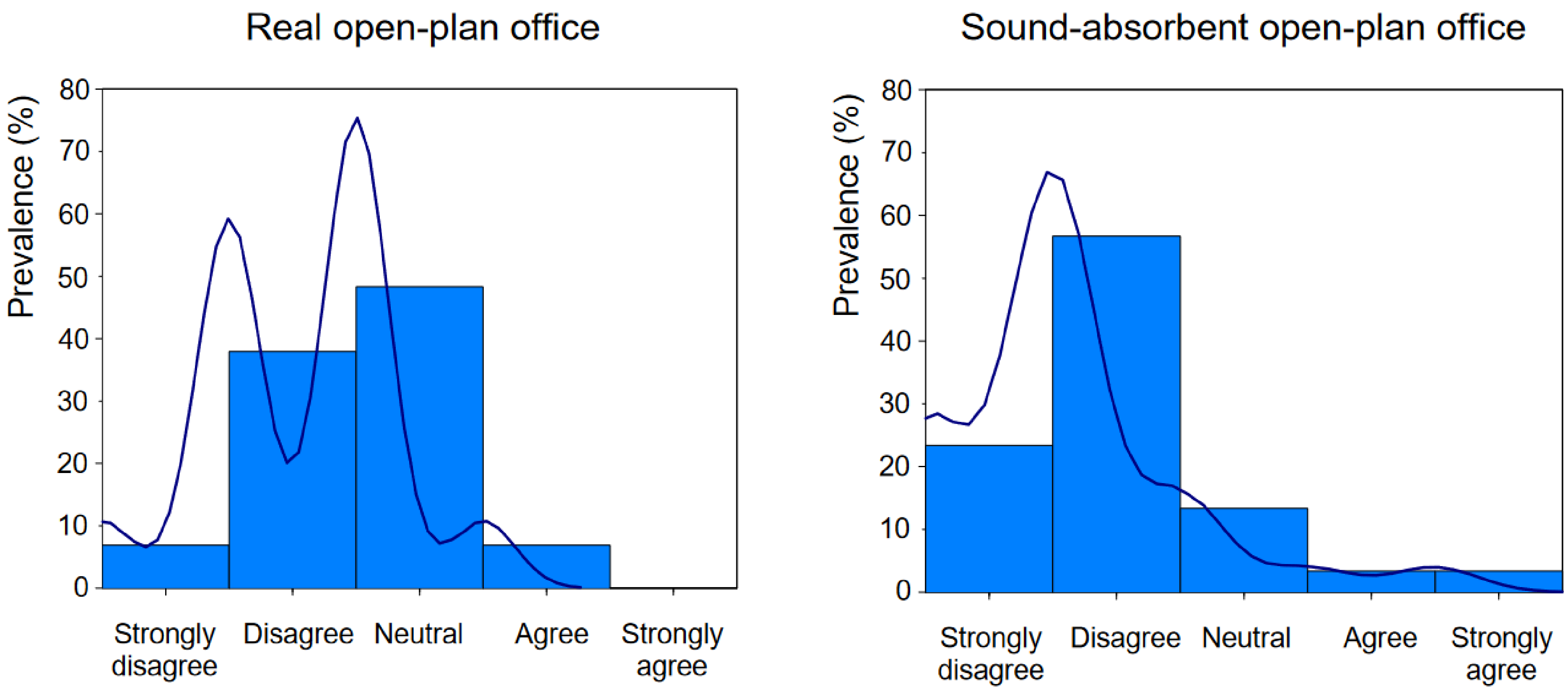


Figure 5. Distribution of responses to the statement: "If I always was to work in the conditions similar to the ones I am experiencing I could work uninterrupted for long periods."

Balazova et al. 2007

Findings in early research projects (DTU)

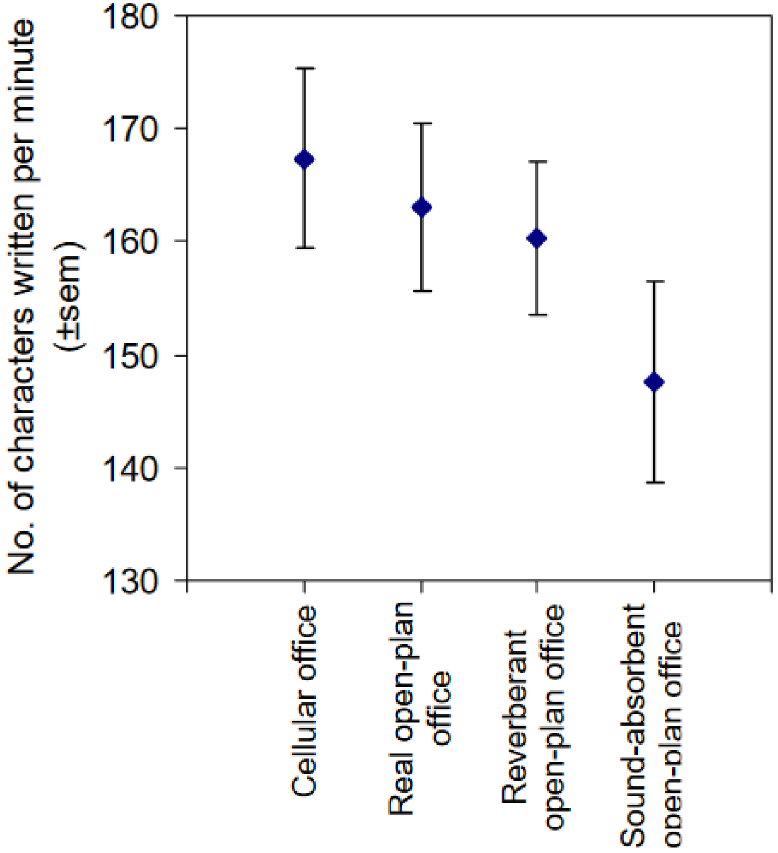


Figure 6. Speed of text typing

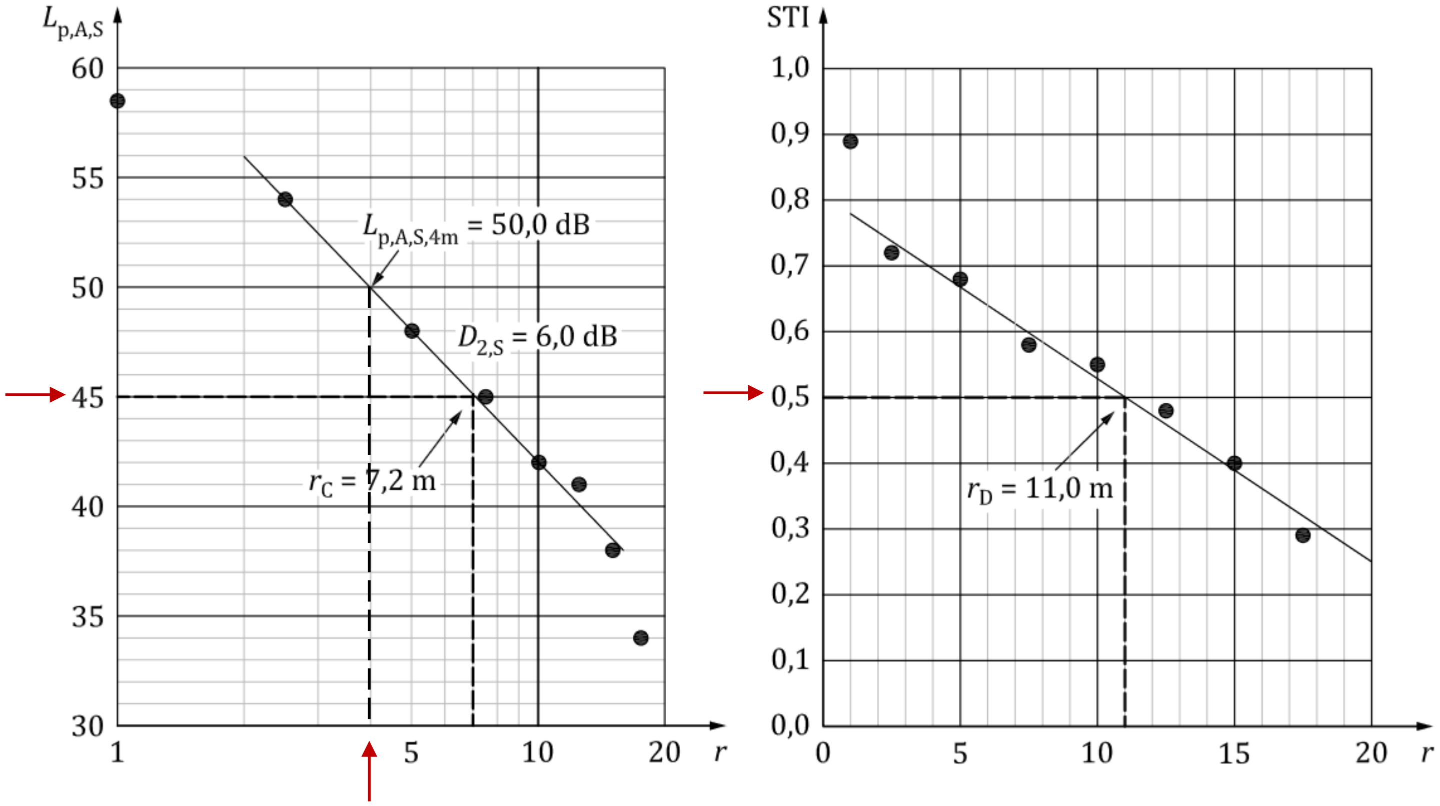
Text writing efficiency

- Best in cellular office
- Worst in open-plan office with additional absorption and screens
- More sound absorption may have an unexpectedly negative impact on performance, perception and acceptability of noise

Balazova et al. 2007

ISO 3382-3 parameters

- Spatial decay rate of speech
- SPL of speech at 4 m
- Comfort distance



a) Determination of $D_{2,S}$, $L_{p,A,S,4m}$, and r_C.
Linear fitting includes the positions within 2 m to 16 m from the OSS

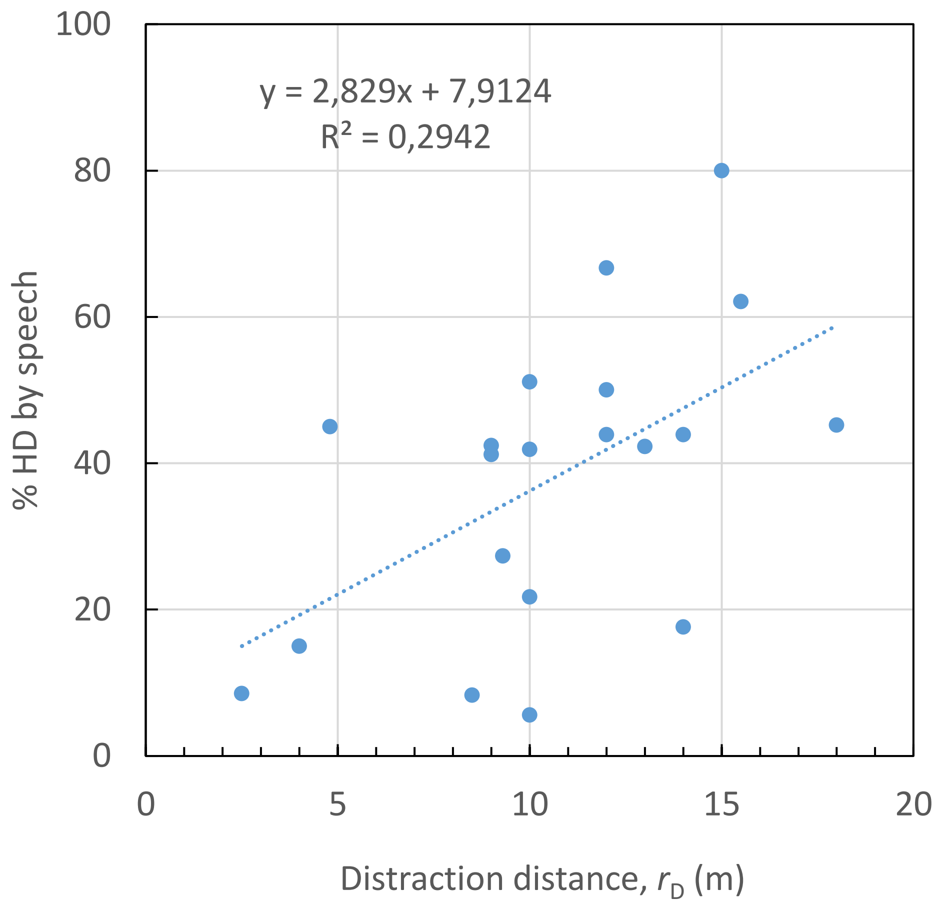
b) Determination of r_D.
Linear fitting includes all positions located beyond 1 m from the OSS

Distraction distance

Noise from human activities

- ISO 3382-3:2012
- Section 6.3 Distraction and privacy distances
- *NOTE – In addition, STI can be determined by using any other measured or simulated background noise, e.g. from a sound-masking system or from human activities.*
- Thus, distraction distance r_D can be determined with assumed noise from human activities
- This information was removed in the second edition 2022.

Disturbance by speech noise



% Highly Distracted (HD) by speech – related to measured data in 20 offices (Haapakangas et al. 2017)

	R^2 speech
r_D (m)	0.294
r_C (m)	0.160
$D_{2,S}$ (dB)	0.007
$L_{p,A,S,4m}$ (dB)	0.327
$L_{p,A,B}$ (dB)	0.266

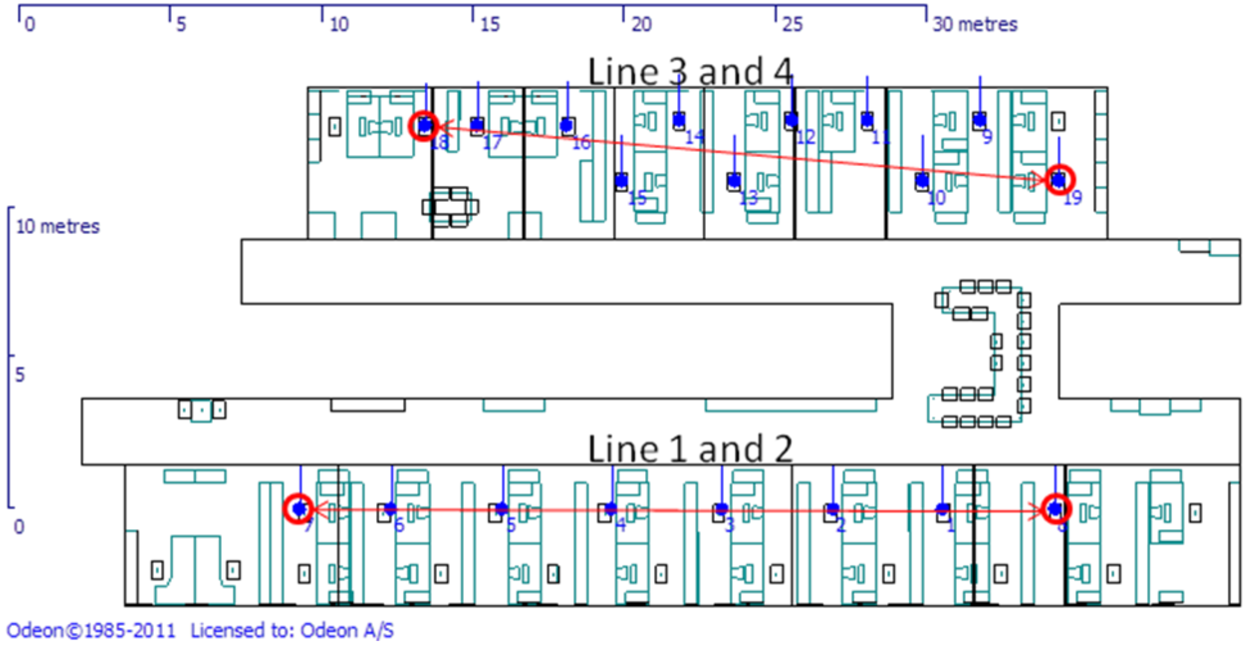
← Not important ($D_{2,S}$)

← Most important ($L_{p,A,S,4m}$)

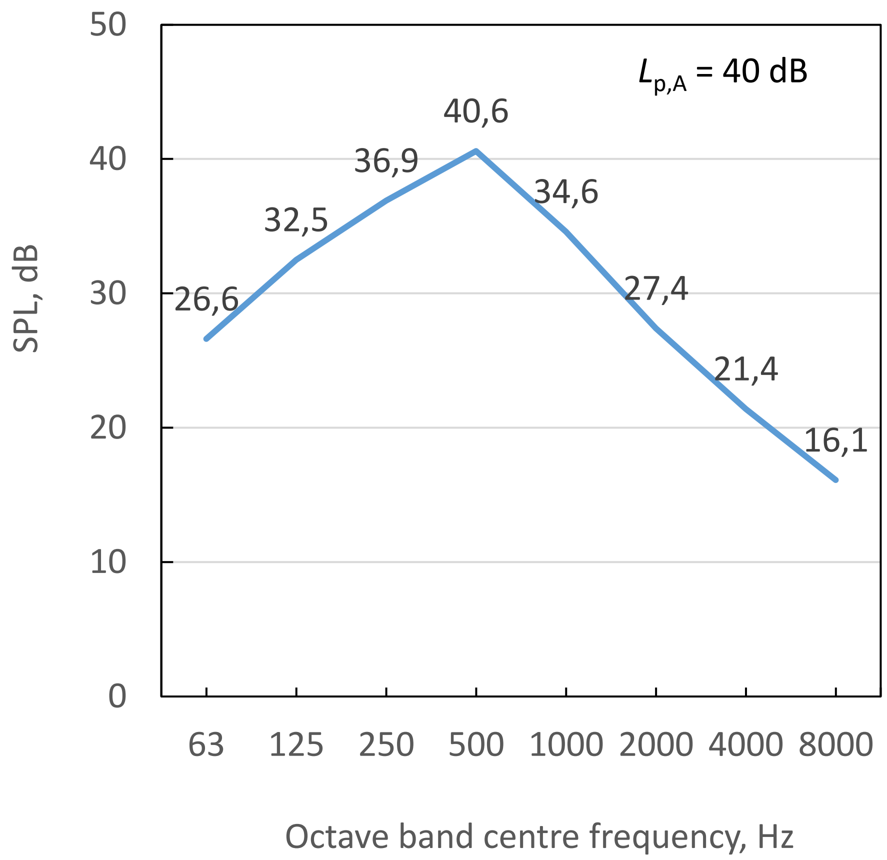
Simulations

- 4 source positions,
- Series 1 and 2 with 7 mic. positions
- Series 3 and 4 with 10 mic. Positions

Variation of RT,
screen height,
background noise

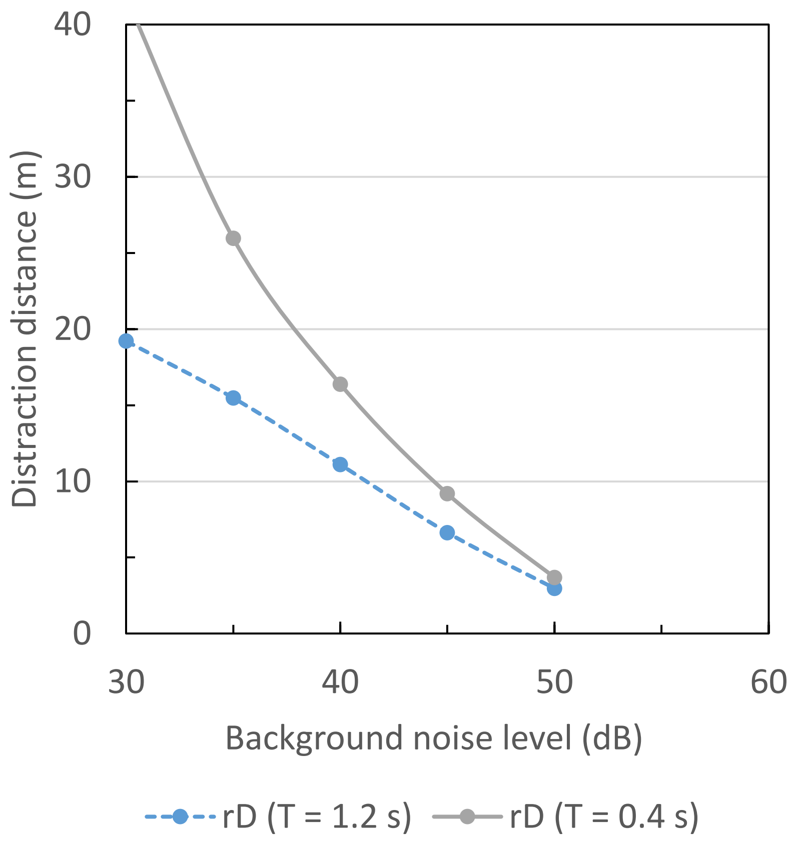


Spectrum of speech noise



- Far-field spectrum from ISO 3382-3
- Applied as ambient noise for simulations of noise from human activities
- Simulations in 5 dB steps from $L_{p,A}$ = 30 dB to 60 dB

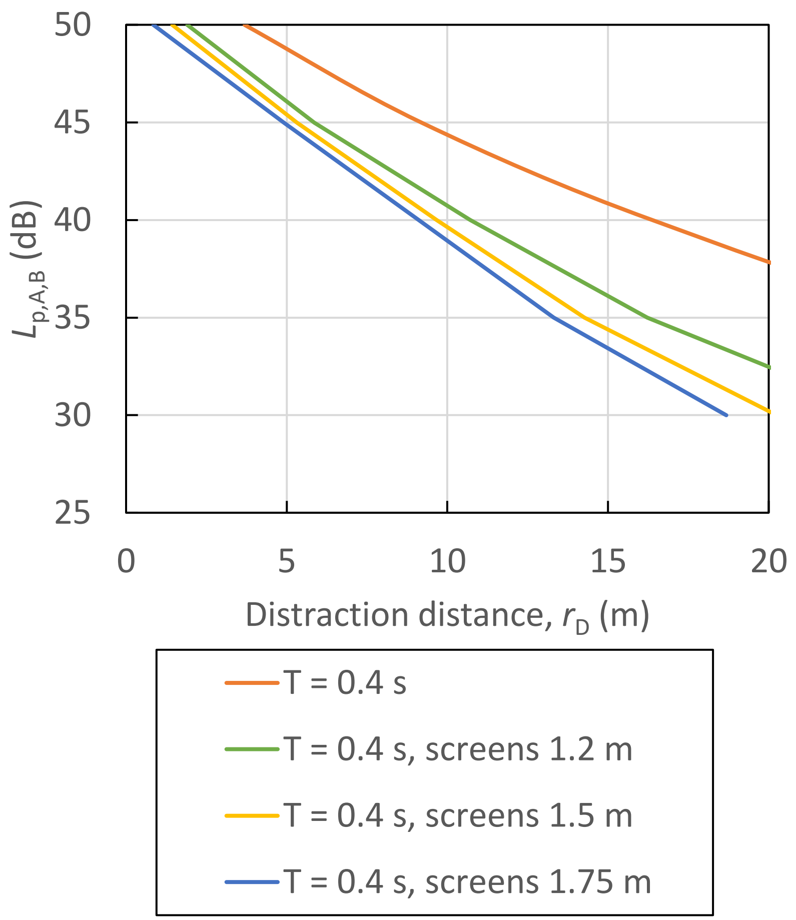
Distraction distance and reverberation time



- Simulations in open-plan offices
- Longer RT and higher background noise means that distraction distance r_D decreases
- r_D disappears (negative distance) if background noise exceeds 50 dB

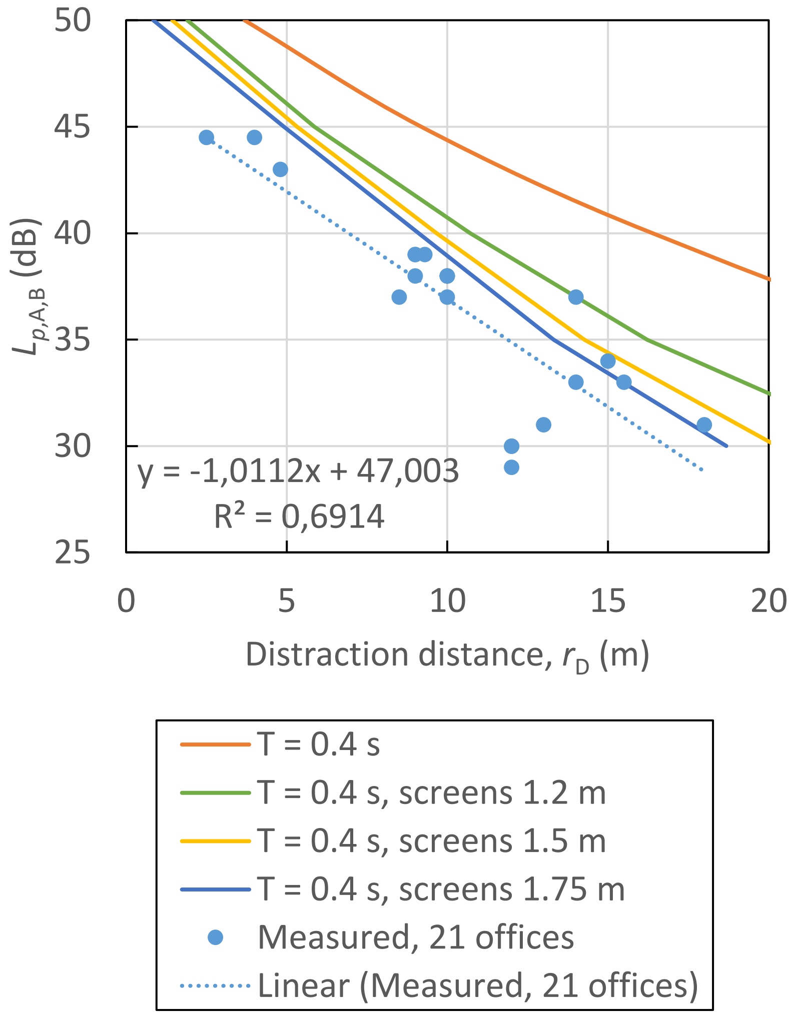
ROOM ACOUSTICS SOFTWARE

Distraction distance and screen height



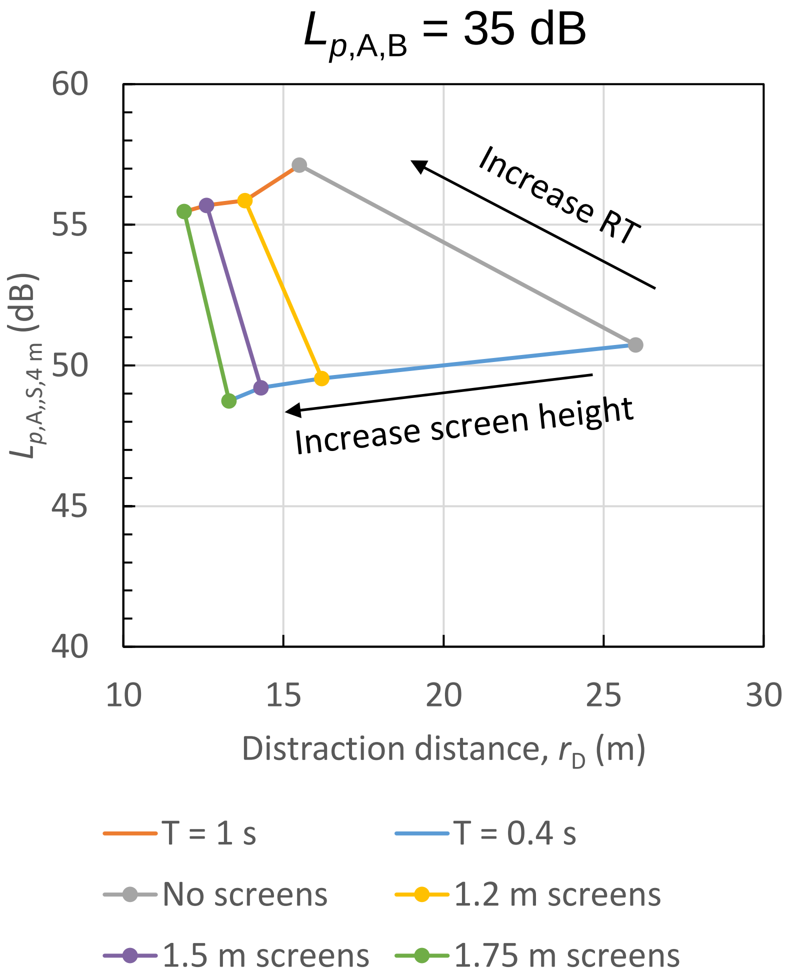
- Simulations with various screen heights and background noise (speech)
- Increasing screen height above 1,2 m has minor importance
- The approximate slope is: -1 dB/m, i.e.:
- Increasing background noise by *x* dB => decrease of distraction distance by *x* m

Distraction distance and background noise



- Measured data from 21 offices (Haapakangas et al. 2017)
- Quite strong correlation between r_D and background noise, and same slope as found in simulations
- Information about background noise should always follow r_D
- The question is, if this makes r_D redundant?

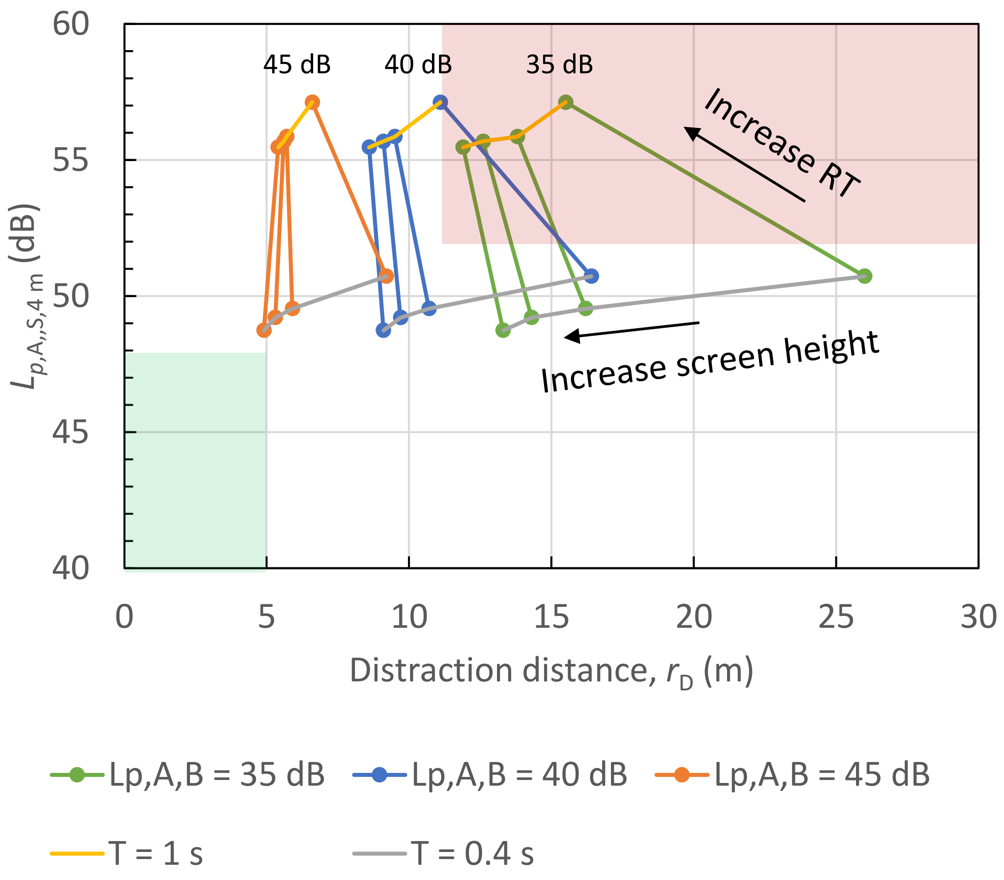
Distraction distance and SPL at 4 m



- Screen height has only minor influence on SPL at 4 m
- SPL at 4 m will be too high (> 52 dB) if RT is increased from 0,4 s to 1,0 s

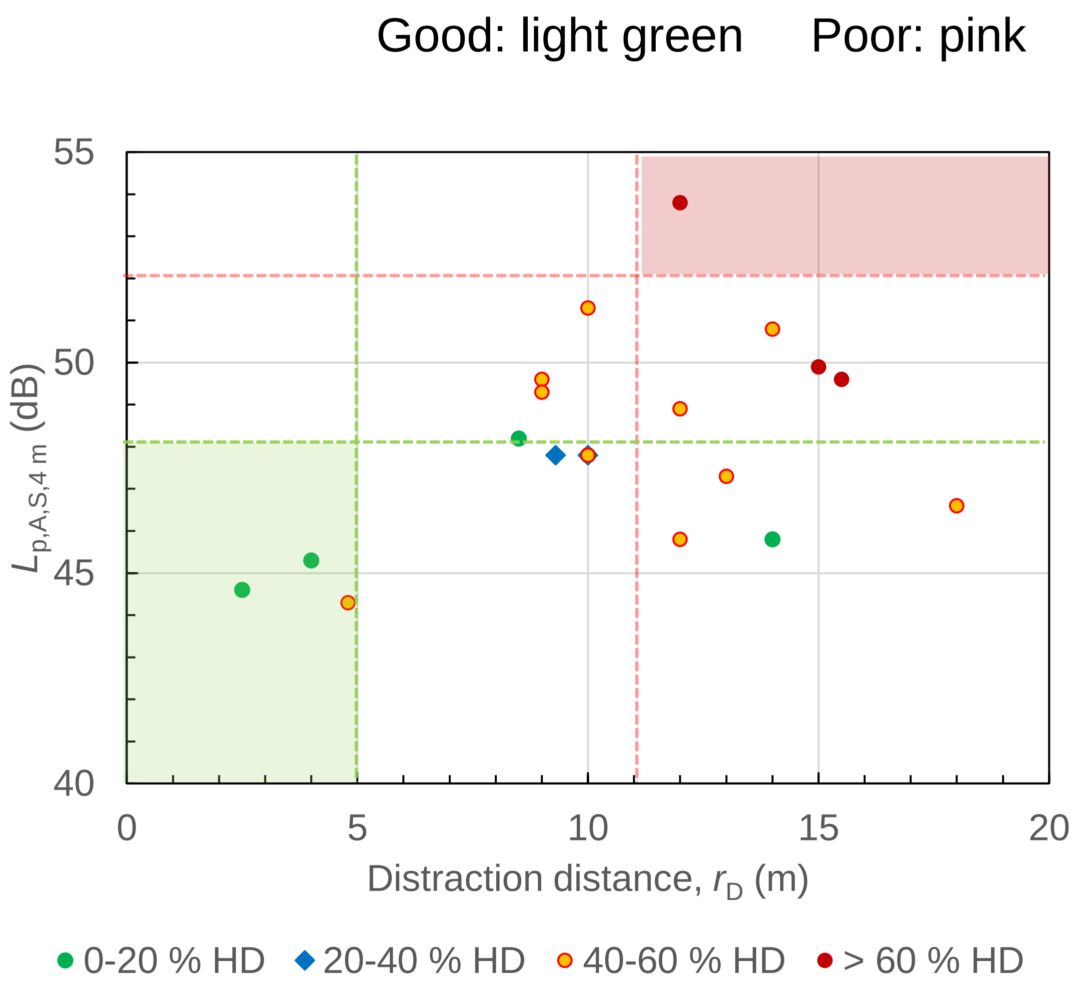
Target values in Annex C of ISO 3382-3

Good: light green Poor: pink



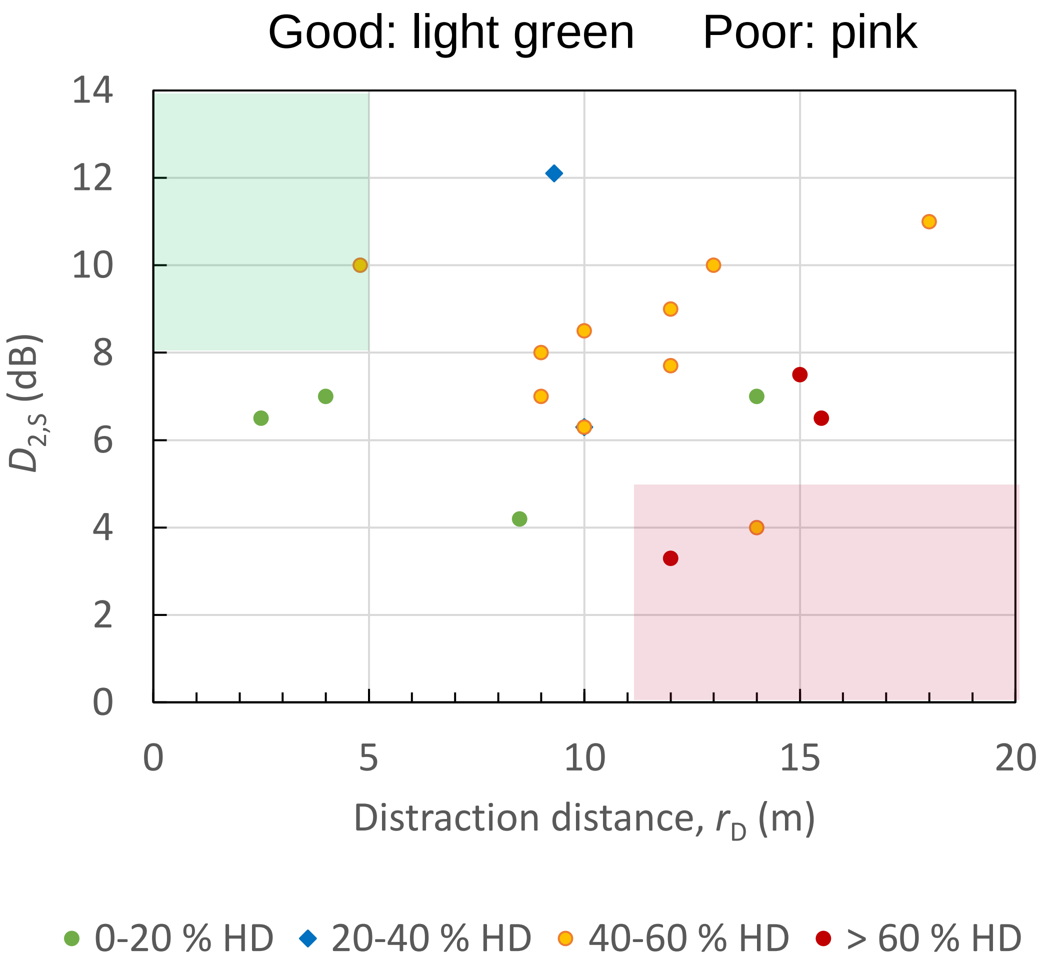
Parameter	Poor acoustics	Good acoustics
r_D	> 11 m	< 5 m
r_C	> 11 m	< 5 m
$D_{2,S}$	< 5 dB	> 8 dB
$L_{p,A,S,4m}$	> 52 dB	< 48 dB
$L_{p,A,B}$	< 35 dB or > 48 dB	40 dB to 45 dB

ISO target values - % HD by speech



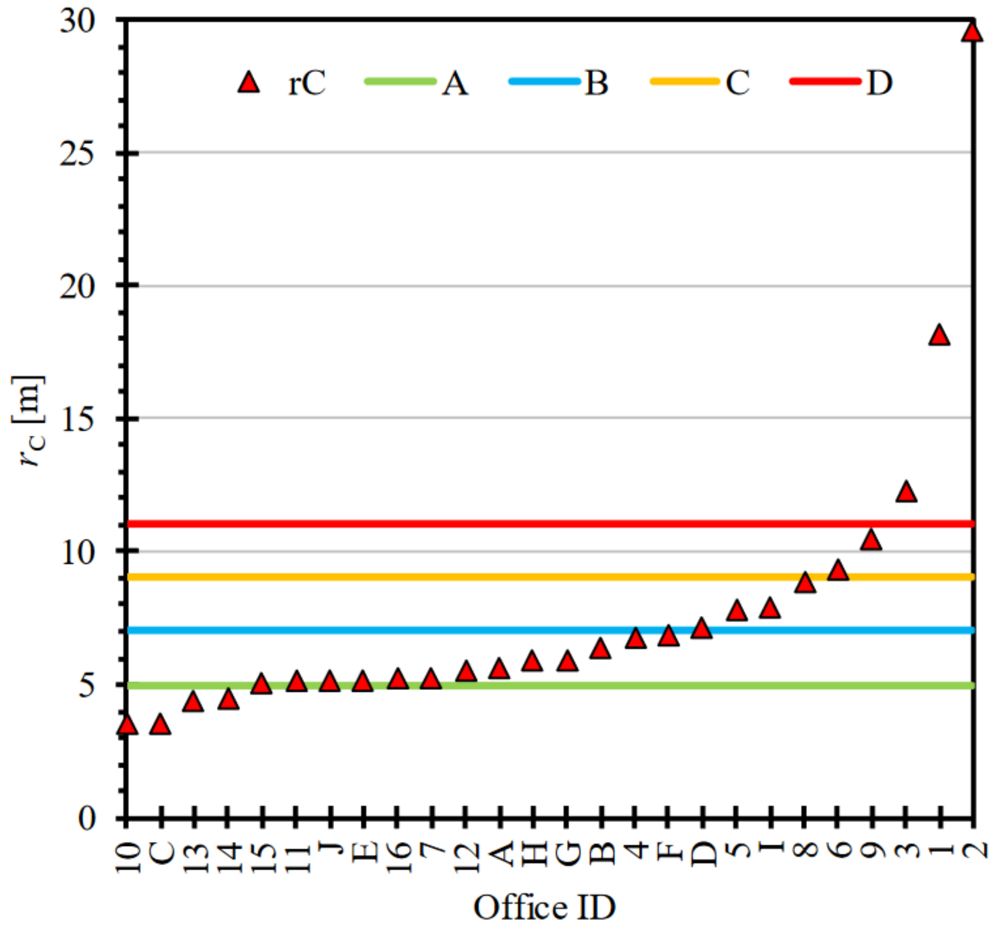
- % Highly Distracted (HD) by speech – related to measured data in 20 offices (Haapakangas et al. 2017)
- Experimental results compared with target values in Annex C of ISO 3382-3
- Target value for $L_{p,A,S,4\ m}$ < 48 dB seems reasonable

ISO target values - % HD by speech



- % Highly Distracted (HD) by speech – related to measured data in 20 offices (Haapakangas et al. 2017)
- Target values in Annex C of ISO 3382-3
- Target values for $D_{2,S}$ make no sense

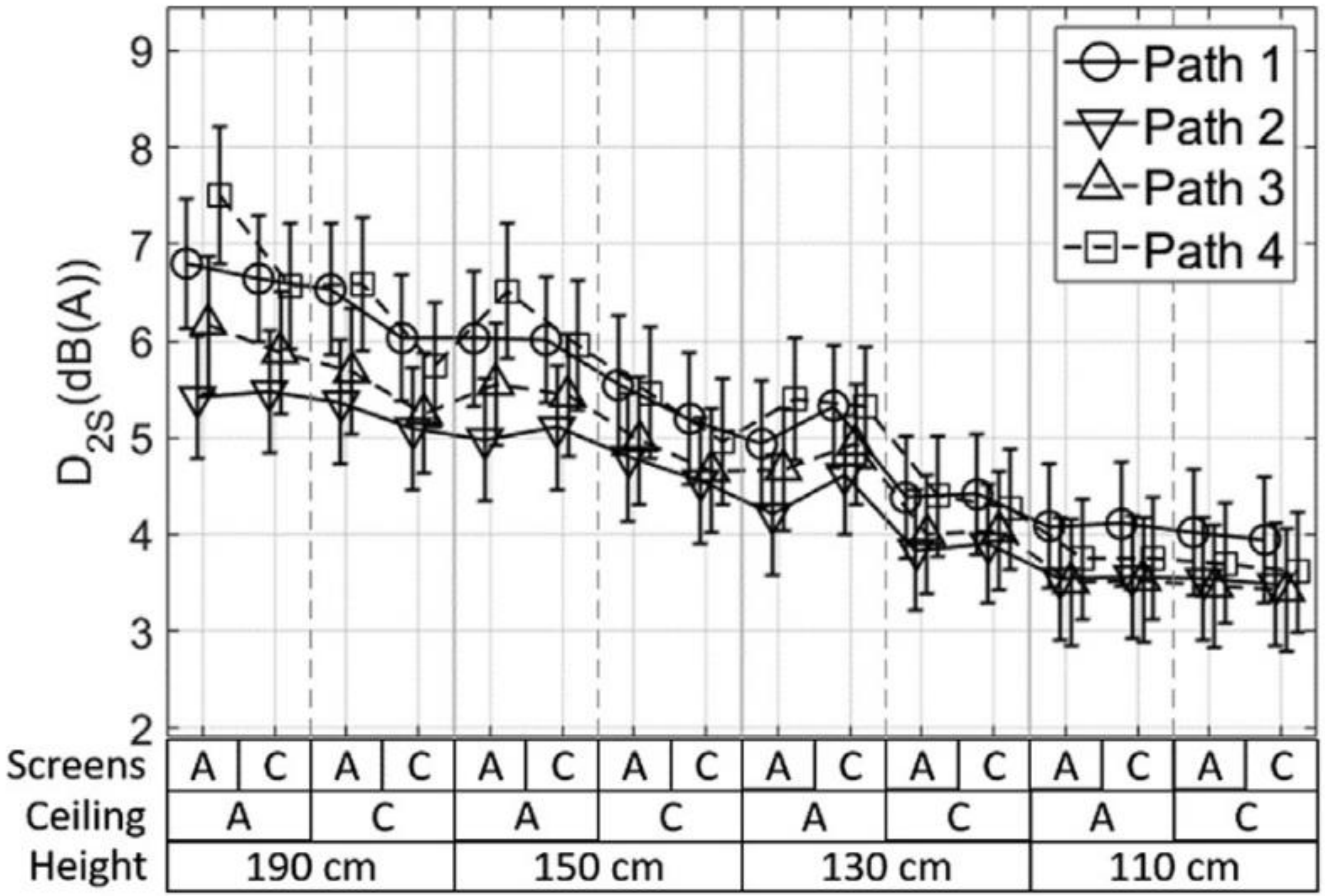
The comfort distance



- Results from measurements in 26 offices
- Suggested classes A through D
- Class A: $r_C < 5$ m
- Class B: $r_C < 7$ m
- Class C: $r_C < 9$ m
- Class D: $r_C < 11$ m

Hongisto & Keränen (2020)

Parameter study including measurement uncertainty



Simulations with

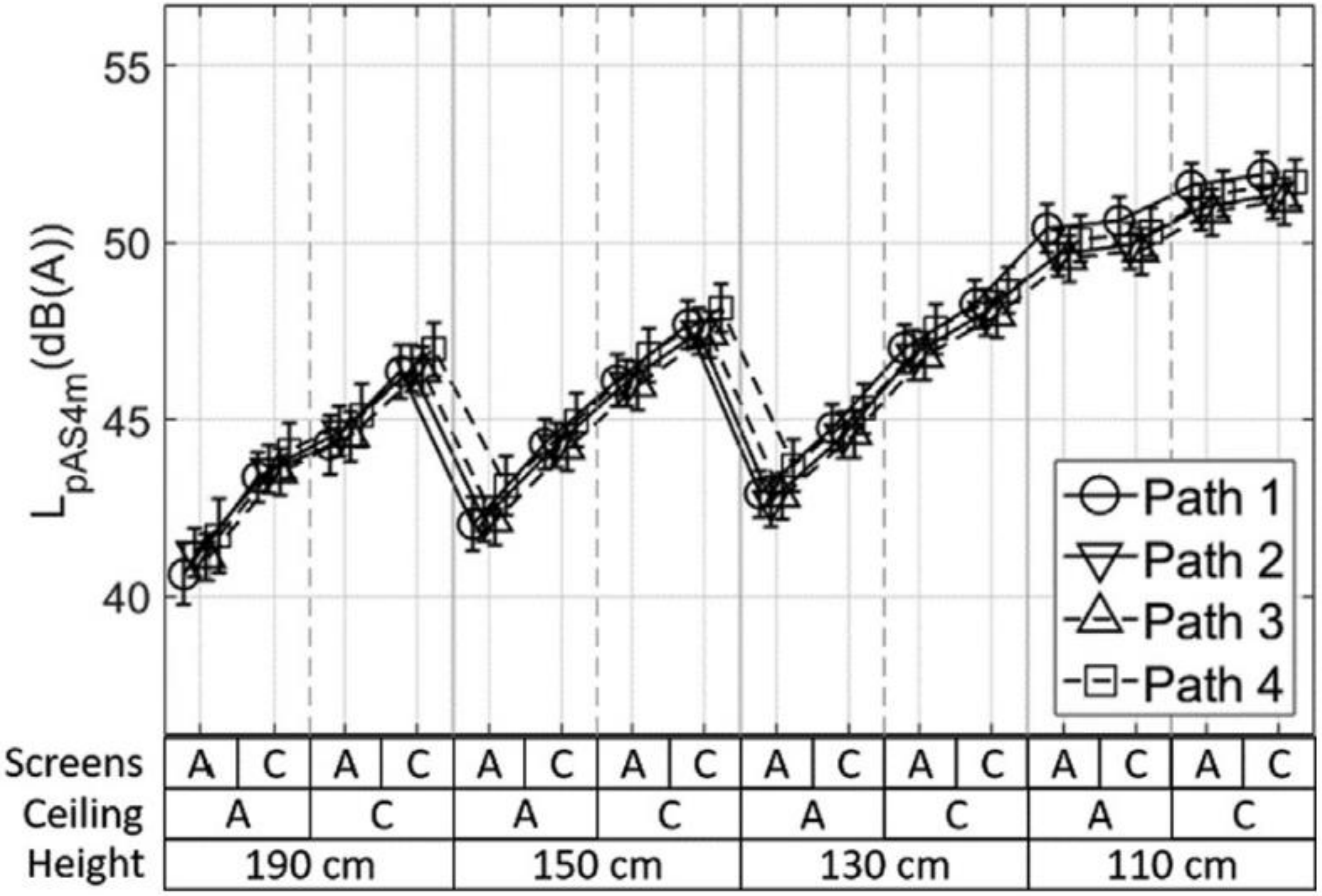
- four screen heights,
- ceiling absorbing or hard (A/C),
- screens absorbing or hard (A/C)

Spatial decay rate $D_{2,S}$ shows some dependency of screen height, but only minor dependency of sound absorption

NB: High uncertainty for this parameter

Lenne et al. (2021)

Parameter study including measurement uncertainty

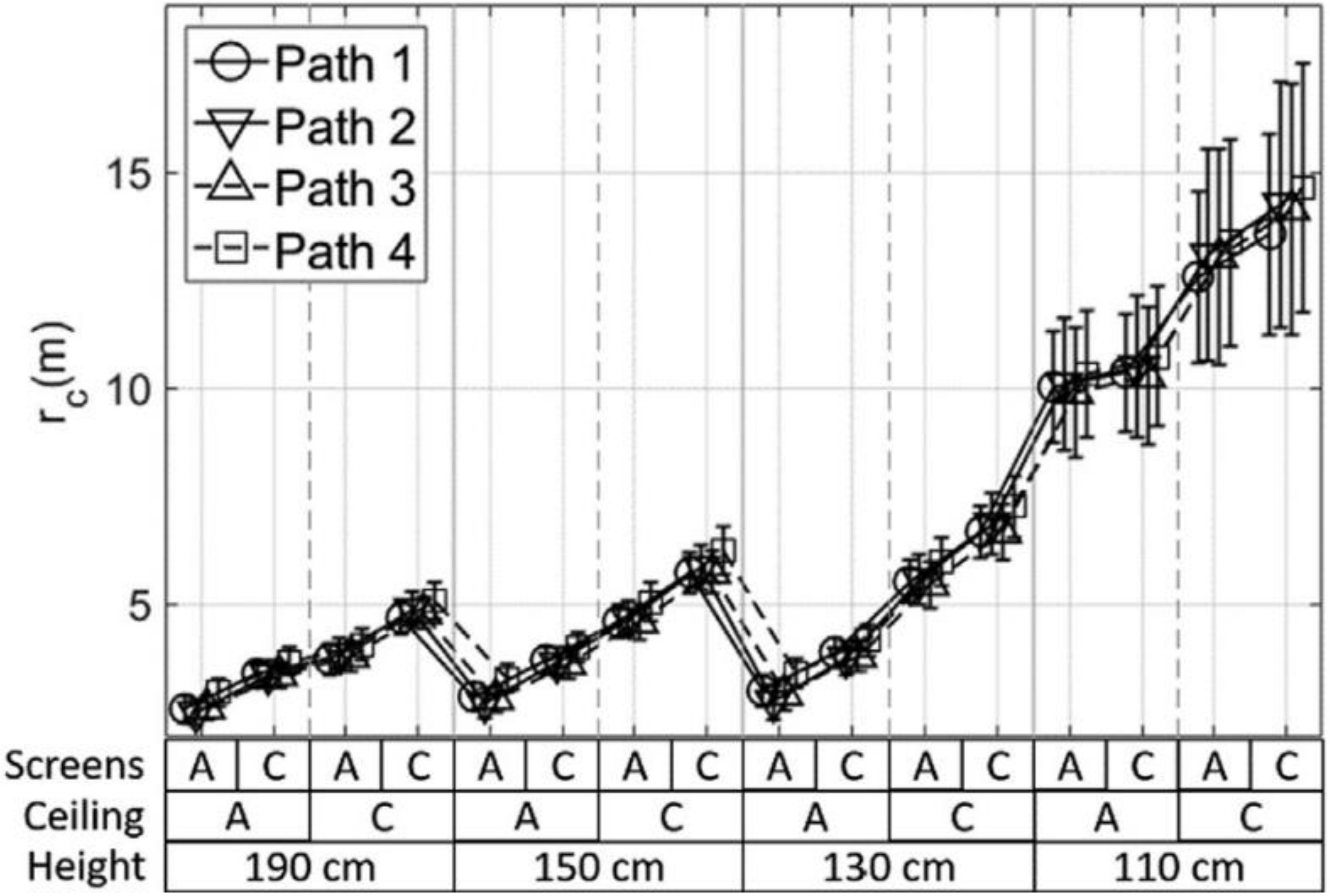


SPL at 4 m shows strong dependency of sound absorption, but only minor dependency of screen heights above 110 cm

The target value < 48 dB can be reached with screens higher than 110 cm

Lenne et al. (2021)

Parameter study including measurement uncertainty



The comfort distance r_C shows behaviour very similar to that for SPL at 4 m.

Strong dependency of sound absorption, but only minor dependency of screen heights above 110 cm

The target value < 5 m can be reached with screens higher than 110 cm and absorbing ceiling

Lenne et al. (2021)

Summary concerning the ISO parameters

- Spatial decay rate $D_{2,S}$ has no correlation with disturbance, and it has high measurement uncertainty. It and can be removed
- Background noise is clearly very important, for masking speech and for annoyance
- Distraction distance r_D varies with screen height, but it is also closely correlated with the background noise level, which makes r_D redundant
- The SPL at 4 m $L_{p,A,S,4m}$ is the parameter that correlates best with disturbance. It is controlled by screens and absorption
- Comfort distance r_C (introduced 2022) seems to correlate with $L_{p,A,S,4m}$. More experience is needed, but the relevance of this parameter is not obvious

References

- ISO 3382-3 (2022). Acoustics – Measurement of room acoustic parameters – Part 3: Open-plan offices. (2nd edition).
- C.B. Pop, J.H. Rindel (2005). Perceived Speech Privacy in Computer Simulated Open-plan Offices. Inter-noise 2005. Rio de Janeiro, Brazil, 7-10 August 2005.
- I: Balazova, G. Clausen, J.H. Rindel, T. Poulsen, D.P. Wyon (2007). Noise in open-plan office environments: a laboratory experiment on human perception, comfort and office work performance. Proceedings of SSTP – 6th International Conference on Indoor Climate of Buildings, High Tatras, Slovakia 2007.
- A. Haapakangas, V. Hongisto, M. Eerola, T. Kuusisto (2017). Distraction distance and perceived disturbance by noise - An analysis of 21 open-plan offices. J. Acoust. Soc. Am. 141, 127-136.
- V. Hongisto, J. Keränen (2020). Comfort distance – a single-number quantity describing spatial
- attenuation in open-plan offices. Forum Acusticum, Lyon, France, 7-11 December 2020.
- L. Lenne, P. Chevret, É. Parizet (2021). Measurement uncertainty and unicity of single number quantities describing the spatial decay of speech level in open-plan offices. Applied Acoustics 182 (2021) 108269.