Perception- and effect-related evaluation of open-plan office acoustic design

Dr. Andreas Liebl

Fraunhofer Institute for Building Physics

Department Acoustics, Stuttgart

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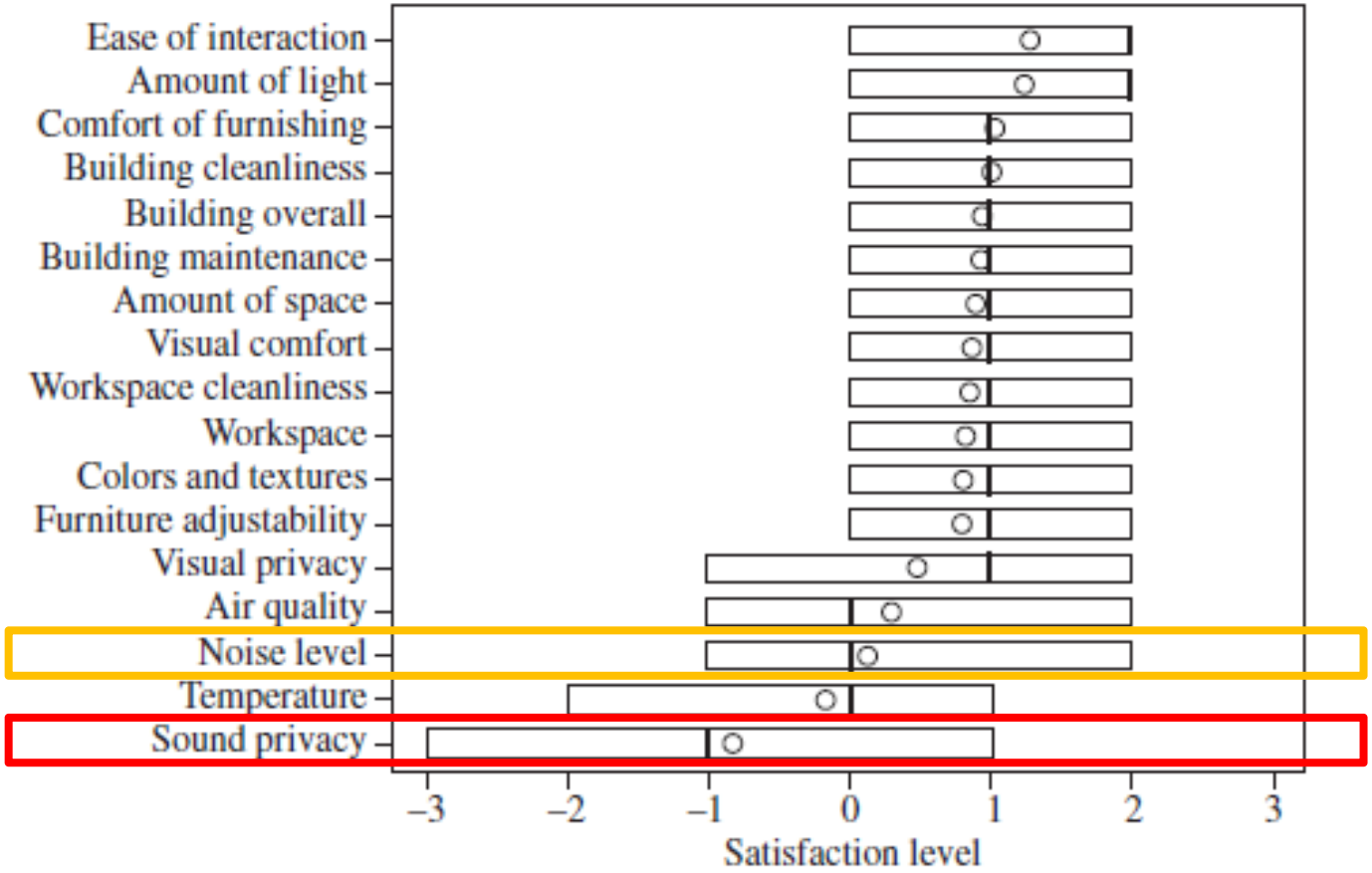
Status quo



Judgments of satisfaction with regard to different aspects of the working environment (Frontczak et al., 2012; n = 52.980)

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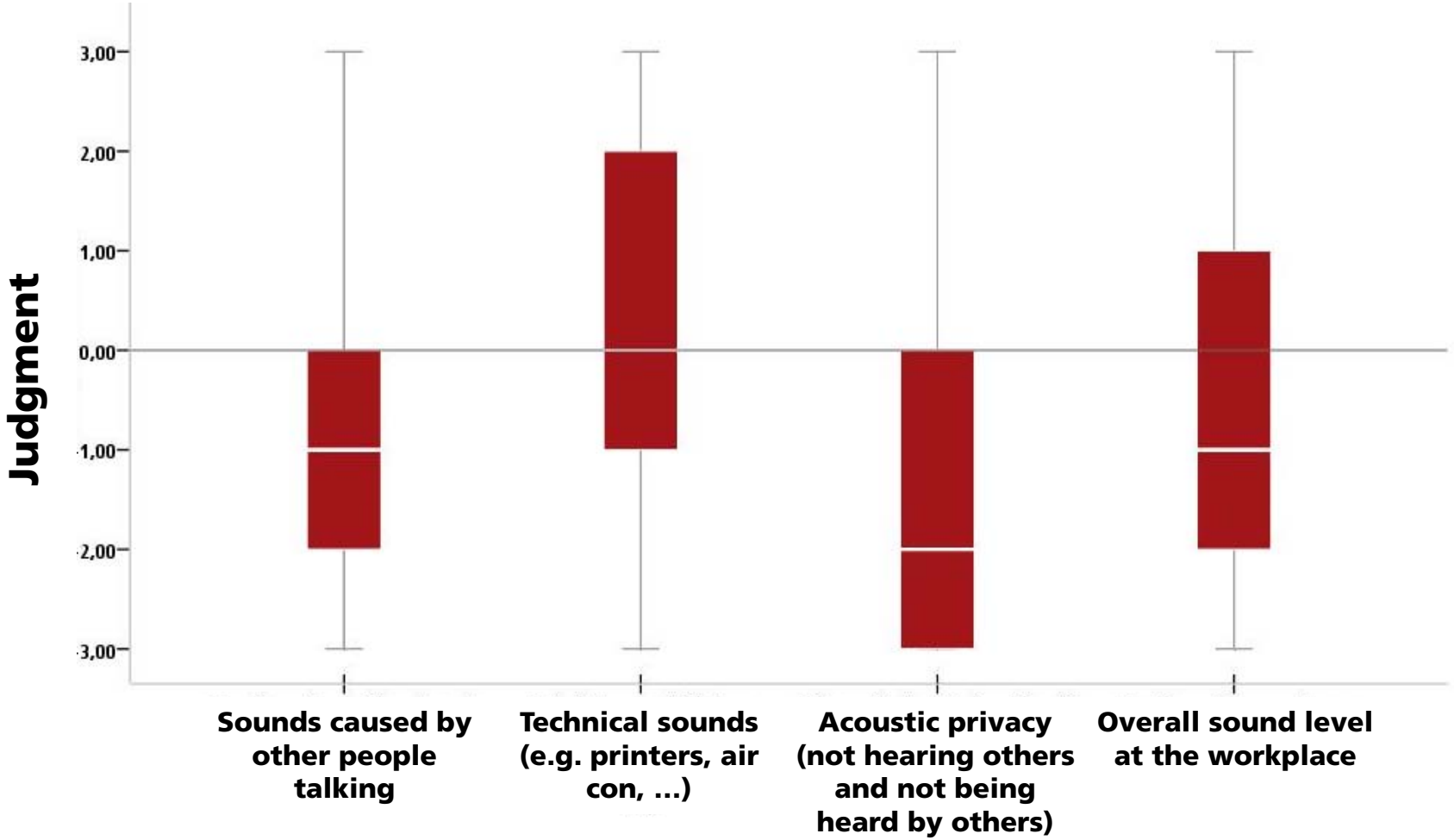
Status quo



Judgments of satisfaction with regard to different aspects of the acoustic working environment (Liebl et al., 2011; n = 659)

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Status quo

VDI 2058-3: 2014-08 Assessment of noise in the working area with regard to specific operations

Job Classification	Target Value Rating Level L_r dB
predominant cognitive work	≤ 55
simple or practiced office work or comparable work	≤ 70
other work	> 70

Recommended rating level for different job classifications

Upcoming

VDI 2569: Draft 2014-01 Sound protection and acoustical design in offices

Room Acoustics Category	Requirements to room acoustical parameters	T_{max}		$L_{NA, Bau}$
		125 Hz	250 Hz bis 4000 Hz	
A	2/3 of measuring paths Level 1 Remaining paths at least Level 2	≤ 0,8 s	≤ 0,6 s	≤ 35 dB
B	2/3 of measuring paths Level 2 Remaining paths at least Level 3	≤ 0,9 s	≤ 0,7 s	≤ 40 dB
C	1/3 of measuring paths Level 2 Remaining paths at least Level 3	≤ 1,1 s	≤ 0,9 s	≤ 40 dB

Requirements to room acoustical parameters and to the maximum building noise levels in open-plan offices

Upcoming

VDI 2569: Draft 2014-01 Sound protection and acoustical design in offices

Level	$D_{2,\,S}$ [dB]	$L_{p,S,4m}$ [dB]
1	≥ 8	≤ 47
2	≥ 6	≤ 49
3	≥ 4	≤ 51

Requirements to room acoustical parameters for the classification of measuring paths

Will this help?

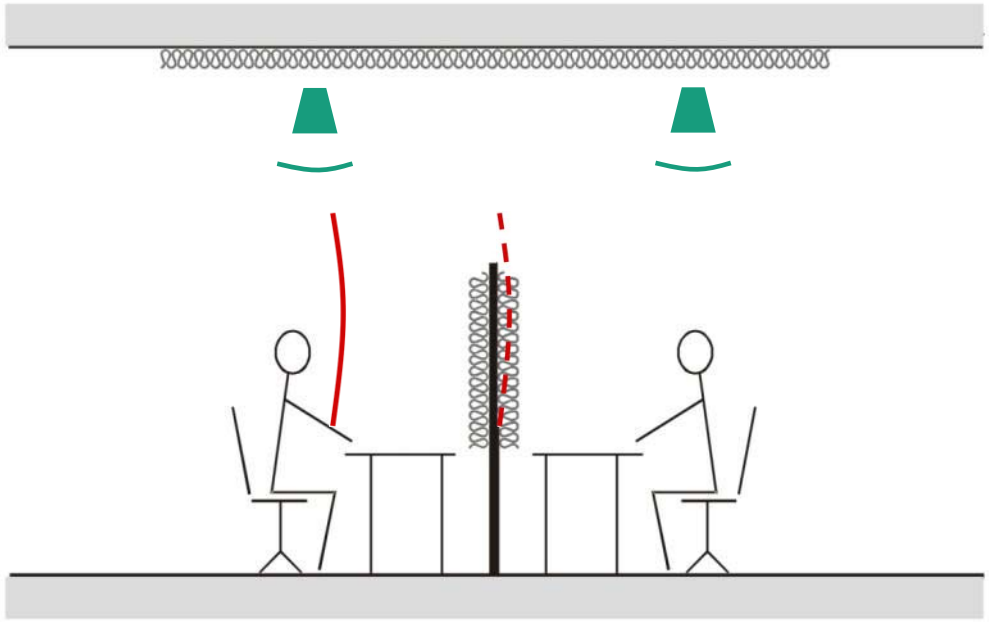
Experiment I: Research Question and Variables

- **Research Question**:

  Is it possible to differentiate the room acoustics categories defined in the draft of VDI 2569 by means of perceptual and cognitive psychology?

- **Independent Variables:**
  - Room acoustics category (A, B, C)
  - Distance from speaker (3,2 m; 6,2 m; 12,3 m)
  - Sound masking (signal to noise ratio -5dB)
- **Dependent Variables:**
  - Working memory performance (serial recall task)
  - Workload (NASA-TLX)
  - Annoyance (in the style of ISO/TS 15666)

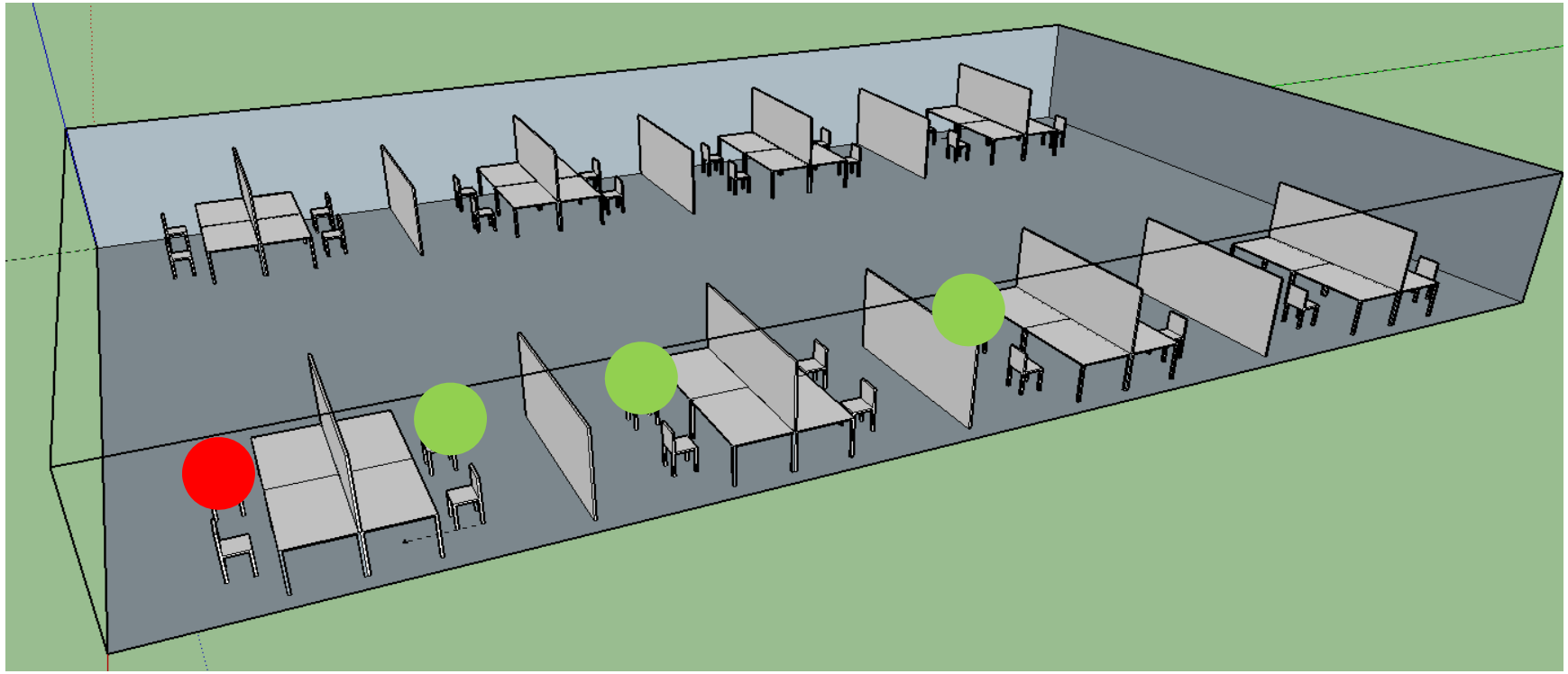
Experiment I: Sound Masking



typically noise (e.g. pink noise) $L_p \leq 42$ dB (A)

Experiment I: Method

- Auralisation of room acoustics categories according to draft VDI 2569 with ODEON
- Additional sound masking with speech noise (only category A)



Room model corresponding to the draft of VDI 2569 as basis for auralisation

Experiment I: Method

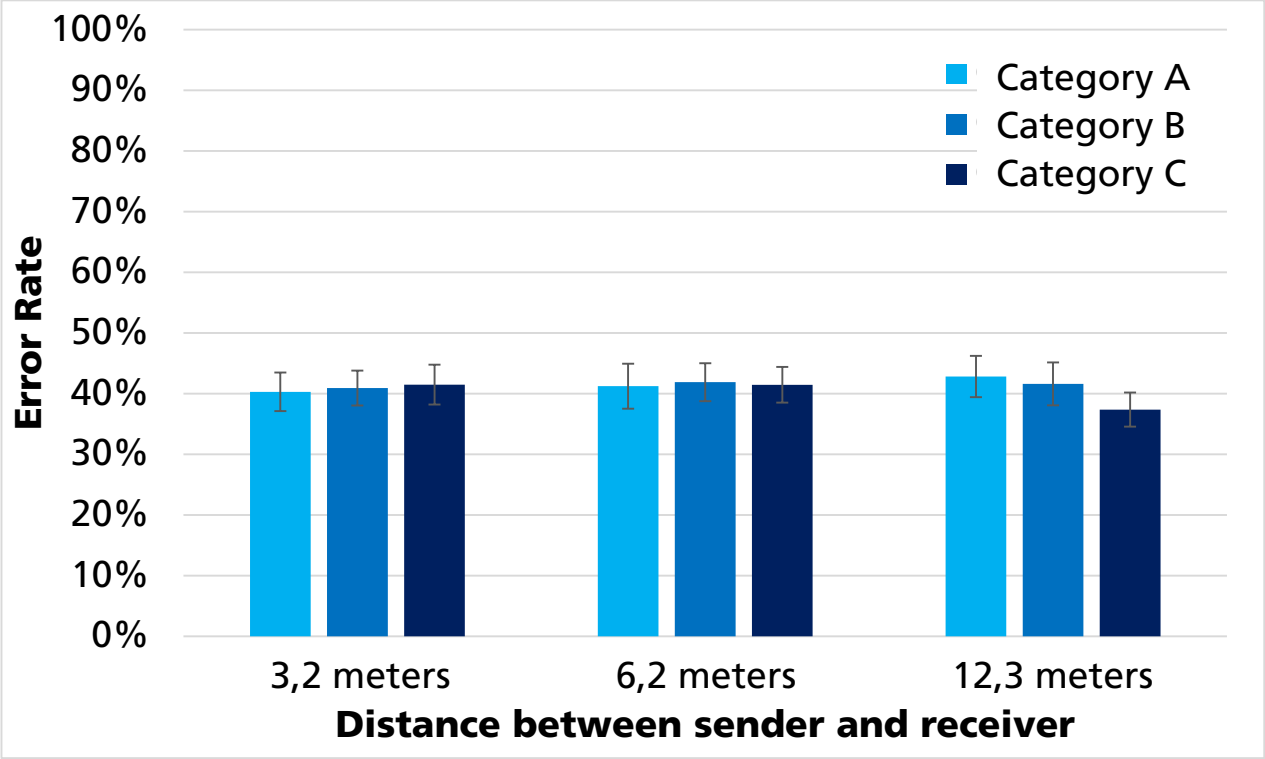
- 24 participants (Ø 24 years; 79% female, 21% male)

Distance	3,2		6,2		12,3	
Room Acoustics Category	Speech level	Signal to noise ratio	Speech level	Signal to noise ratio	Speech level	Signal to noise ratio
A	51.3	16.3	39.6	4.6	34.9	-0.1
B	51.6	11.6	41.1	1.1	37.6	-2.4
C	51.7	11.7	42.8	2.8	39.5	-0.5
A+Masking	51.3	-5	39.6	-5	34.9	-5

Speech level and signal to noise ratios of the experimental conditions

Experiment I: Results

- Room acoustics category: $F(2,46) = 0.323$, $p > .05$, $\eta = 0.014$
- Distance: $F(2,46) = 0.269$, $p > .05$, $\eta = 0.012$
- Interaction: $F(4,92) = 1.383$, $p > .05$, $\eta = 0.057$



Error Rate (serial recall task)

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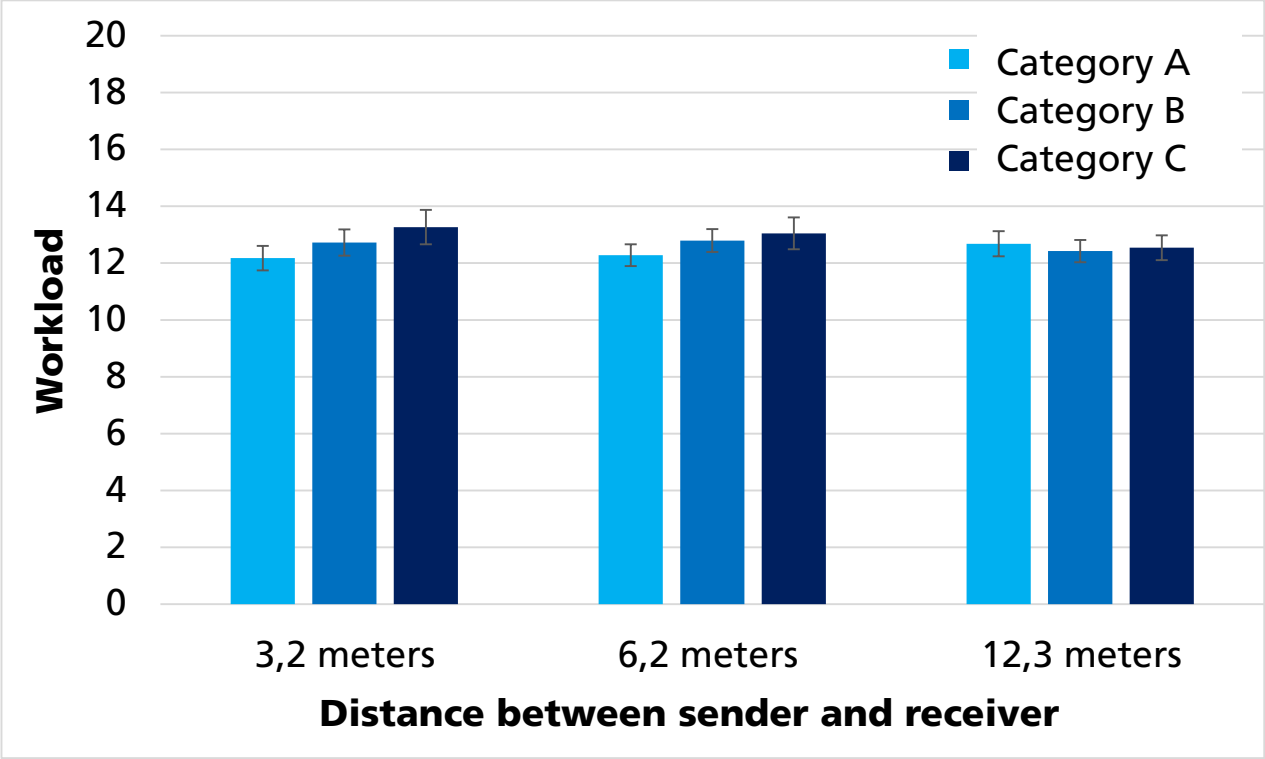
Experiment I: Results

- Room acoustics category: $F(2,36) = 1.461$, $p > .05$, $\eta = 0.075$
- Distance: $F(2,36) = 0.189$, $p > .05$, $\eta = 0{,}01$
- Interaction: $F(4,72) = 0.937$, $p > .05$, $\eta = 0.049$



Workload (NASA-TLX)

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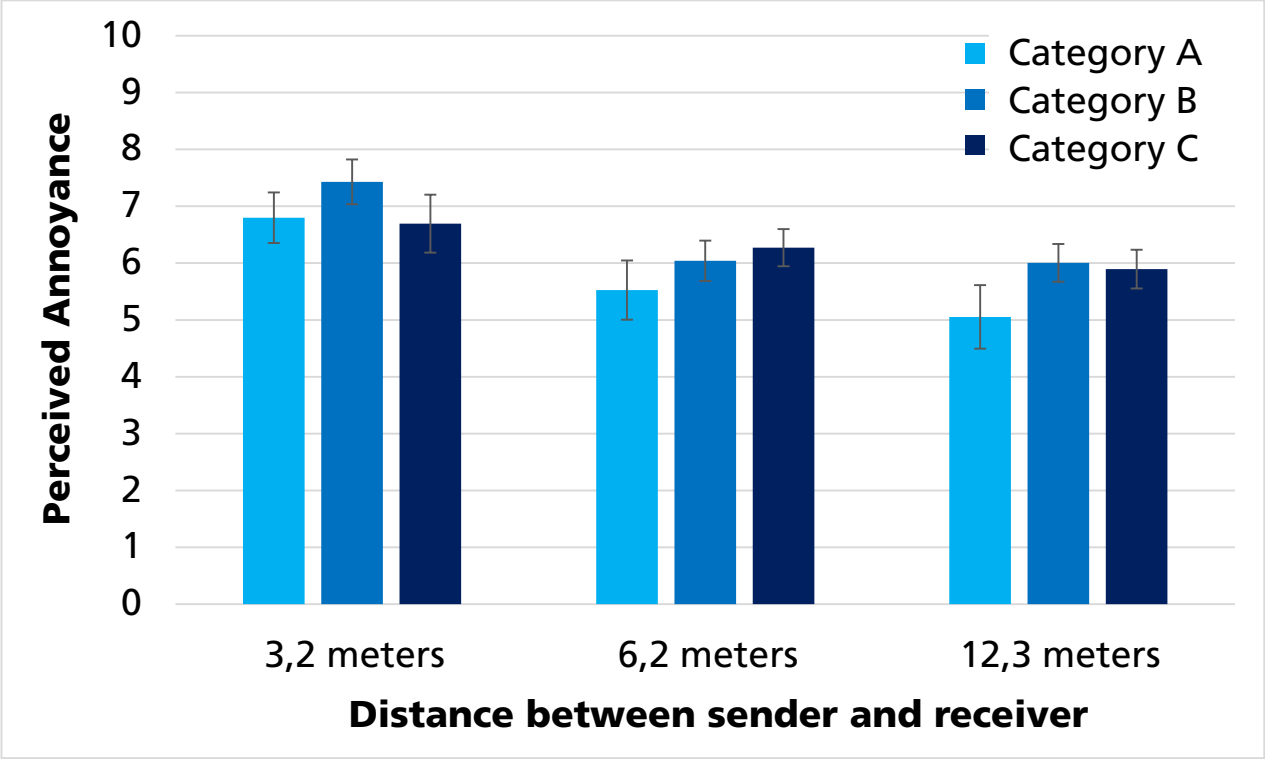
Experiment I: Results

- Room acoustics category: $F(2,36) = 1.409$, $p > .05$, $\eta = 0.073$
- Distance: $F(2,36) = 13.787$, $p < .01$, $\eta = 0.434$
- Interaction: $F(4,72) = 0.760$, $p > .05$, $\eta = 0.041$



Annoyance (in the style of ISO/TS 15666)

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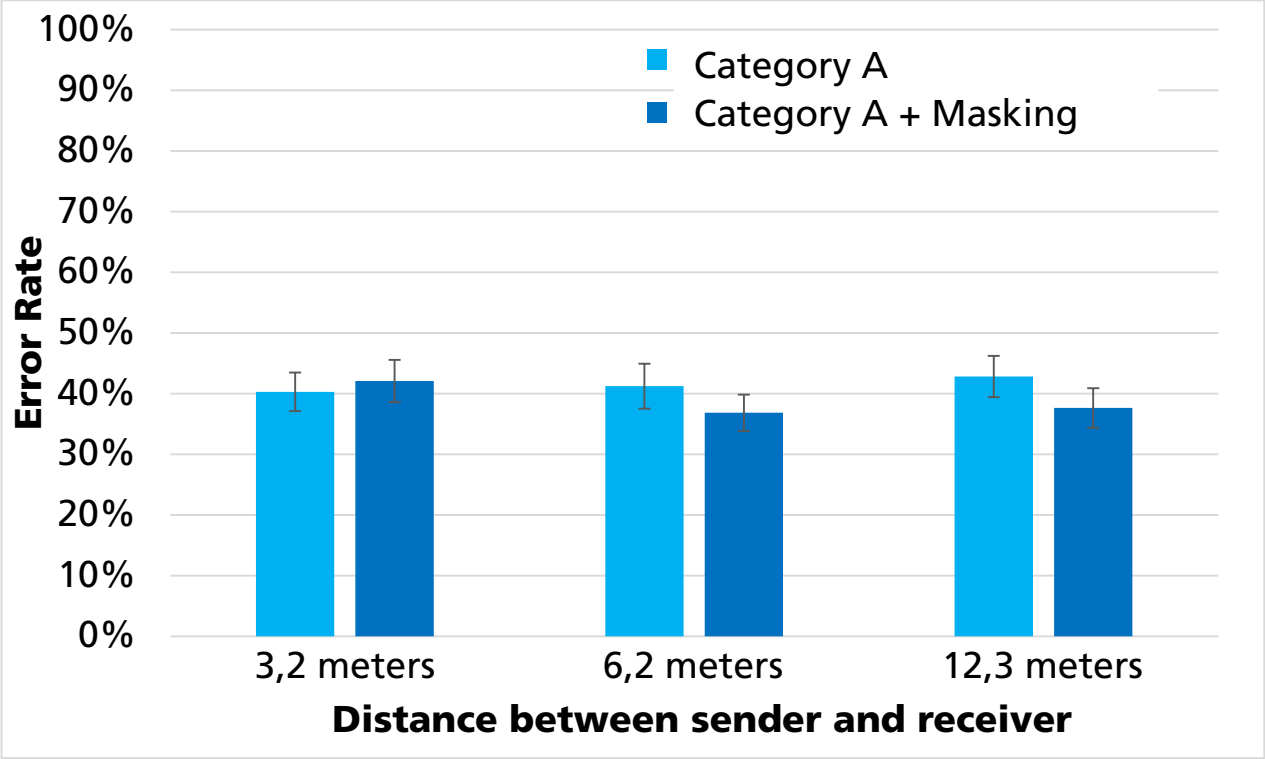
Experiment I: Results

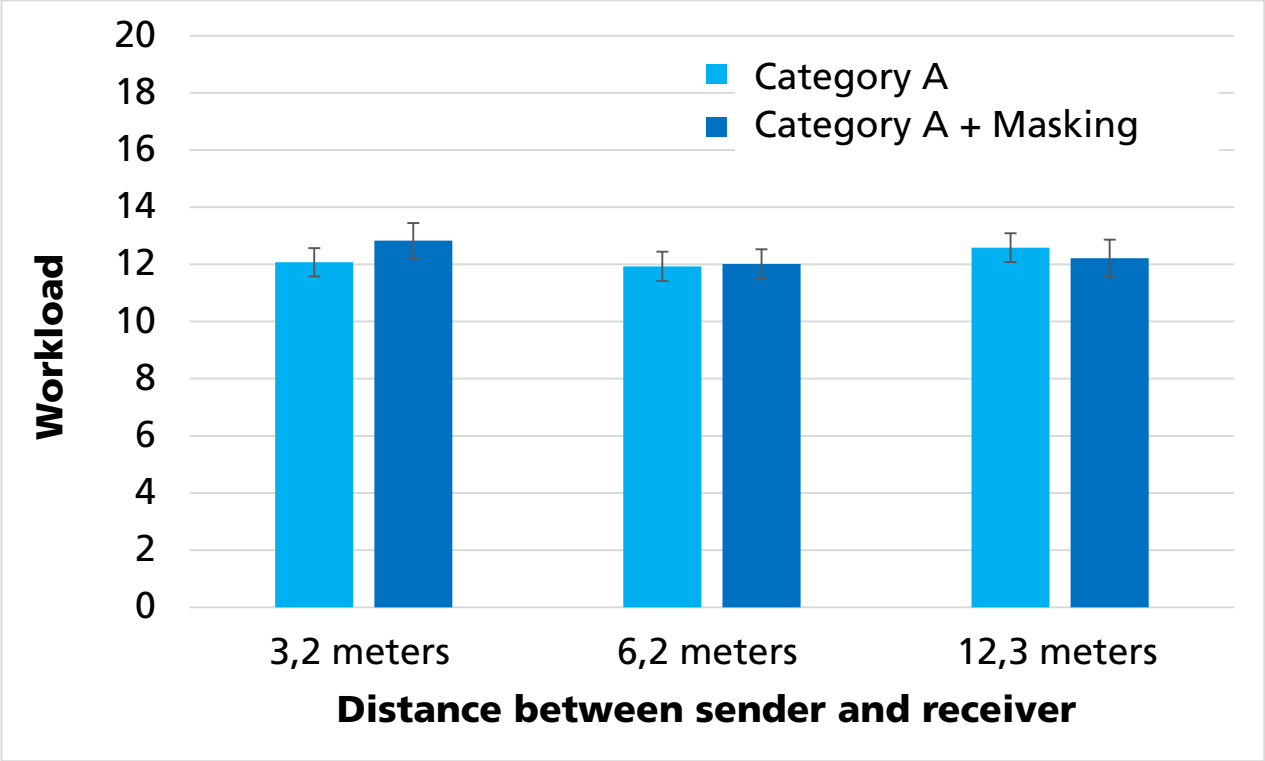
- Distance 3,2 meters: $t(23) = 0.738$, $p > .05$
- Distance 6,2 meters: $t(23) = 1.590$, $p > .05$
- Distance 12,3 meters: $t(23) = 1.970$, $p = .033$



Error Rate (serial recall task)

Experiment I: Results

- Distance 3,2 meters: $t(18) = 1.202, p > .05$
- Distance 6,2 meters: $t(18) = 0.018, p > .05$
- Distance 12,3 meters: $t(18) = 0.638, p > .05$



Workload (NASA-TLX)

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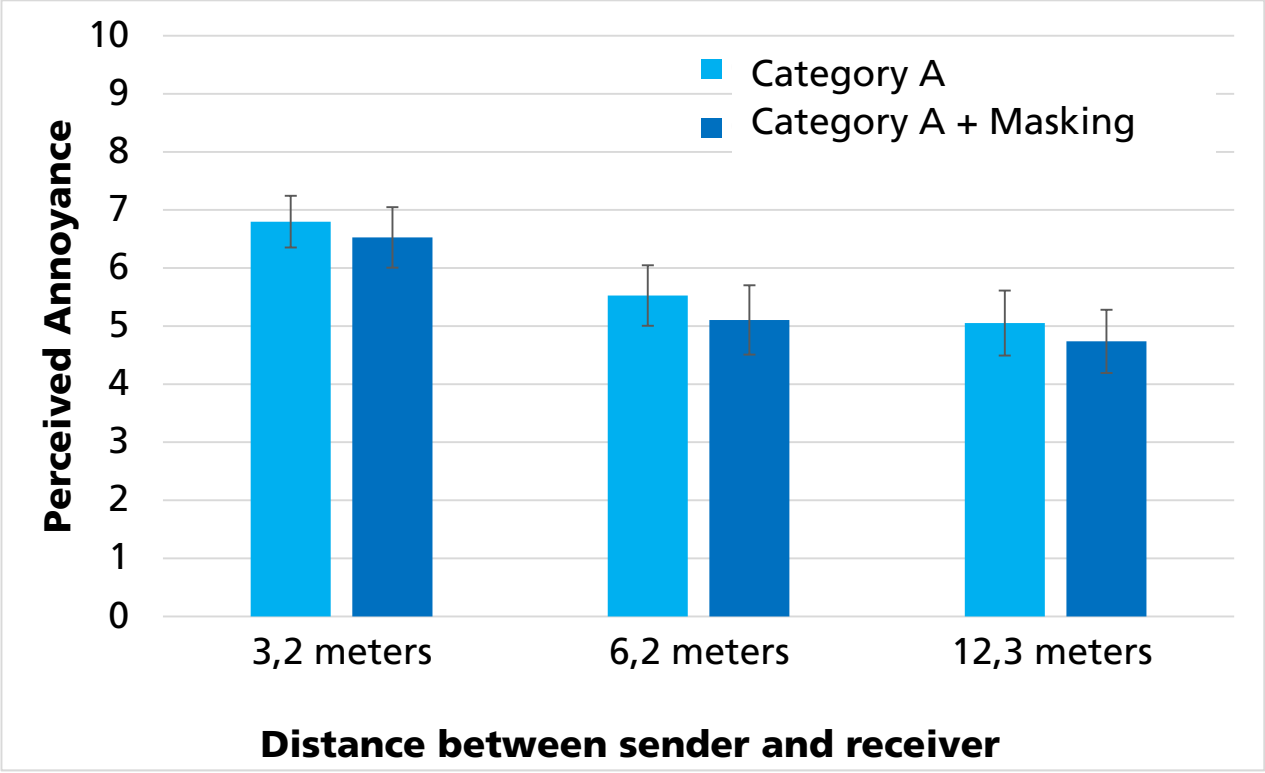
Experiment I: Results

- Distance 3,2 meters: $t(18) = 0.395, p > .05$
- Distance 6,2 meters: $t(18) = 0.479, p > .05$
- Distance 12,3 meters: $t(18) = 0.578, p > .05$



Annoyance (in the style of ISO/TS 15666)

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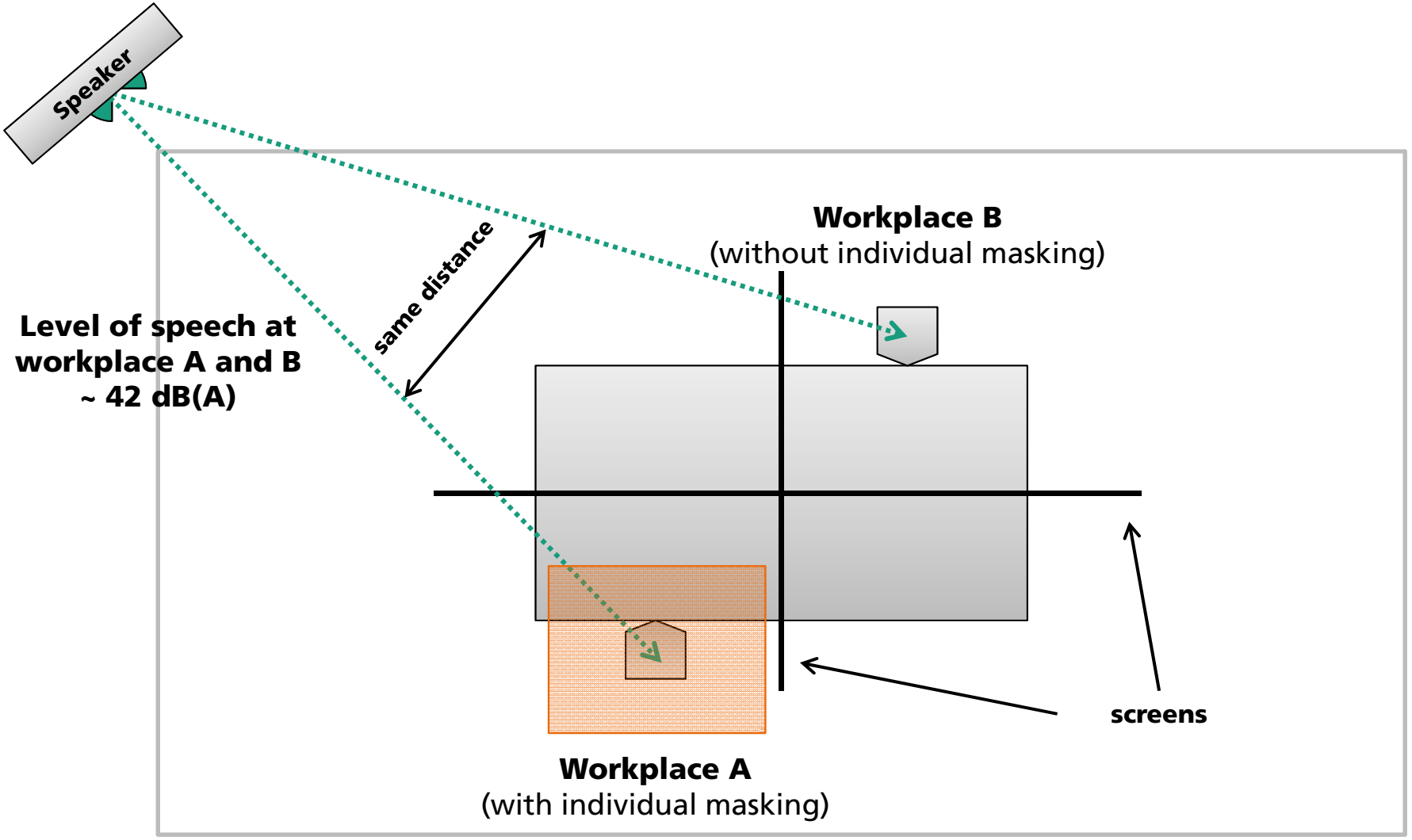
What to do?

Experiment II: Sound Masking



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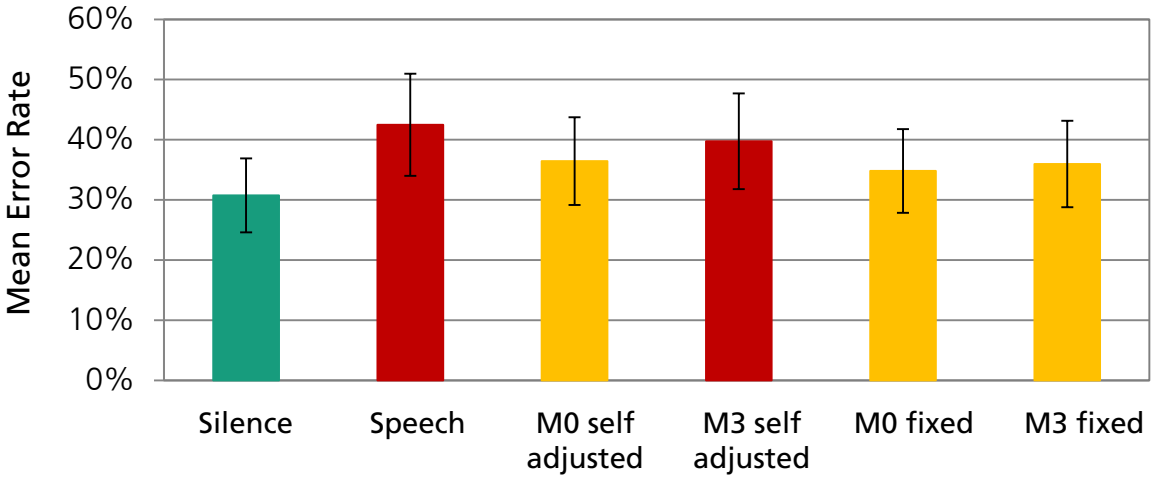
Experiment II: Sound Masking

- 50 participants (25 per group; Ø 31,02 years; 46% female, 54% male)

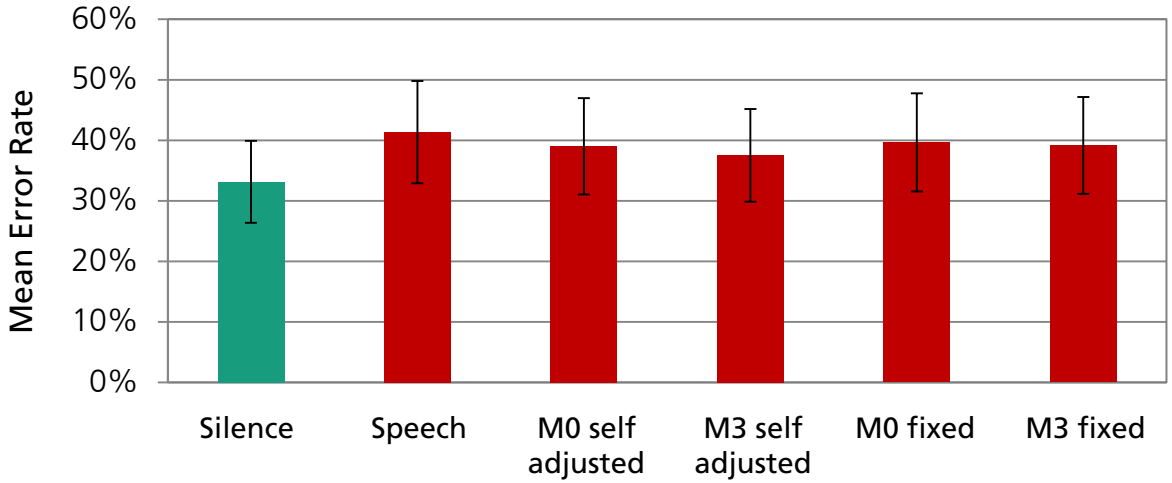
Setting	dB(A) M0 A;B	Quantity M0	dB(A) M3 A;B	Quantity M3
Setting 1	0 (off)	0	0 (off)	1
Setting 2	41,7;36,4	0	41,3;38,4	2
Setting 3	45,9;40,6	5	45,5;42,6	3
Setting 4	49,9;44,6	11	49,7;46,8	9
Setting 5	54,2;48,9	9	54,1;51,2	10

Level and quantity of the selected sound masking setting (M0;M3 at workplace A and B

Experiment II: Sound Masking



Workplace A
The masking sound has a positive effect (significantly) on performance (serial recall). An improvement is observed as compared to the speech condition.



Workplace B
There is no effect at the workplace without individual sound masking.

Error rate during serial recall at workplace A and B

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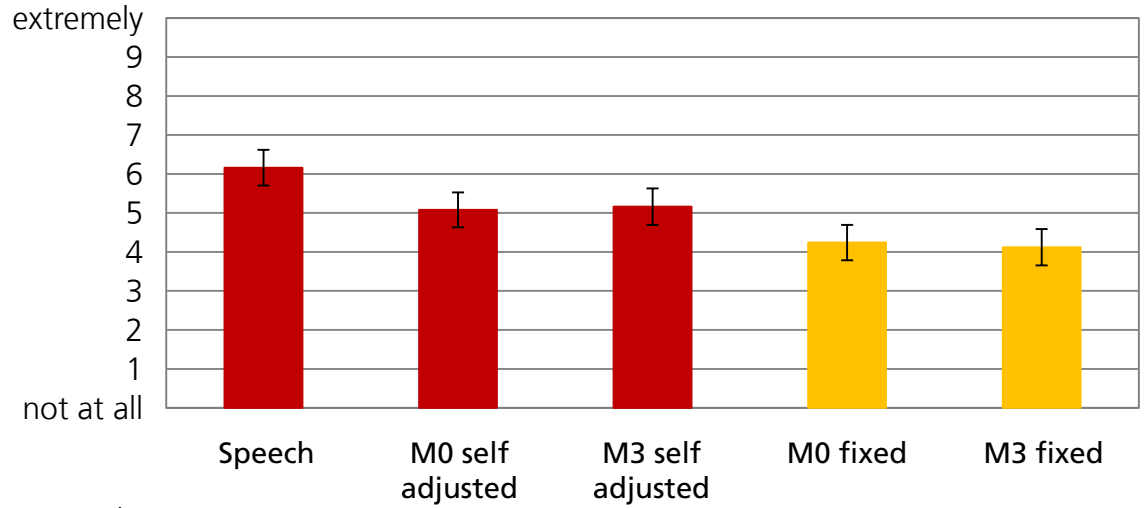
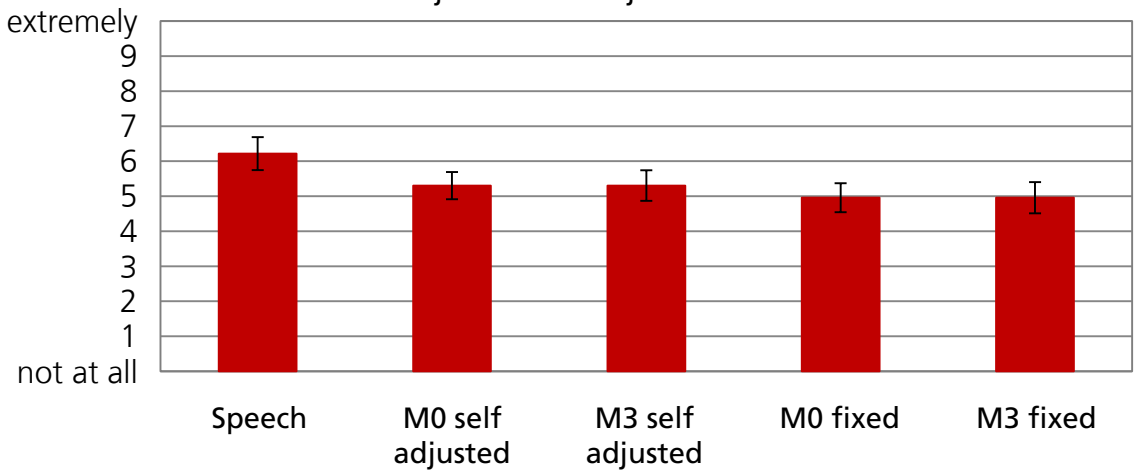
Experiment II: Sound Masking



Workplace A
Perceived annoyance due to background speech is reduced (significantly) if a masking sound is presented.



Workplace B
There is no effect at the workplace without individual sound masking.

Perceived annoyance at workplace A and B

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Conclusion

- The VDI 2569 will be a step forward since it aims at reducing the negative impact of background speech and at improving acoustic privacy but
  - the effects of typical room acoustical measures are limited.
- The effect of sound masking is limited.
- Research is lacking which directly links room acoustical measures with health, performance or perception based outcome variables.
- It will not be possible to provide few simple target values which cover all kinds of different workplaces and guarantee for health, performance and well-being.