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Users' satisfaction of indoor environmental quality conditions in ZEB+ at high latitudes

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I | BASIS FOR EXPERIMENTAL RESEARCH

G. Comfort	<ul style="list-style-type: none"> • Thermal conditions • Visual conditions • Acoustic conditions • Indoor air quality (IAQ)
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ASHRAE TC1.6, Heinzerling et al., 2013, Frontczak and Wargocki, 2011

Global Comfort				
	Thermal	Acoustic	Visual	Indoor air
Parameters	<ul style="list-style-type: none"> • Physical: Air temp, mean radiant temp, relative air velocity, and air humidity. • Human: activity level and clothing. 	<ul style="list-style-type: none"> • Physical properties of sound: Sound level pressure (dBA) • Physical properties of room. 	<ul style="list-style-type: none"> • Illuminance, Luminance distribution, glare, colour of light, c. rendering, amount daylight. 	<ul style="list-style-type: none"> • CO₂
Objective monitoring	<ul style="list-style-type: none"> • Temporal: From 15 minutes to continuous 24h – 72h m. • Spatial: Workspaces, current position of surveyed occupants. 		<ul style="list-style-type: none"> • Different fixed locations (e.g. 0.76 m above floor, 3 spots). 	<ul style="list-style-type: none"> • As thermal and acoustic cond.
Subjective monitoring and analysis	<ul style="list-style-type: none"> • Simultaneous right-now survey • Satisfaction scales (Likert scales) • Data analysis: Regression analyses (linear, multivariate) 			



2 | METHOD

RQ: Which IEQ parameters are rated as the most important determinants of comfort?

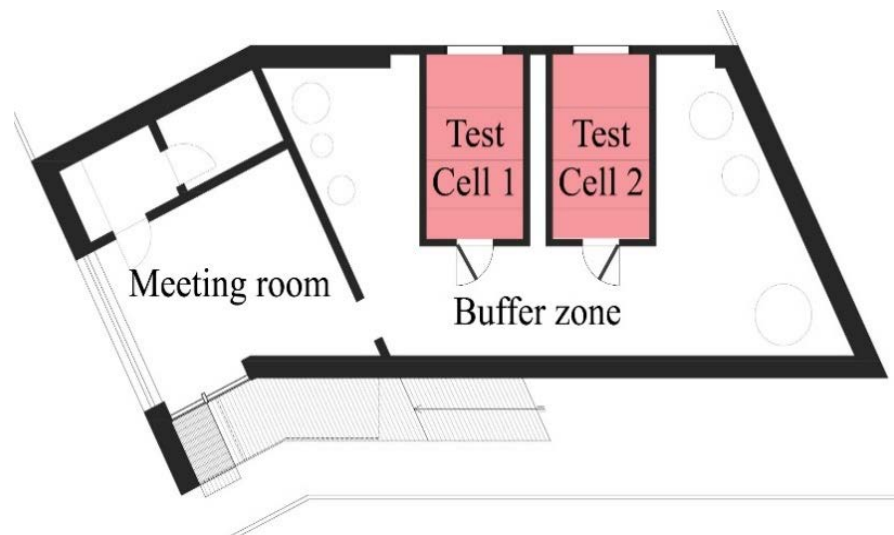
- How do different temperatures affect visual comfort?
- How do different noise levels affect visual comfort?

H_A:
Thermal, acoustic, and visual comfort, together with indoor air quality do *not* equally contribute to global comfort

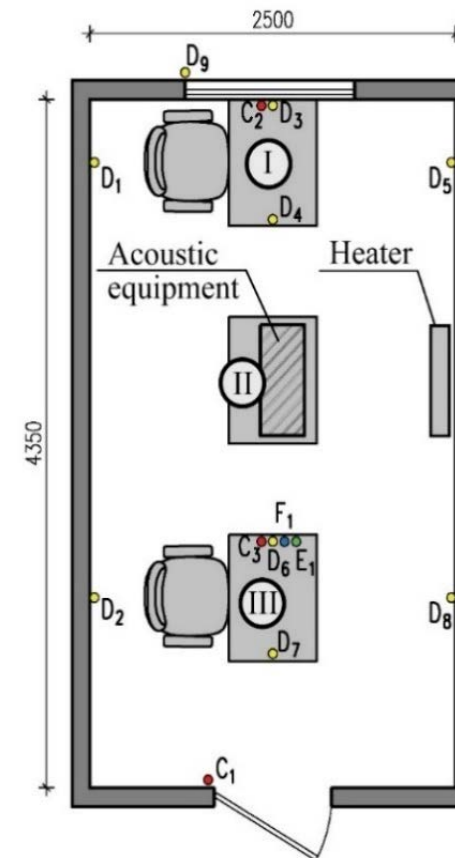


2 | METHOD

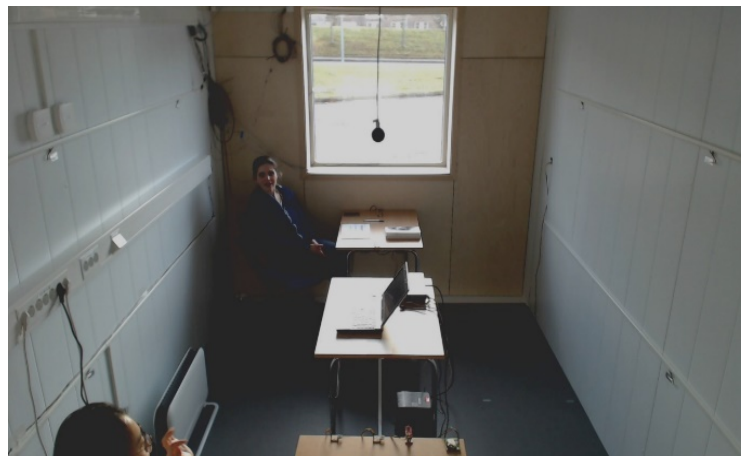
[a]



[b]

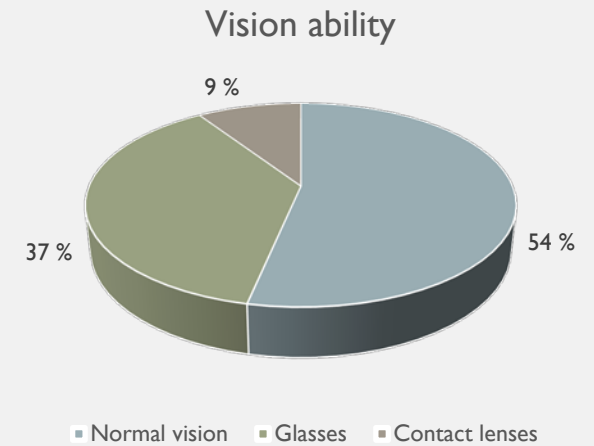
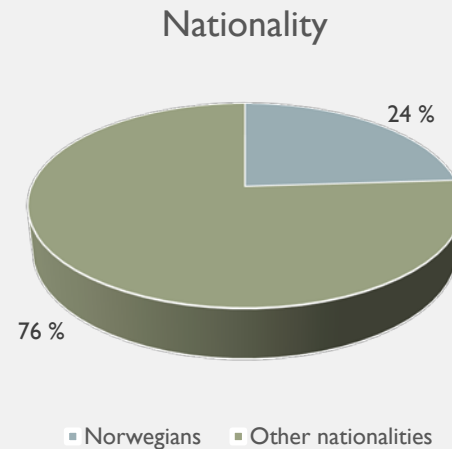
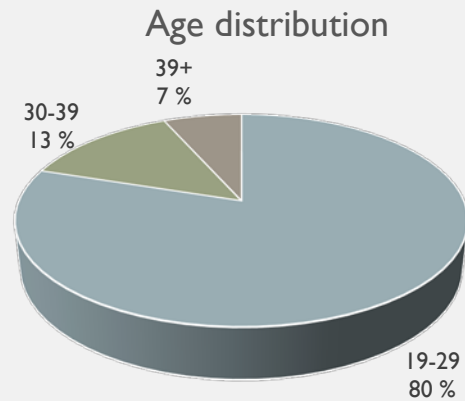


[c]



2 | METHOD

- 75 participants.
- Clothing insulation of the participants varied from 0.31 to 1.34 clo, with an average value equal to 0.78 clo.
- 95 % of participants self-reported good hearing ability.



2 | METHOD

- Trondheim, Norway - 63°43'N, Climate "Dfc" – Continental Subarctic climate.
- November – winter conditions
- Daylight: overcast sky



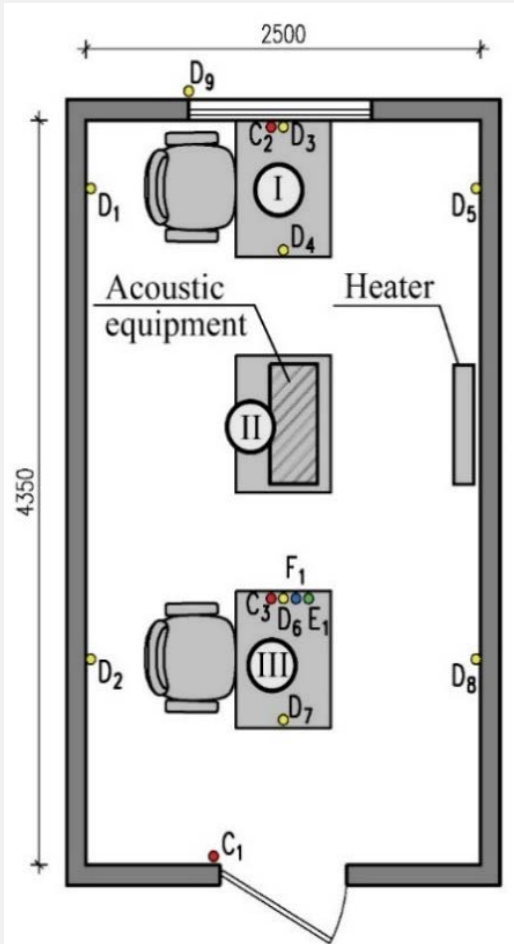
Independent variables

- Thermal conditions: 21°C - comfortable
25°C – uncomfortable
- Visual conditions: close to window - comfortable
far from window - uncomfortable
- Acoustic conditions: 38 dBA – comfortable
50 dBA – uncomfortable

Dependent variables

- Overall comfort (all three factors of IEQ)
 - Thermal comfort, acoustic comfort and visual comfort separately
 - Satisfaction with the air quality of the room
 - Satisfaction with the view out from seating position
-
- Choice of most important factor
 - Choice of most disturbing factor
-
- Preferred changes to the perceived thermal-, acoustic- and visual conditions.

2 | METHOD



- D_N - sensor for illuminance measurements
- C_N - temperature and humidity sensor
- F_1 - sensor for noise measurements
- E_1 - sensor for CO₂ measurements

Stimuli combination	Corresponding indoor environmental condition
SC 1	$T_c + A_c + V_c$
SC 2	$T_c + A_u + V_c$
SC 3	$T_c + A_c + V_u$
SC 4	$T_c + A_u + V_u$
SC 5	$T_u + A_c + V_c$
SC 6	$T_u + A_u + V_c$
SC 7	$T_u + A_c + V_u$
SC 8	$T_u + A_u + V_u$



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3 | RESULTS

	Odds Ratio	Standard Error	z	P> z
View satisfaction	1.055	0.118	0.48	0.634
Thermal comfort satisfaction	2.428	0.193	11.17	0.000
Acoustic comfort satisfaction	1.669	0.147	5.81	0.000
Visual comfort satisfaction	1.521	0.138	4.61	0.000
Indoor air quality (IAQ) satisfaction	1.146	0.105	1.48	0.139
Psychological atmosphere at work	1.236	0.147	1.79	0.073
Illuminance at the desk (E_{desk})	0.997	0.003	-1.30	0.192
Illuminance in the room (E_{room})	1.009	0.004	2.48	0.013
Temperature at the desk (T_{desk})	0.605	0.152	-2.00	0.046
Temperature in the room (T_{room})	1.544	0.412	1.63	0.103
Noise _(mode)	0.952	0.018	-2.65	0.008
CO ₂	1.000	0.001	0.23	0.820
Humidity in the room (H_{room})	0.972	0.023	-1.19	0.234
Level 2 variance	0.901	0.288		

3 | RESULTS

Factors tested:	Significance of each factor for particular stimuli combination							
	SC1 T _c +A _c +V _c	SC2 T _c +A _u +V _c	SC3 T _c +A _c +V _u	SC4 T _c +A _u +V _u	SC5 T _u +A _c +V _c	SC6 T _u +A _u +V _c	SC7 T _u +A _c +V _u	SC8 T _u +A _u +V _u
Thermal comf. satisf.	***	***	***	***	***	***	***	***
Visual comf. satisf.	***		**	**			***	***
Acoustic comf. satisf.	***	***		**		***	**	***
Noise, mode value	**							
Air quality satisfaction								
CO ₂ level (registered)		*						
View out satisfaction								
M illuminance room			*					
Prior coffee consumption					*			
M temp. room					**	***		***
M temp. desk								***
M _{lux} desk					**	**		
M _{lux} wall front partic.					*			
Ratio[M _{lux} desk/M _{lux} room]					*			
Psych. comf. work/univ						***	*	
Clo value								*

Table showing simplified statistical results as significance of each tested factor for each particular SC, where *** means highly significant, ** - moderate significance, * - just significant.

3 | RESULTS

- Mean illuminance of the room (rather than illuminance on the desk), mean temperature at the participants' desks (rather than in the room) and noise mode were factors that were of importance according to analysis.
- The thermal conditions that were expected to be uncomfortable (25° C), were, in fact, more preferred by participants than conditions with 21 degrees that were considered to be comfortable.
- Interestingly, even though the average illuminance at the working place situated by the window was low (oscillated around 100 lux), it has been perceived as comfortable by most participants.
- From the numerical results and comparing SC6 (Tu+Au+Vc), SC7 (Tu+Ac+Vu) and SC8 (Tu+Au+Vu) we may observe that significant dissatisfaction with sound in SC6 or light in SC7 alone does not result with a large number of subjects dissatisfied with IEQ. If the uncomfortable conditions occur for both sound and light simultaneously, as in SC8, the number of subjects dissatisfied with IEQ (14%) is higher than the sum of dissatisfied with IEQ because of sound (3%) and dissatisfied with IEQ because of light (4%).

3 | CONCLUDING REMARKS

- The results showed that in most studied stimuli combinations when the participants experienced moderate discomfort conditions similar to real office conditions, the thermal comfort was the most determinant factor of indoor environmental comfort.
- When asked which environmental condition was the most important for the experience of overall comfort, lighting scored considerably higher than noise in all stimuli combinations; temperature scored highest.

IEQ is a multilateral concept affected by physical and psychosocial aspects. Being in a small office in a modern energy-efficient building with minimized adaptive opportunity, thermal, visual and acoustic conditions are highly important. Workstations placed by the window may be sufficiently illuminated exclusively by daylight over a longer time than it happens in practice creating good conditions for cognitive work, view out and energy saving.



Thank you for your attention.

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