Interactive Breezemaker

A Design Framework for Personal Environmental Control Systems

P5 / 20-06-2024 / Roelof Kooistra



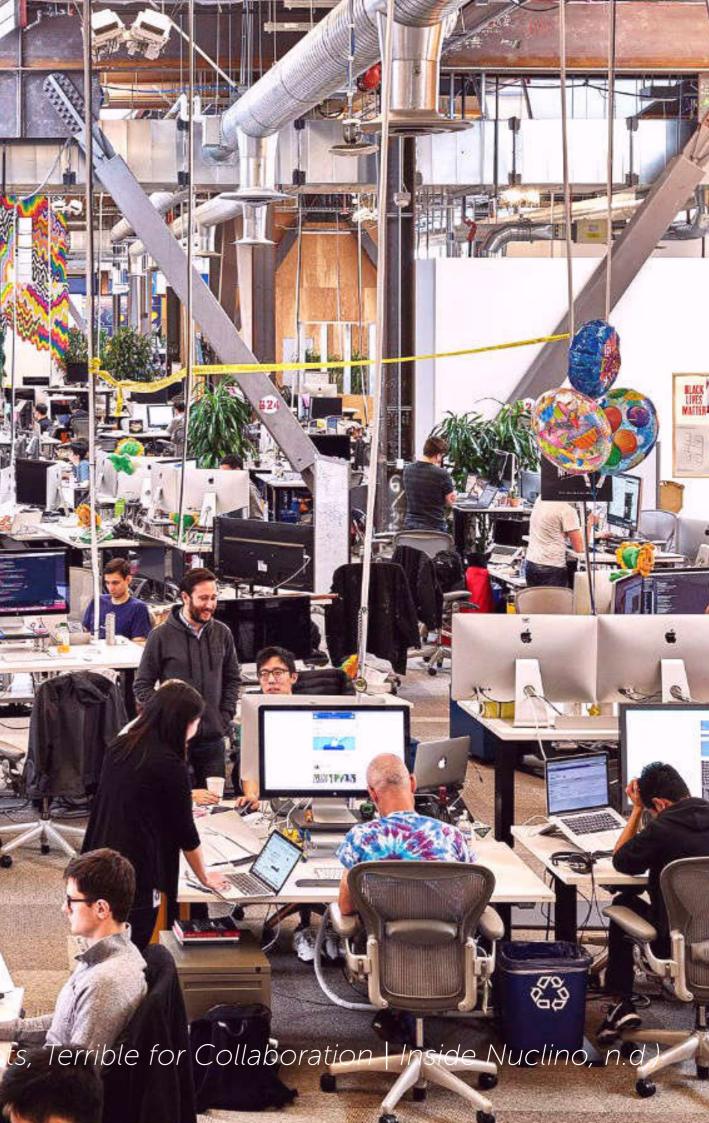








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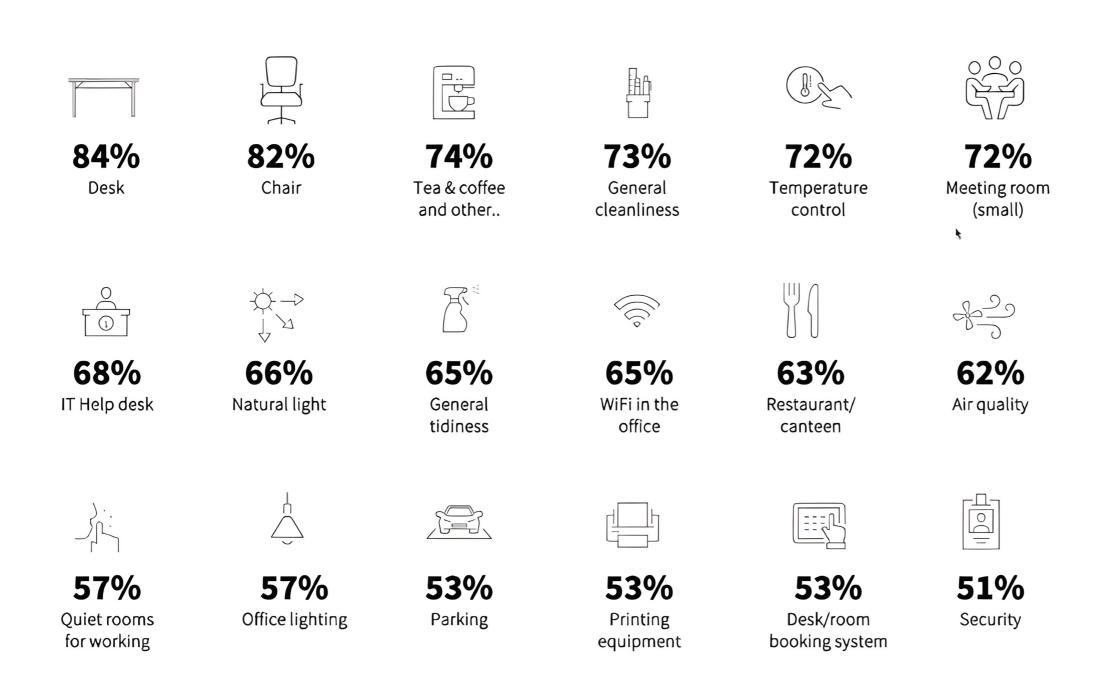


How do people feel in these environements?

How would they rate their thermal comfort?



Importance of office features and services







68% Noise levels



59% Computing equip



58% Meeting room (large)

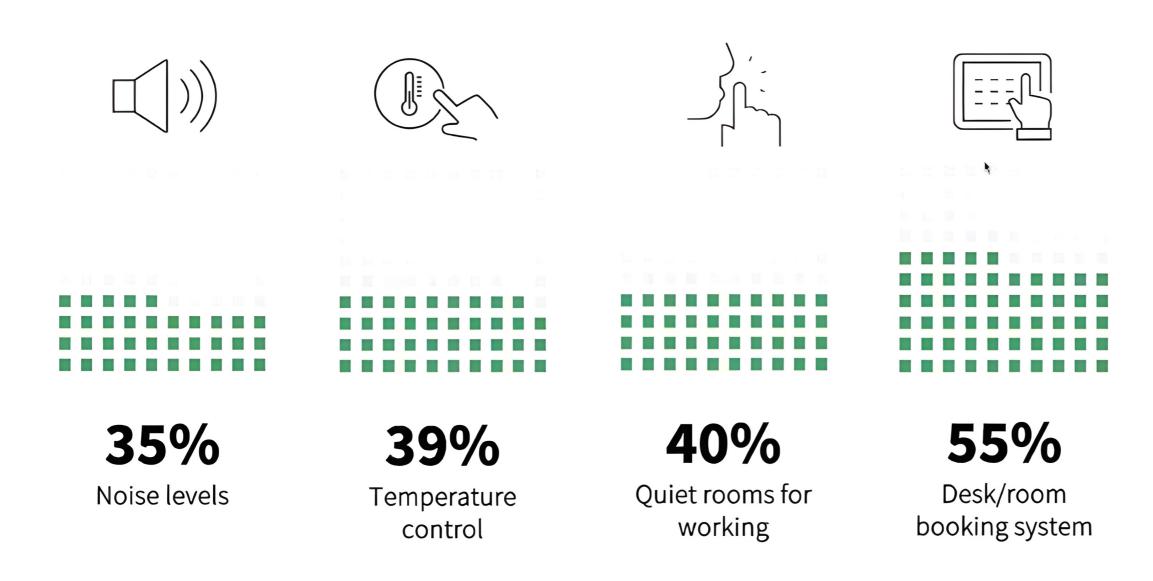




Remote access to files

(Leesman, 2024)

Employee satisfaction with critical features and services





Restaurant/ canteen

(Leesman, 2024)

39% is satisfied about the temperature control 61% is not



Mean Radiant Temperature (°C)

Relative Humidity (%)

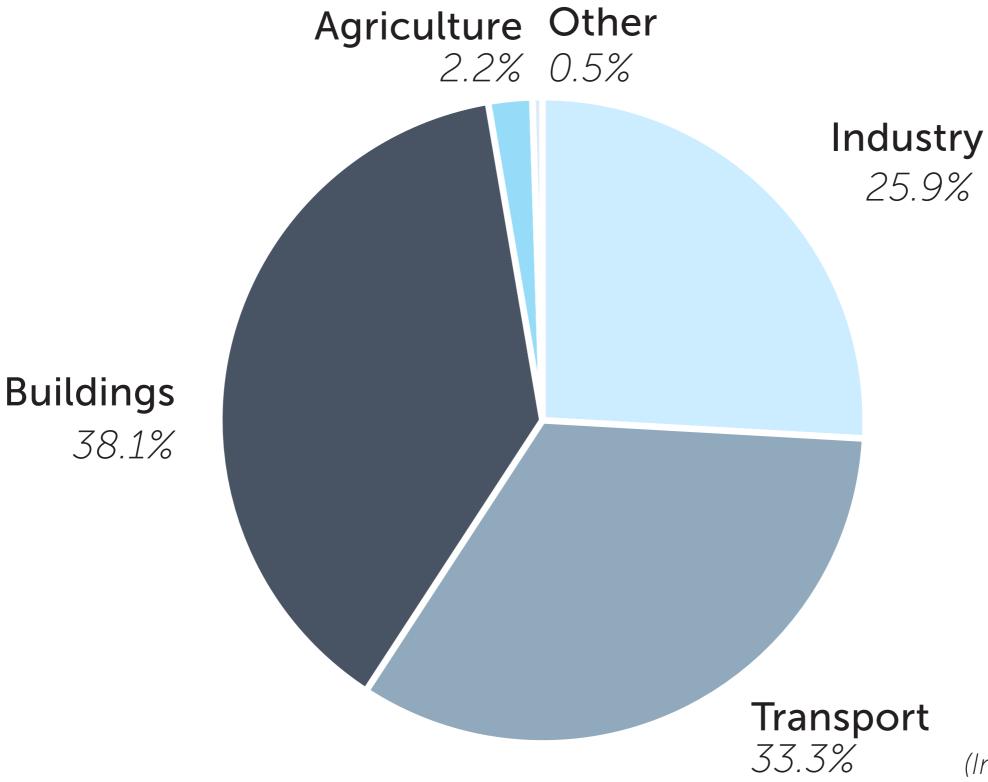
Airspeed (m/s)





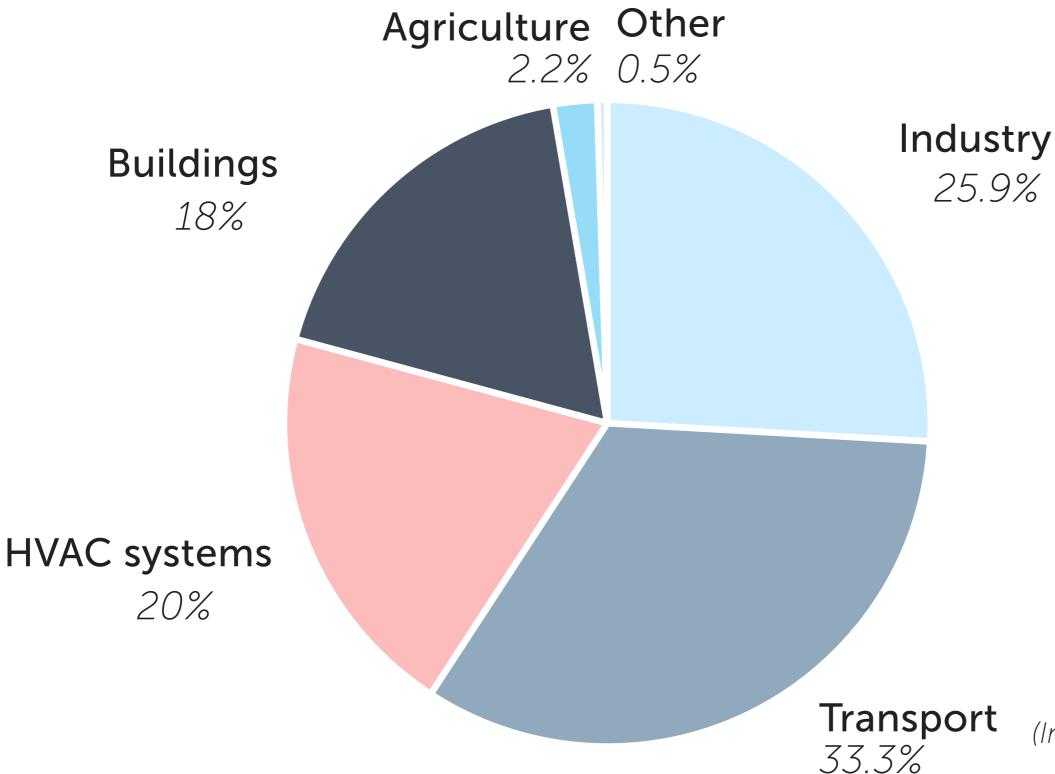
Clothing Insulation (clo)

Primary energy consumption in the U.S. and EU



(International Energy Agengy, 2013)

Primary energy consumption in the U.S. and EU



(International Energy Agengy, 2013) (X. Cao et al., 2016)

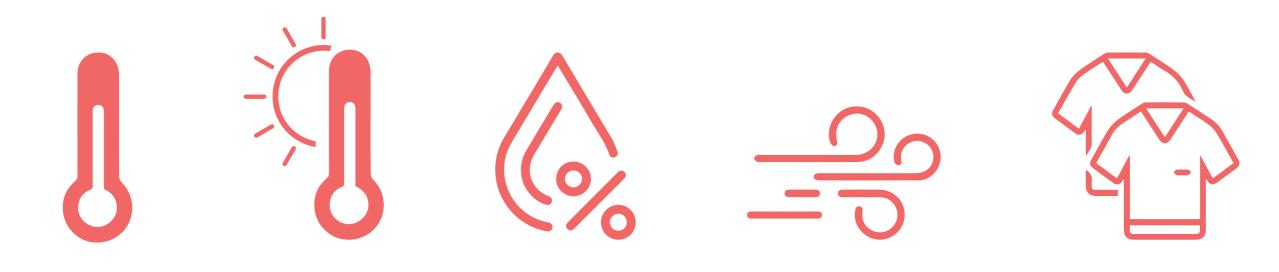








Is there a way to provide people with more personal control over the temperature in a more effective and energy-efficient manner?



Mean Radiant Temperature (°C)

Relative Humidity (%)

Airspeed (m/s)



Clothing Insulation (clo)



Mean Radiant Temperature (°C)

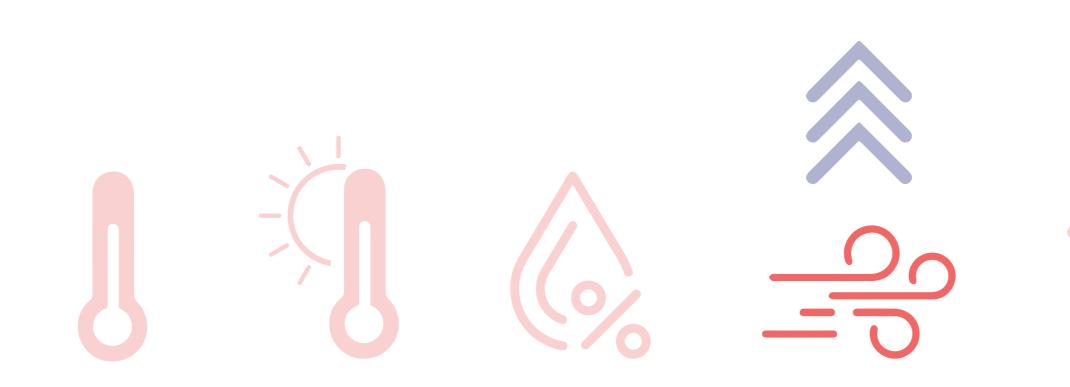
Relative Humidity (%)

Airspeed (m/s)





Clothing Insulation (clo)



Mean Radiant Temperature (°C)

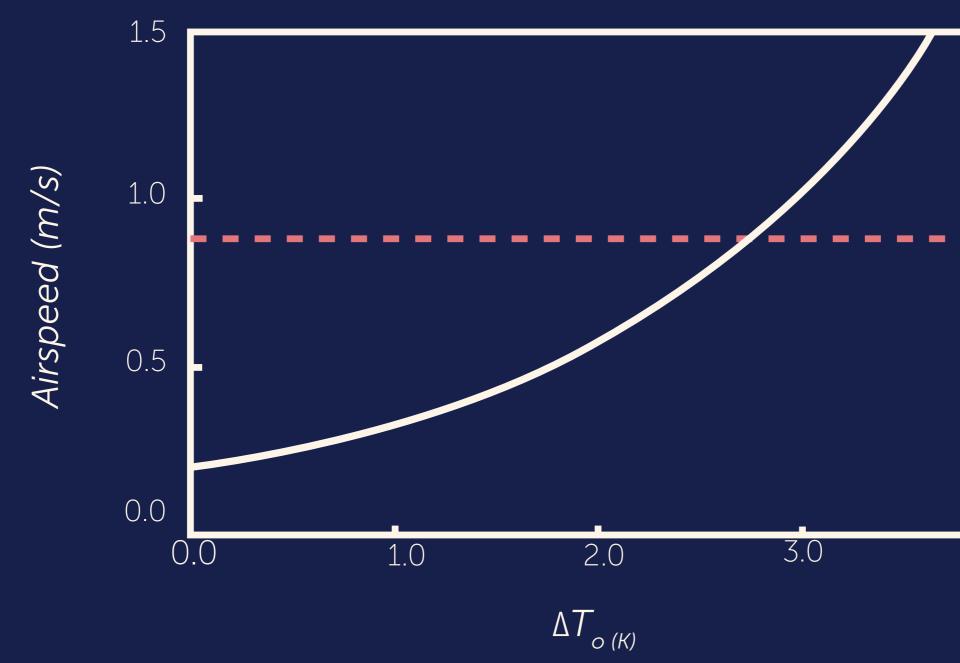
Relative Humidity (%)

Airspeed (m/s)





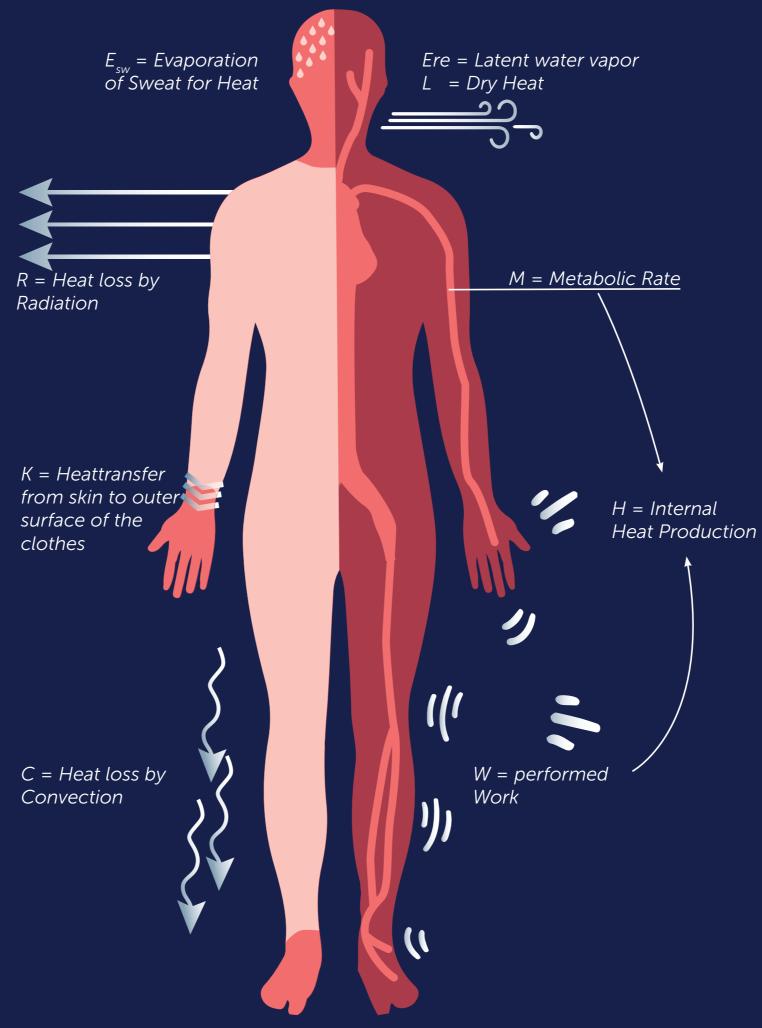
Clothing Insulation (clo)



25



(NEN-EN 16798-1, 2019)



Research question

How can we develop an evidence-based framework to implement personalized air velocity for occupants in open-plan offices during summer and design an effective solution?

Methodology

Literature Review

Literature Review



Literature Review











Literature review



Perceived Control

the **belief** in one's ability to exert control over situations or events

Conceptual model perceived control simpliefied

Perception Environmental



Conceptual model perceived control simpliefied

Perception Environmental







Temperature $(^{\circ}C)$

24-30 °C

(%)

40 - 60%

Airspeed (m/s)

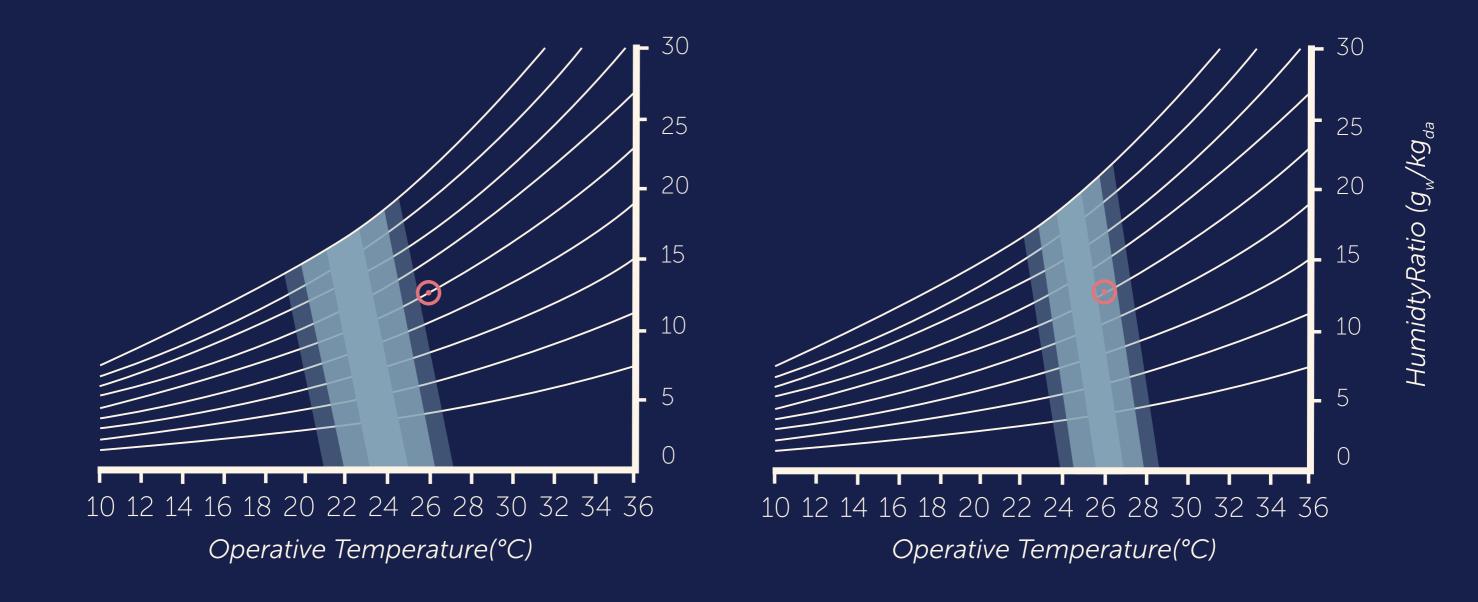
(clo)

0.6 clo



Metabolic Rate (met)

1 - 1.4 met

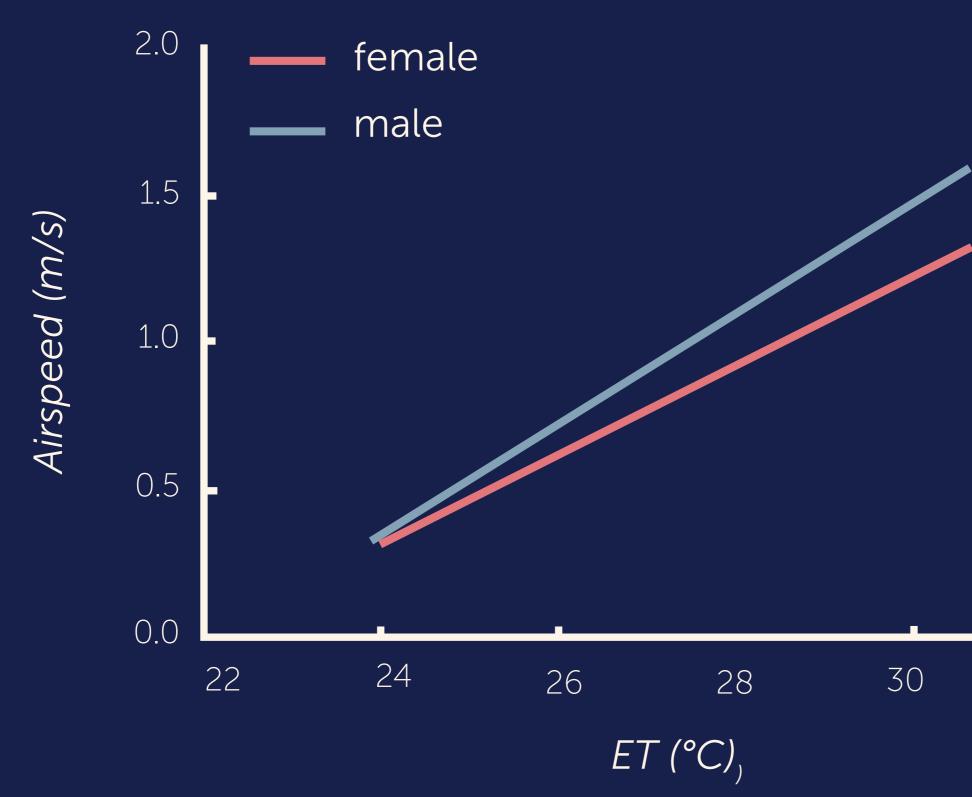


0 m/s

0.7 m/s

1.4 met , 60%

(Zhai et al., 2017)

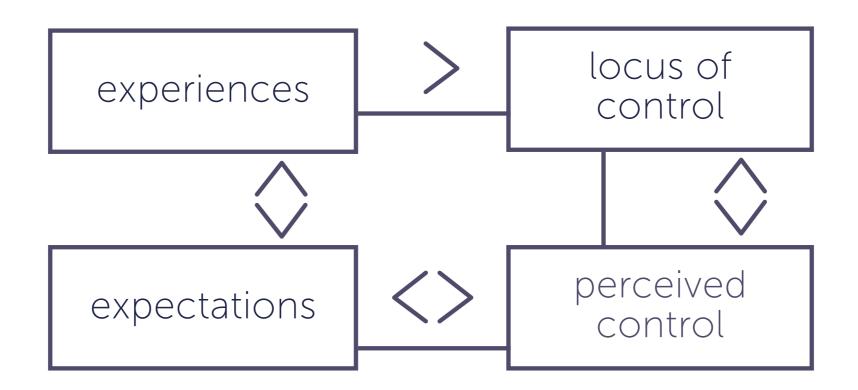


Prefered airspeed under different temperatures for male and female (Zhai et al., 2017)



So give someone control over the airspeed and done?

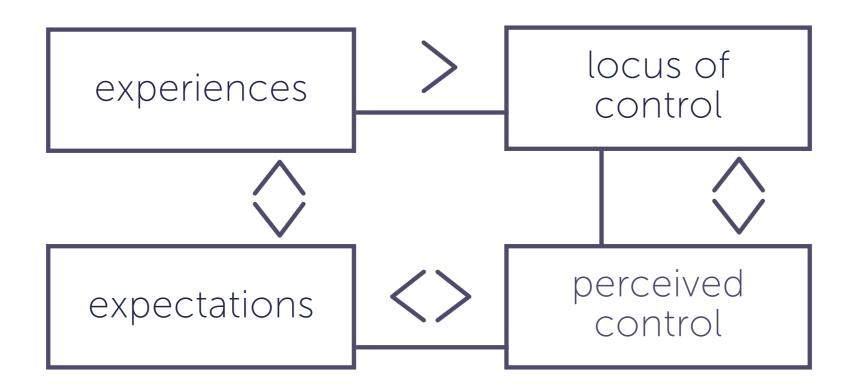
Perception Environmental



Locus of control

- Internal locus of Control

- External locus of Control



Is it a problem that we don't know those experiences and expectations?

Perception Environmental

Perception Environmental

Before we continue, are there any applications that already provide increased airspeed and perform well in an open-plan office environment?



table fan (Ubuy Netherlands, n.d.)



(Ubuy Netherlands, n.d.)



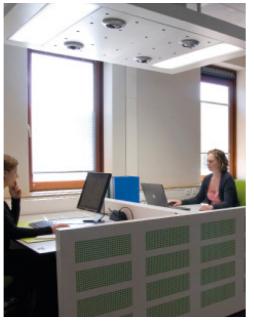
bladeless ceiling fan (O'Donnell, 2024)



ceiling fan (Asahi Home Appliances, 2023)



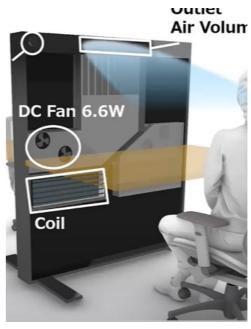
openable window (40 Mm Openable Window, n.d.)



climate ceiling TNO (TNO, 2014.)



climate table Ahrend (DESKs | Ahrend, n.d.)

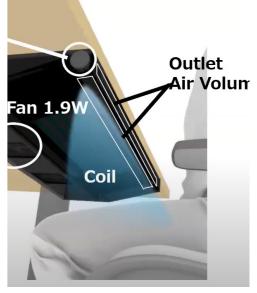


(INIVE, 2023)



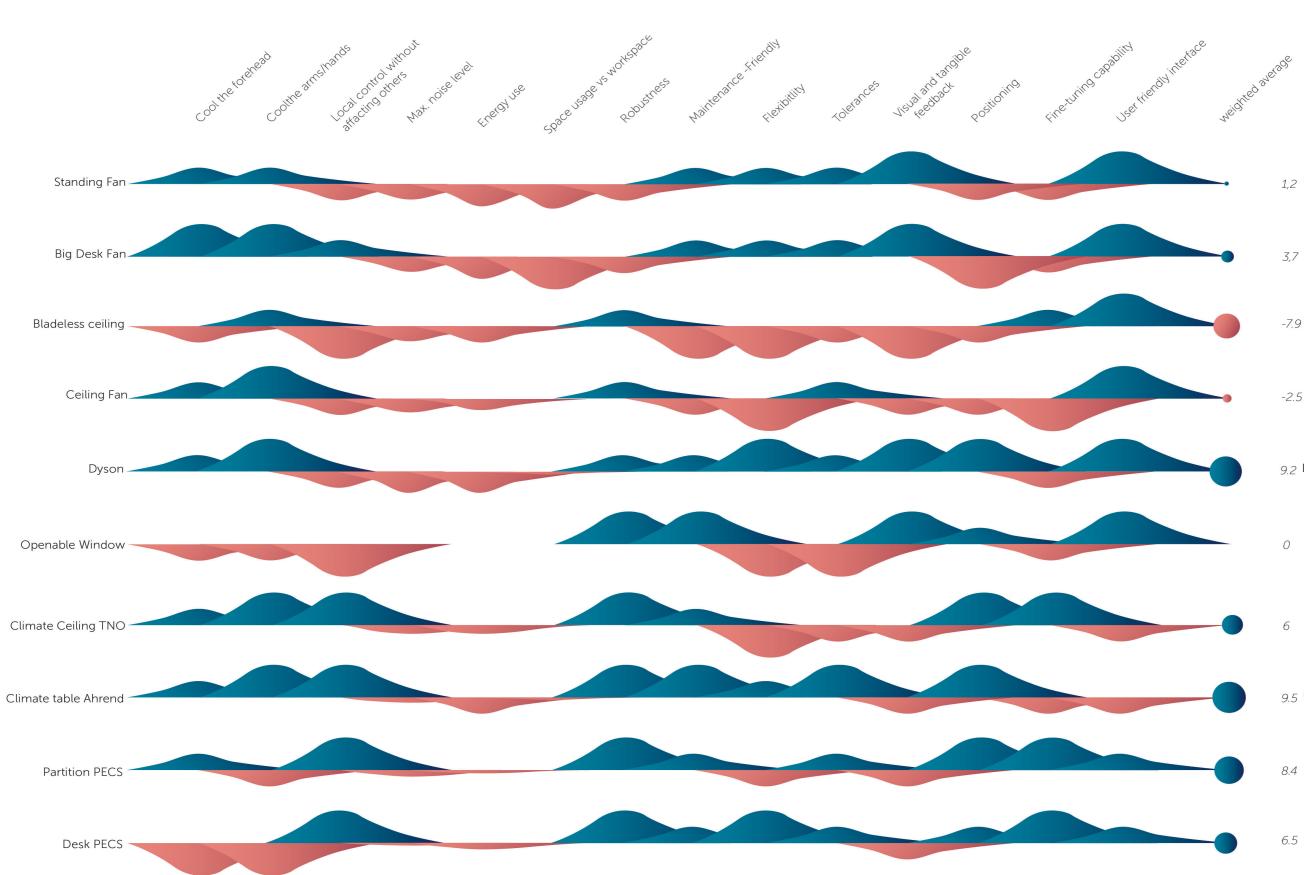
Dyson purifier

(Dyson, 2024)

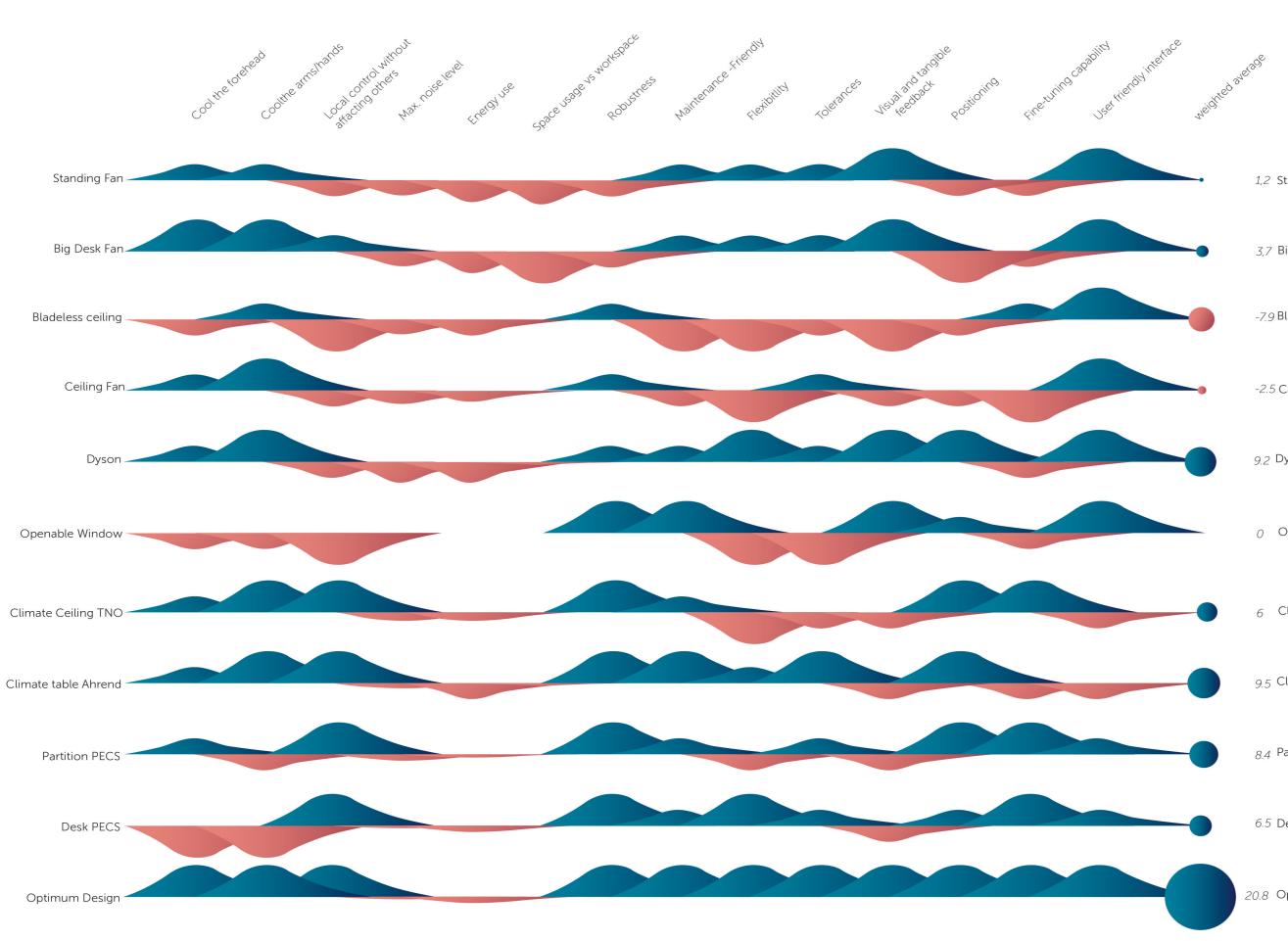


desk PECS

(INIVE, 2023)



- 1,2 Standing Fan
- 3,7 Big Desk Fan
- -7.9 Bladeless ceiling Fan
- -2.5 Ceiling Fan
- 9.2 Dyson
- 0 Openable Window
- 6 Climate Ceiling TNO
- 9.5 Climate table Ahrend
- 8.4 Partition PECS
- 6.5 Desk PECS



1,2 Standing Fan

3,7 Big Desk Fan

-7.9 Bladeless ceiling Fan

-2.5 Ceiling Fan

9.2 Dyson

0 Openable Window

6 Climate Ceiling TNO

9.5 Climate table Ahrend

8.4 Partition PECS

6.5 Desk PECS

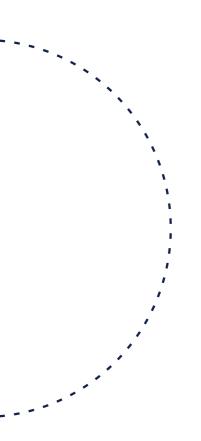
20.8 Optimum Design

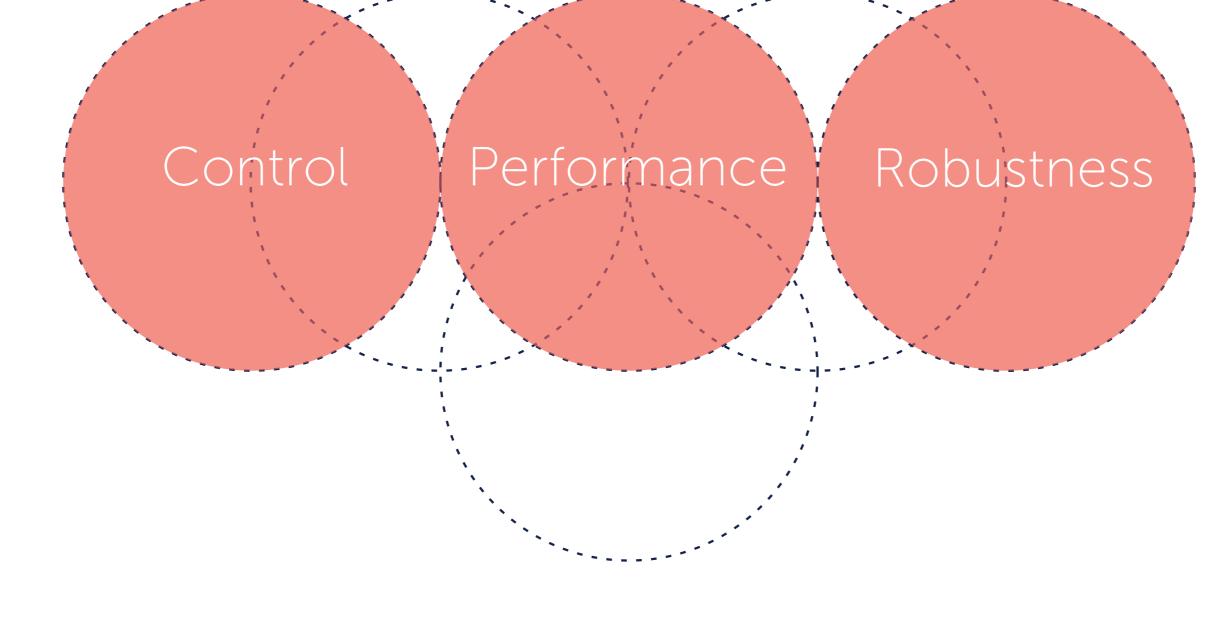
Still a lot of room for improvement.....

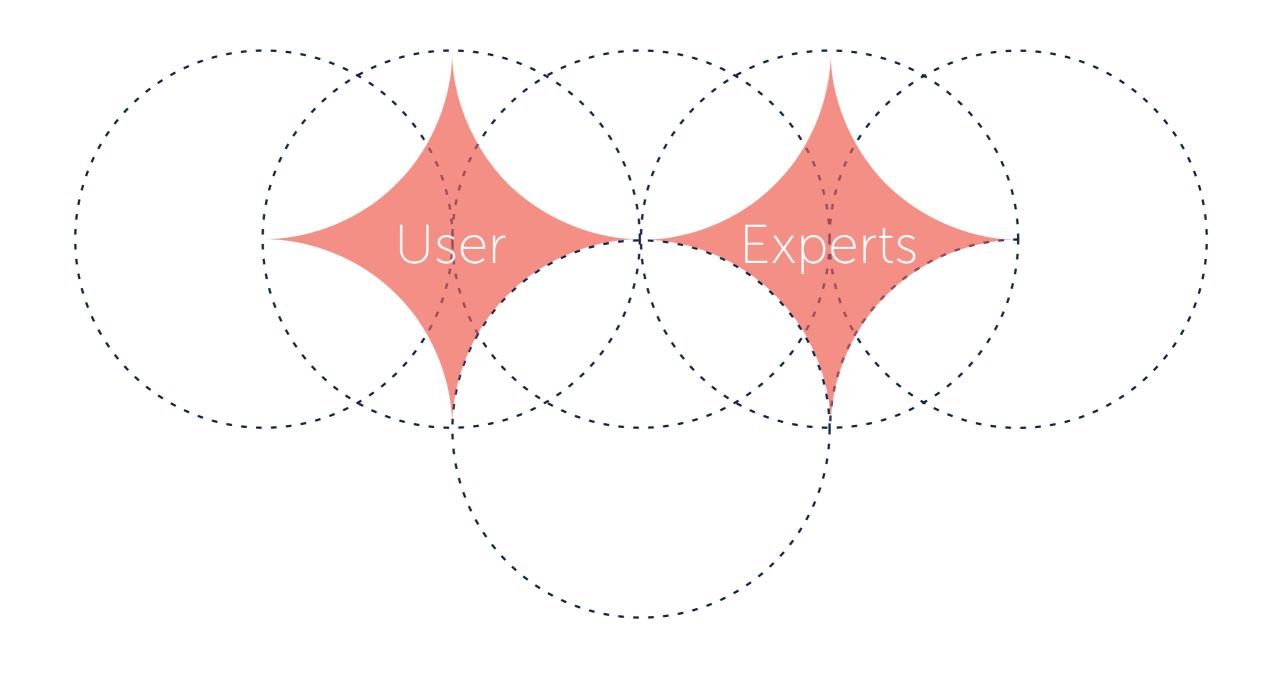
Interviews

Perception Environmental

Perception Environmental

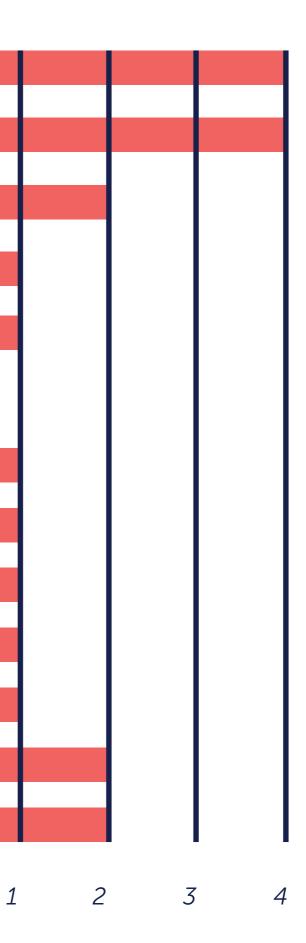




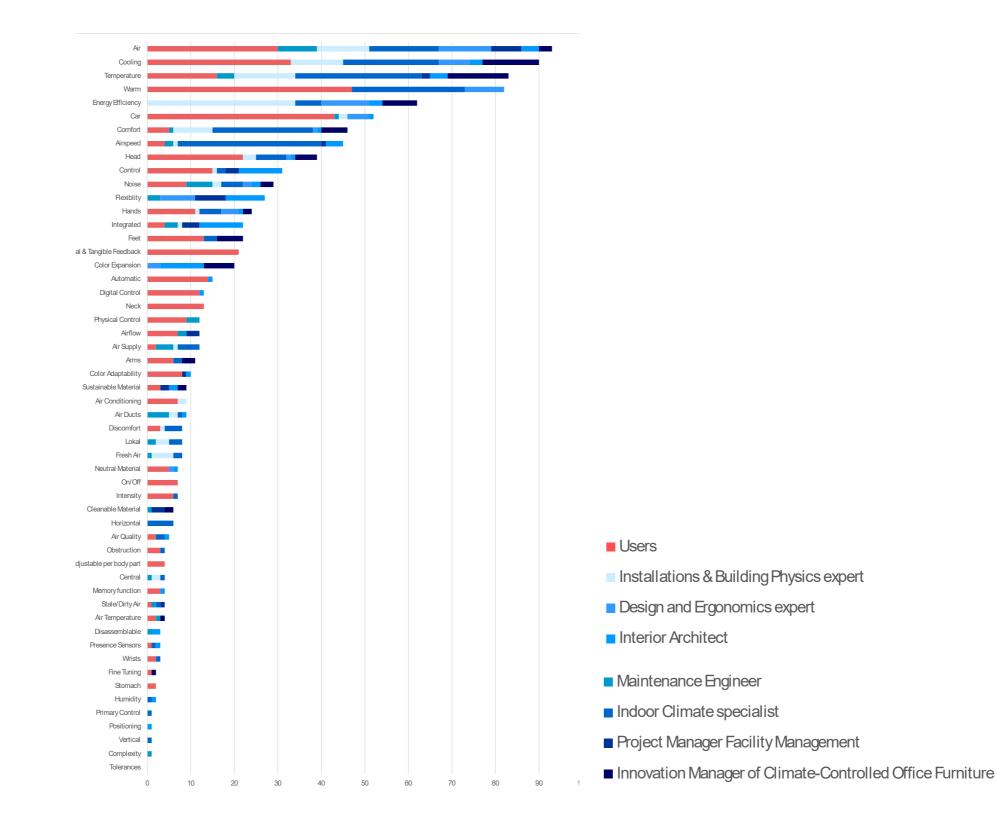


Respondents





Frequency analysis



Qualitative analysis

to those who enjor creating income desirable, but more explanations, more options are desirable, but not as the first step digitally. Users prefer a physical interface over a digital one. Users prefer a physical interface over a digital one often because they want to start immediately and often because they want to start immediately and have a strong distrust of digital or smart building systems. Super a ved about by users, interior architects, those the disting to see the disting to see

and others, everyone entry the manufacturer sustainable materials. Only how manufacturer points out that sustainable does not necessarily mean the lowest CO2 emissions at that moment, as an example, he uses of the table, the finish can be parated from the rest of the table, the finish can be removed, and a new finish applied, while the base and the majority of the tabletop remain the base and the majority of the tabletop.

All users initially prefer not consible only for the the option for vertical being possible only for the shoulder and neck. The indoor climate specialist also prefers horizontal ventilation. Another important element that must be taken into account is that the horizontal airflow should not blow away

papers. Intensity is a term used frequently by users, wiru often find the wind too intense and unpleasant. The indoor climate specialist concurs, stating that for large body areas, it's more important to ventilate the large body areas, it's more important to ventilate the same cubic meter of air but distributed over a larger surface area is preferred over selectively flowing air surface area is preferred over selectively flowing air

to specific UoOy and interior architects primary fine ergonomist and interior architects primary aim for natural materials for various reasons, including sustainability, but also because they remain relatively stable in both warm and cold remain relatively stable in both warm and cold anyironments. Think of materials like leather and

wood. Many people also associate warn temperature. With stuffy rooms/poor indoor air quality. They often reference that an open window symbolizes clean air for them. Good air quality is important, but in only applies in this application when it also involves fresh air supply. In the case of recirculation, the air quality must already be good, recirculation, the air quality must already be good.

arample.
arample.</p

INTERPORT IN TOTAL

noise is complete readom in what you want tool or not. Users are open to this product, but they also have strong opinion that it should simply be "regulated" Some correspondents prefer, just like in a car, an automatic button that adjusts it for you and when exessary. You can adjust it pourself, they want having to readjust it from one setting to another classly related to primary control, suggestions and they are they are they also have the primary opinion of the primary control, suggestions and and the primary control, suggestions and they are they are they are they are they classly related to primary control, suggestions and and they are smaller and and they are they and they are they are they are they are they and they are they are they are they are they were youp that centrally thirds only they were group that centrally thirds only they and they are primary and they are they were any that centrally thirds only they were any that central they thirds only they are the method on the primary centrol, suggestions show had negative experiences with sensors, there are mendous amount of energy. Hany is have had negative experiences with sensors, they should note her they well.

maintenances, bie design should initially not be pa of another function, both for complexity and of another function, both for complexity and sustainability reasons. On the other hand, the manufecturer argues that it's part of a tabletop, ensure it and the stance of parts and the standard of the standard of the standard of the standard comes very significant, but they're more concented about the accessibility of the control and its connection stability of the control and its connection stability of the control and its of they could see it, it would be used earlier than it if they could see it, it would be used earlier than it of they could see it, it would be used earlier than it ergonomic zone, which cannot be reached form a normal goostion, would be the ideal location to place the appointency on the ideal sourtace is taken as a reference point. They also mention that contout should be possible from the normal position but not obstic.

une houndation must be truly simple. While there can be plent simple. While there be something with law complexity to choose from the outset. Complexity can always be increased later. Many users find it important to have a simpl

builton on the systematic to have a simple on/off independently of other settings. They along with other experts, indicate that the primary control should also lie with the duesr. This primary control can, for example, be found in these but also suggests considering an additional onoption.

Interior Architect / IM = Interior Manufa

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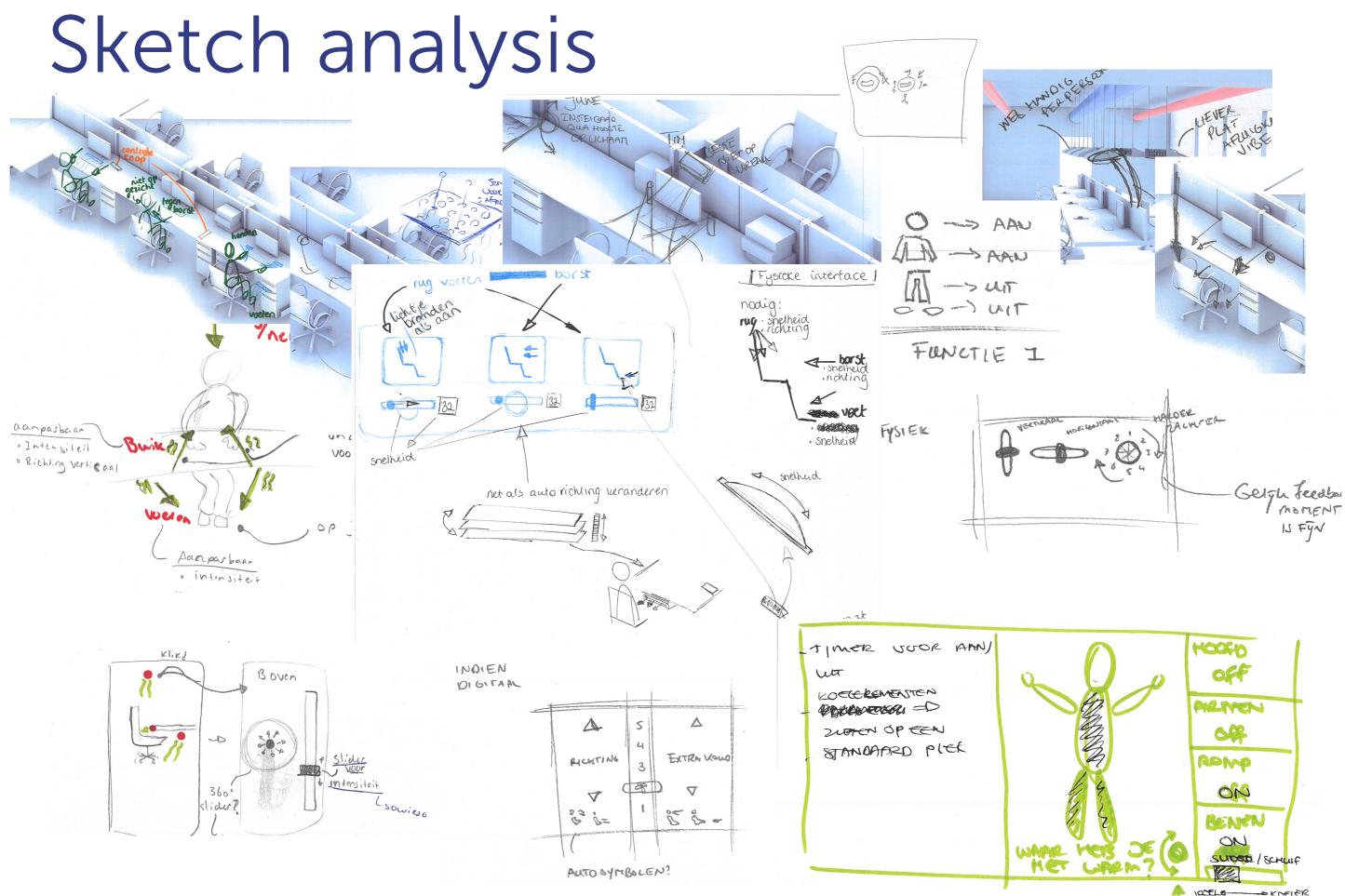
-cern for users, except controls, which they ention prefering a d by points, after ention swere divided which swere divided intons were divided to the thing users should be viding options intonly.

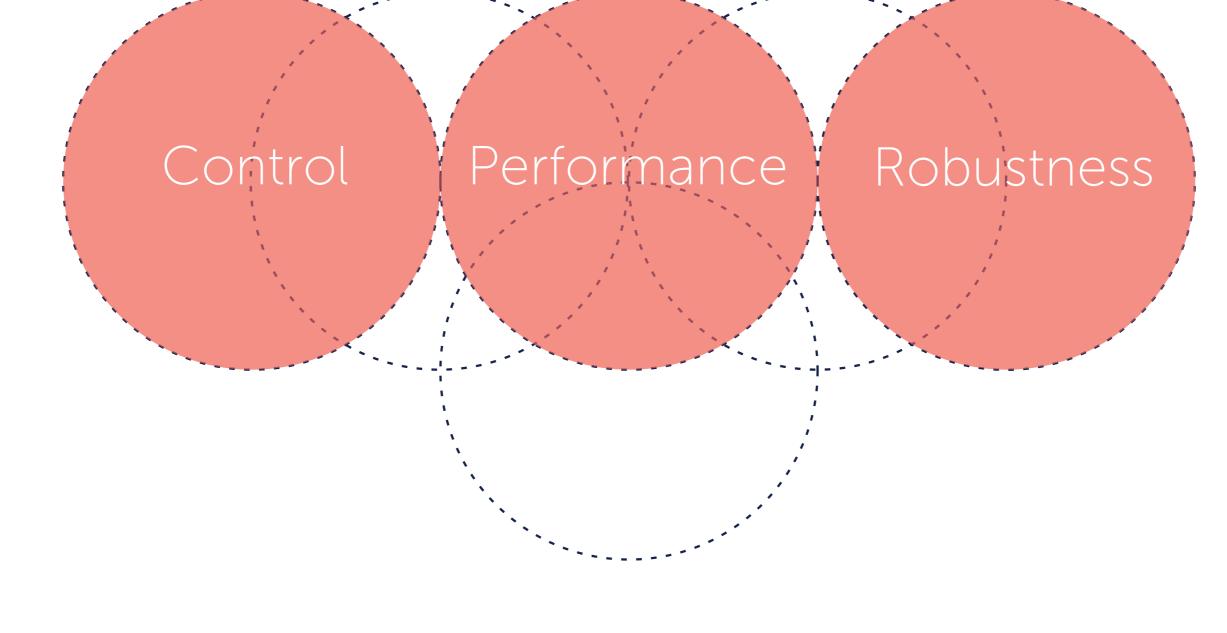
Not. Experts Id also be So, whether valls, etc., a that the

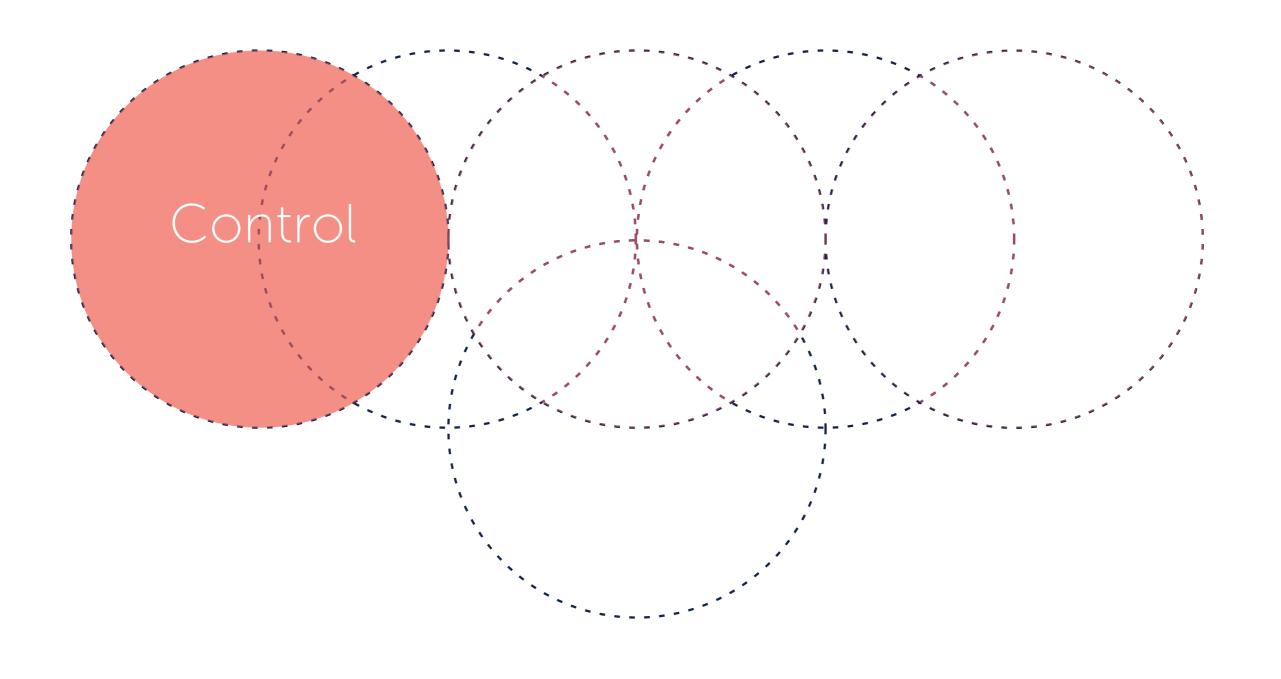
Ist t point. Ild not

Criteria	Frequency								Interpretatio	
	U	ME	IBP	IC	DE	FM	IA	Μ	Total	

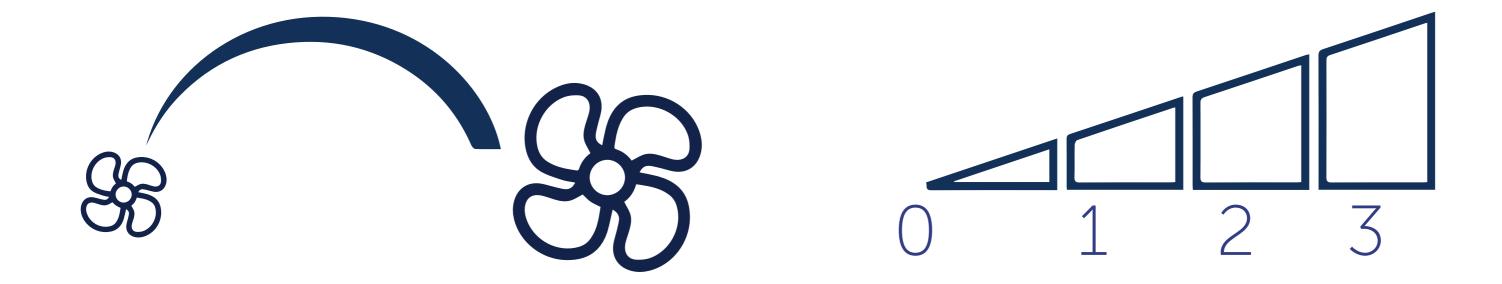
tion and Specification



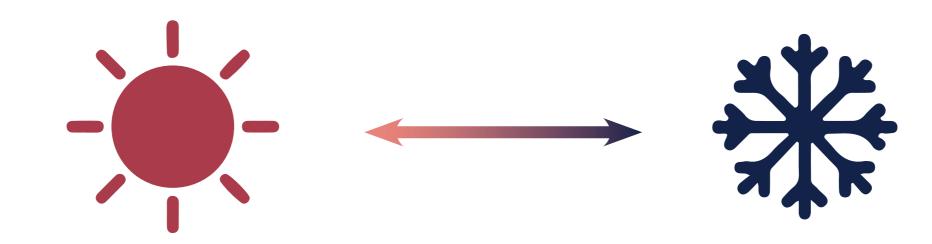








Communication





AUTO ON/OFF

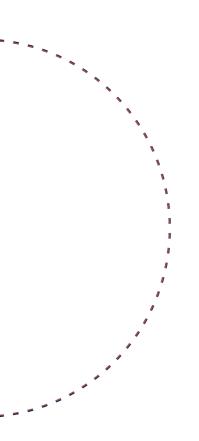
Responsiveness



Responsiveness



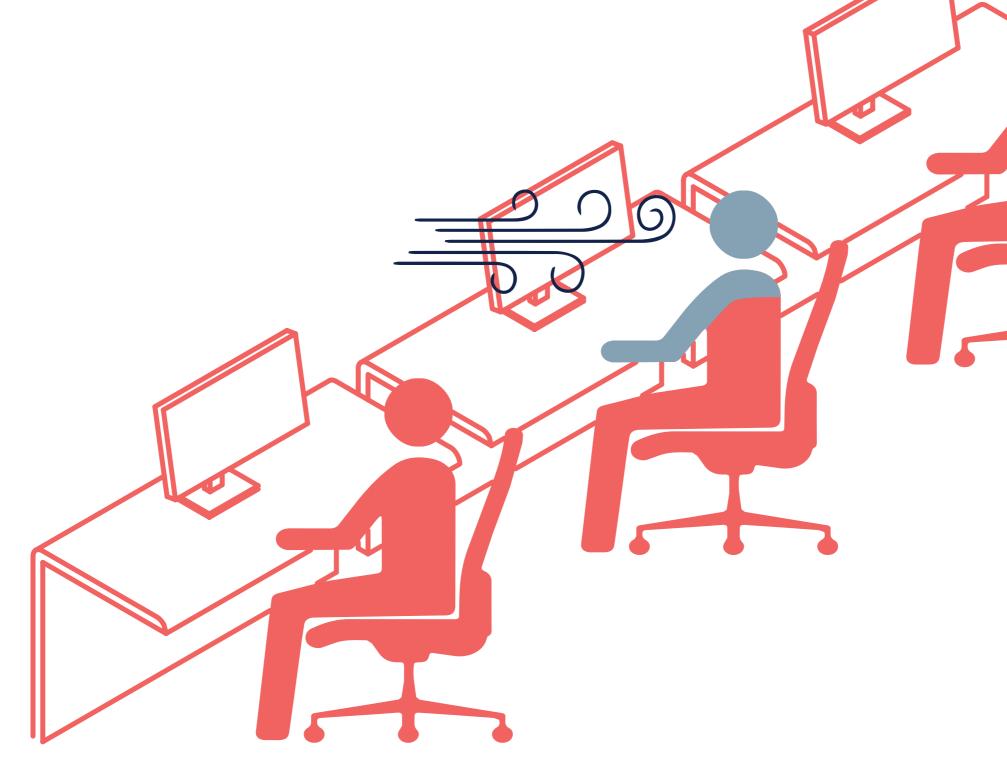
Performance



Draft felt by other occupants

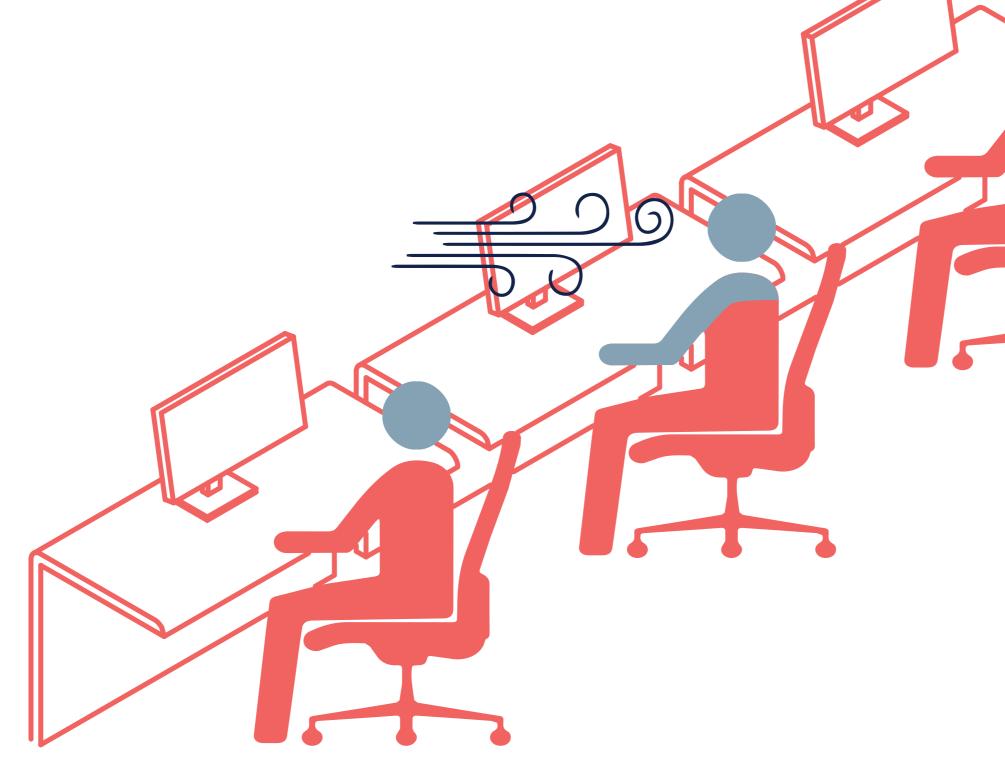


Draft felt by other occupants



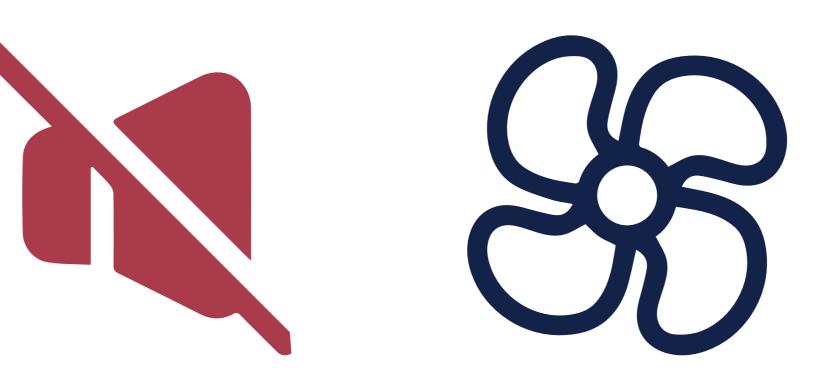


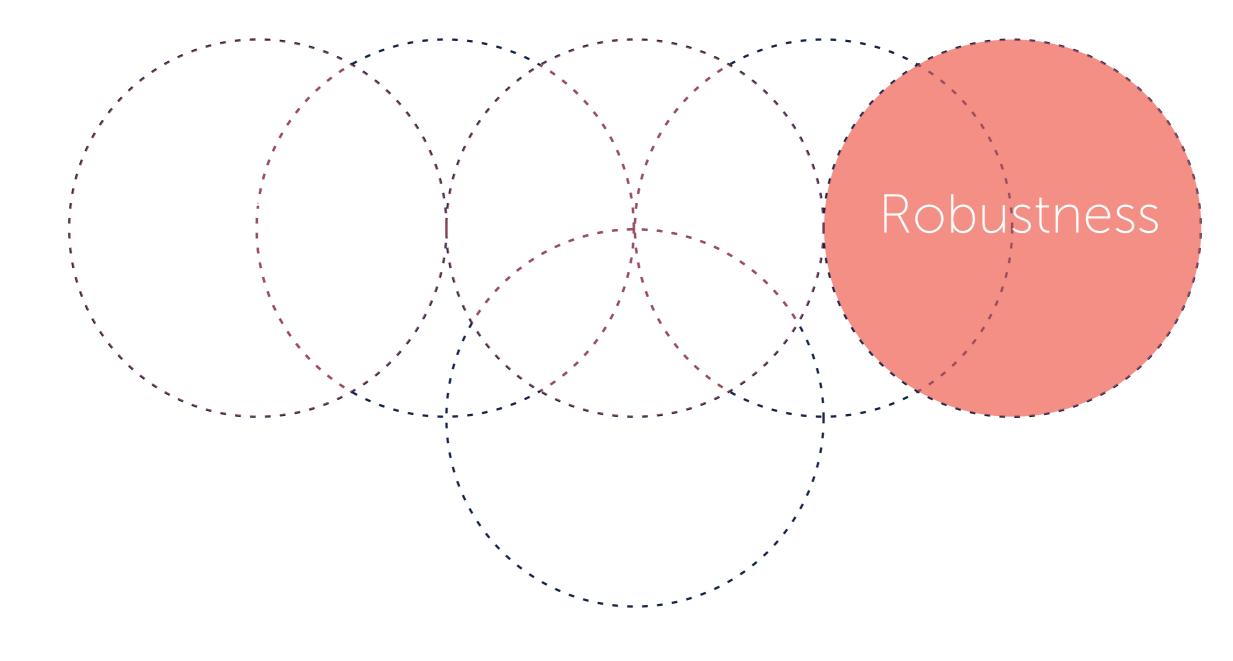
Draft felt by other occupants



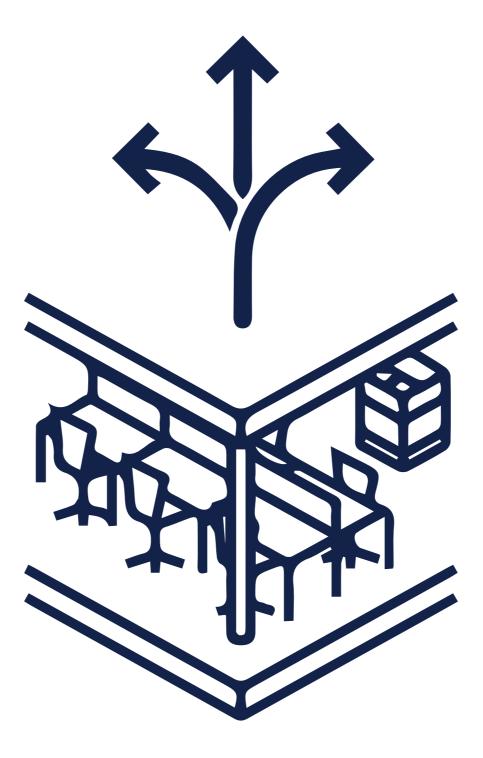


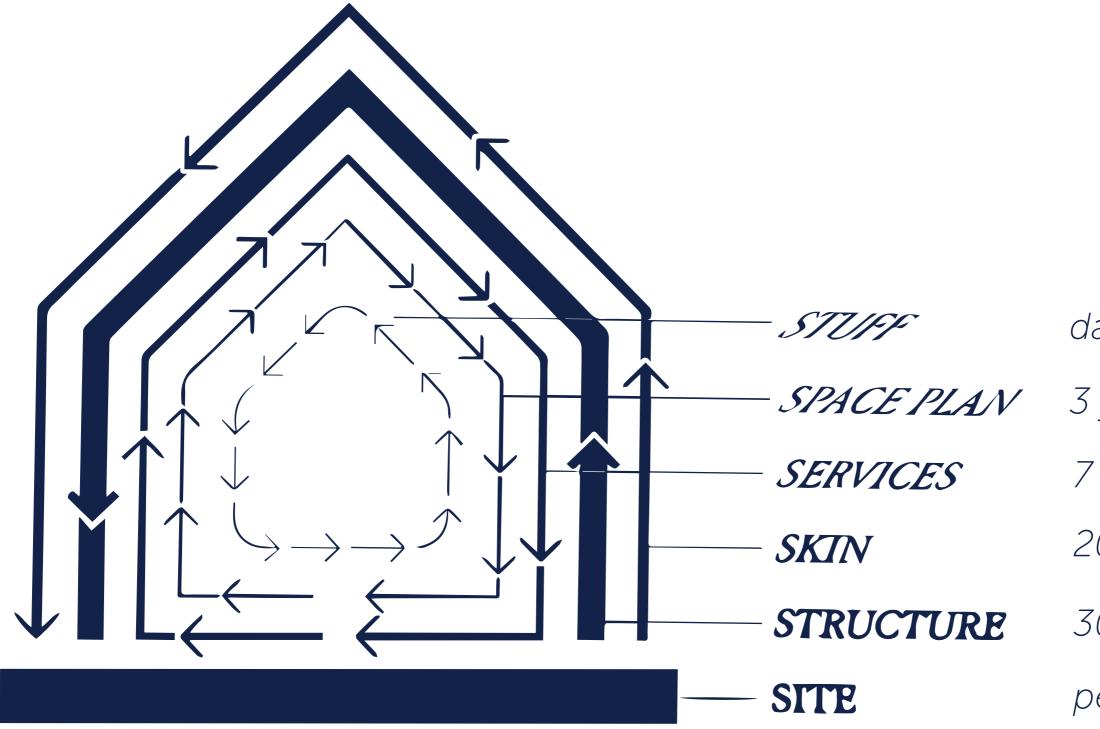
Noise





Flexibility of floorplan





daily 3 years 7 - 20 years 20 + years 30 - 300 years permanent

(Brand, 1994)

Contextual and aesthetic integration



(Melikov, 2007)



(Iwanttoleaveok, 2024)

Performance Robustness

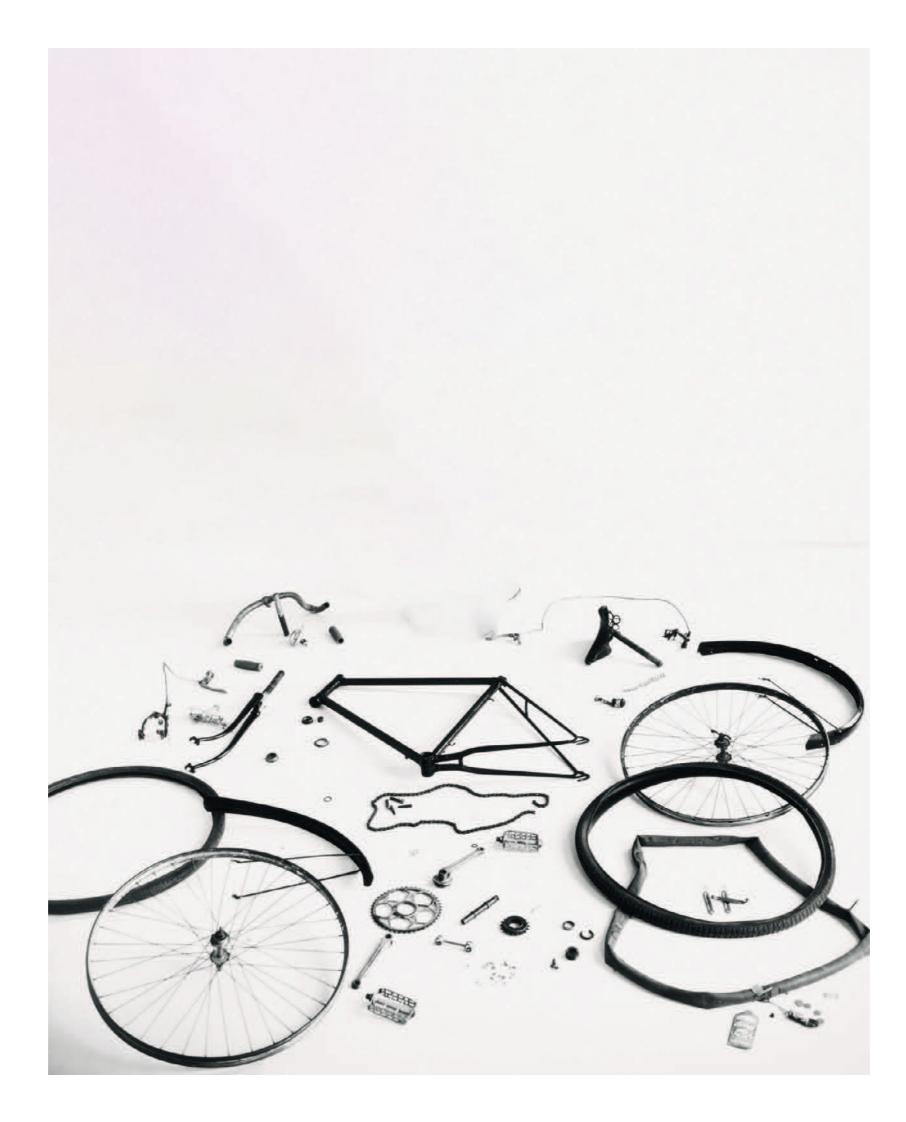
N 1 N 1 N

Contro



All factors have been identified, so we can start

e can start designing Framework



(Tati, 1949)



(Tati, 1949)



Drivers, Criteria, Requirements, and Considerations

Con	trol	Perfor	Robu	
Precize adjustable per body par	Visual & tangible feedback	Silent operation	Avoid draft felt by towards occupants	Contextual and aesthetic integration
Position the contol point in the 2nd or 3rd ergonomic zone	Communicate by using: 1. Buttons, 2. Symbols, 3. Letters/ Numbers	Position the device in the 3rd ergonomic zone or beyond	Selecting energy- efficient fan(s) to produce 1.5 m/s at user's location	Keep each layer easy to separate
Design means for finetuning airspeed	Design means for on/off function	Design means for targeting airflow to arms	Design means for targeting airflow to forehead	Base your design on a 300 mm grid or on furniture size
Design means for automated function	Provide a physical analog control interface	Add HEPA filter (if necessary)	Balancing air speed and volume by maximizing surface area output	Provide devices in multiple colors and textures
Add memory capability function	Provide a digitial interface	Design means for targeting airflow on feet	Provide automatic control of airspeed	Design the PEC as a detachable element from the building
Add presence sensors	integrate with central bulding managment system	Design means for achieving an airpower spectrum slope β≈1.8	Design means for achieving turbulence intensity between 40% - 60%	Select material with low thermal emmissivity

oustness

Flexibiltiy towards the office floorplans

Design for easy maintenance to be done by non-experts

Design for ease of dissassembly

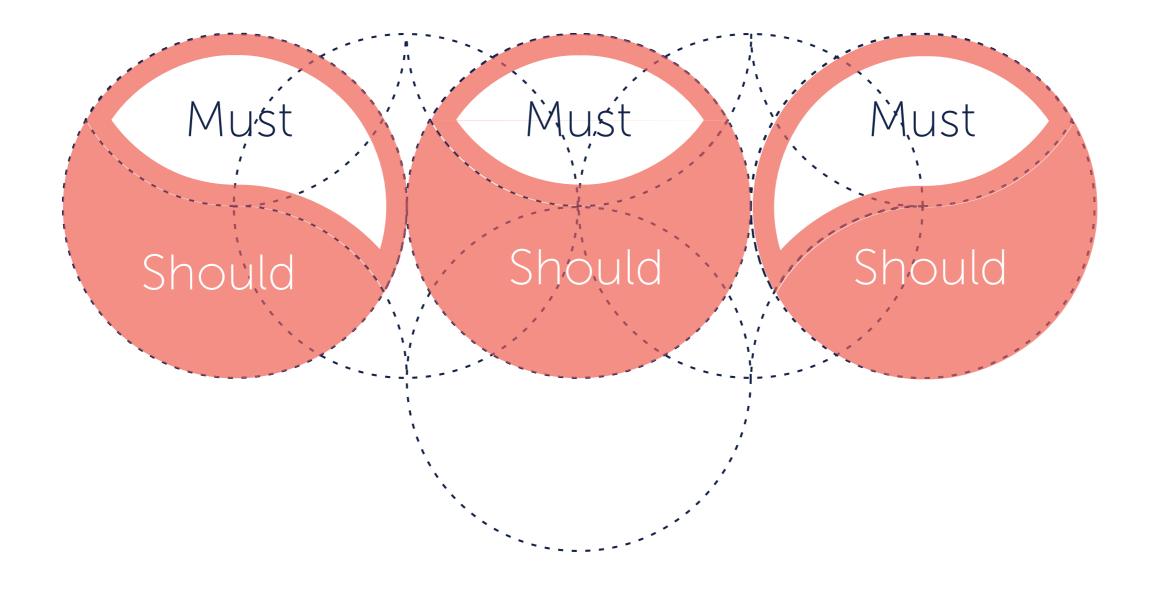
Design means to prevent dirt accumulation

Provide means for adjusting for personal selection of settings

> Select sustainable materials

Contro Robustness Performance





	Con	trol	Perfor	F	
	Precize adjustable per body par	Visual & tangible feedback	Silent operation	Avoid draft felt by towards occupants	Contextua and aesthe integration
JST	Position the contol point in the 2nd or 3rd ergonomic zone	Communicate by using: 1. Buttons, 2. Symbols, 3. Letters/ Numbers	Position the device in the 3rd ergonomic zone or beyond	Selecting energy- efficient fan(s) to produce 1.5 m/s at user's location	Keep each layer easy separate
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SHOULD -	Design means for automated function	Provide a physical analog control interface	Add HEPA filter (if necessary)	Balancing air speed and volume by maximizing surface area output	Provide devices ir multiple col and textur
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Robustness

extual esthetic ration

each easy to arate Flexibiltiy towards the office floorplans

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gn C as chable nt from uilding

ect al with nermal issivity Design for ease of dissassembly

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> Select sustainable materials

Criteria -11 -13 -1-3 Requirements Requirements Requirements ----Criteria Criteria >

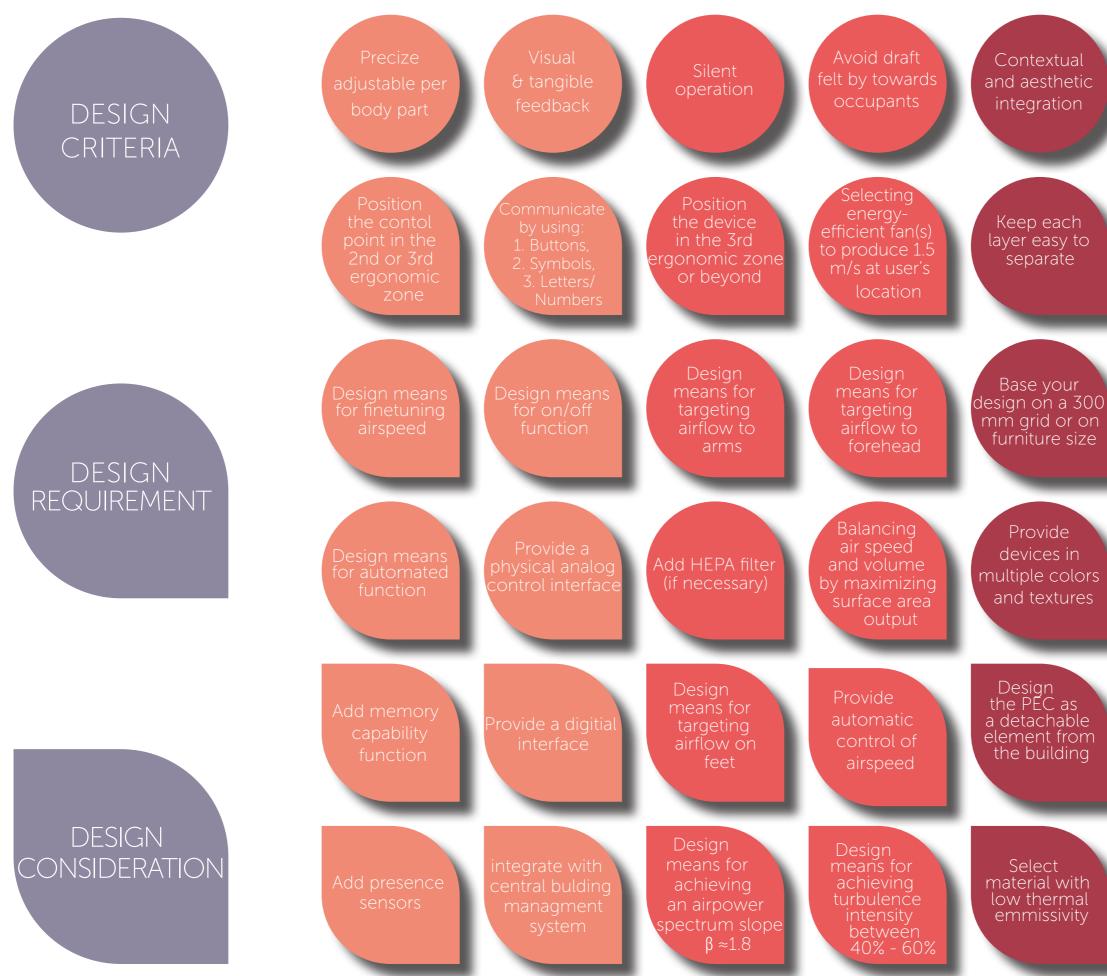
Considerations Considerations

Considerations



Control

Performance



Robustness

Flexibiltiy towards the office floorplans

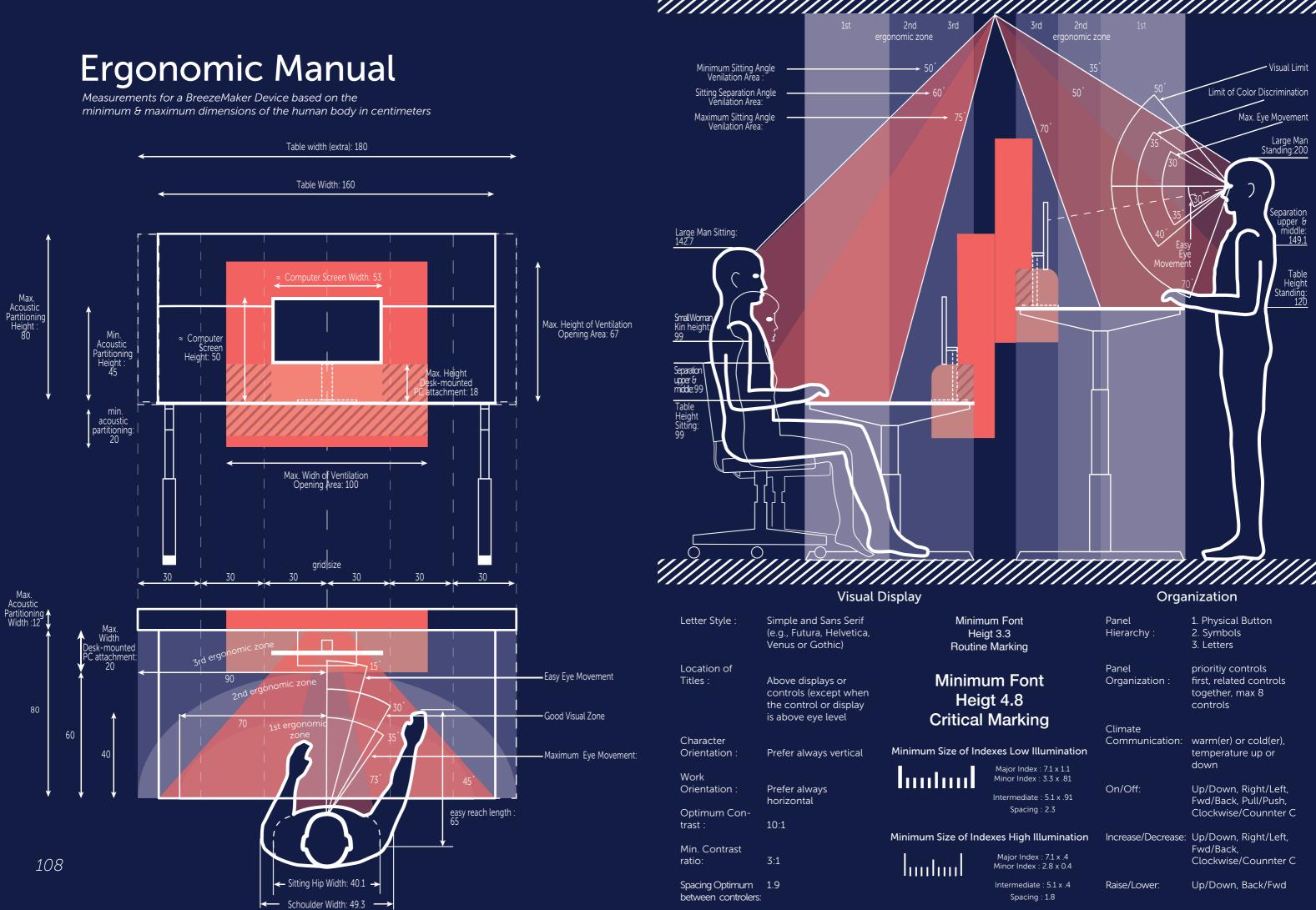
Design for easy maintenance to be done by non-experts

Design for ease of dissassembly

Design means to prevent dirt accumulation

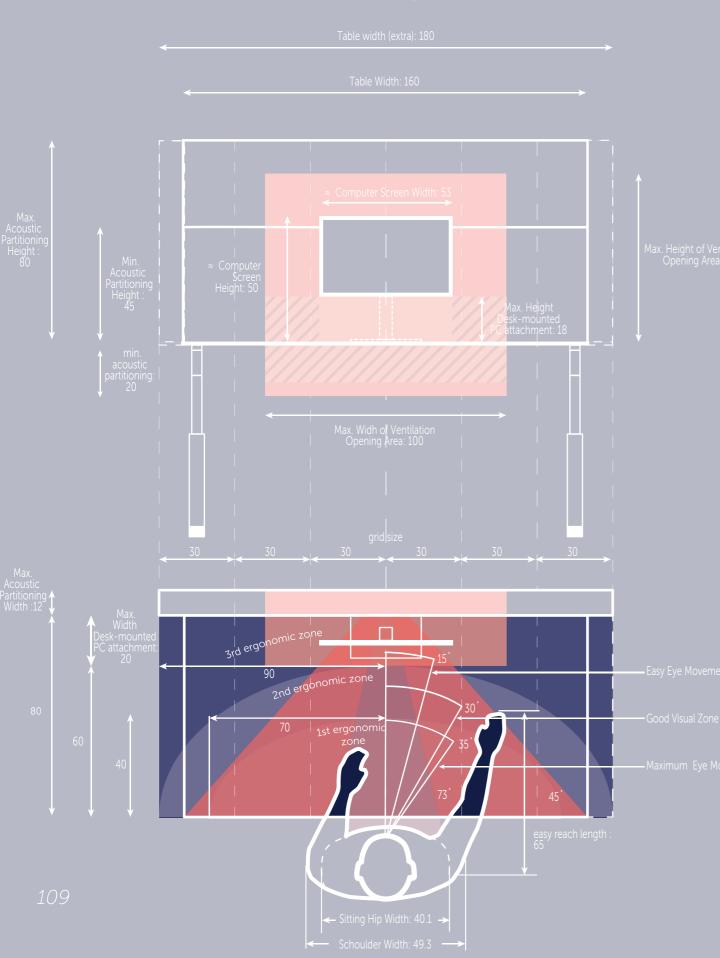
Provide means for adjusting for personal selection of settings

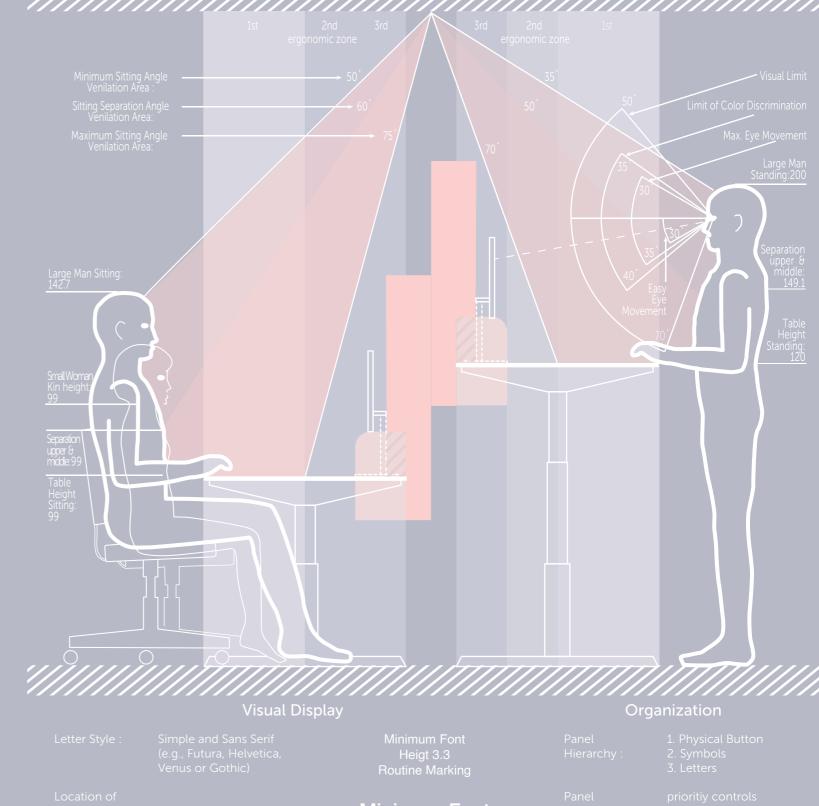
> Select sustainable materials



Ergonomic Manual

Measurements for a BreezeMaker Device based on the minimum & maximum dimensions of the human body in centimeters





Heigt 4.8 **Critical Marking**

huntum

Minimum Font

Application of the Framework



Morphological Chart Method

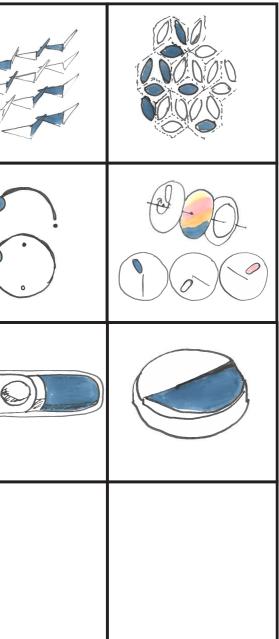
Morphological Chart Method

Design Requirement 1	Variation 1	Variation 2	Variation 3	etc		
Design Requirement 2	Variation 1	Variation 2	Variation 3			
Design Requirement 3	Variation 1	Variation 2	Variation 3	Variation 4	Variation 5	Variation 6

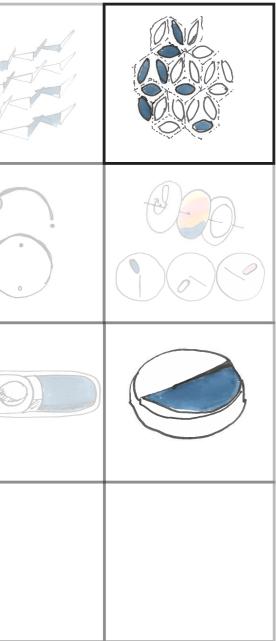


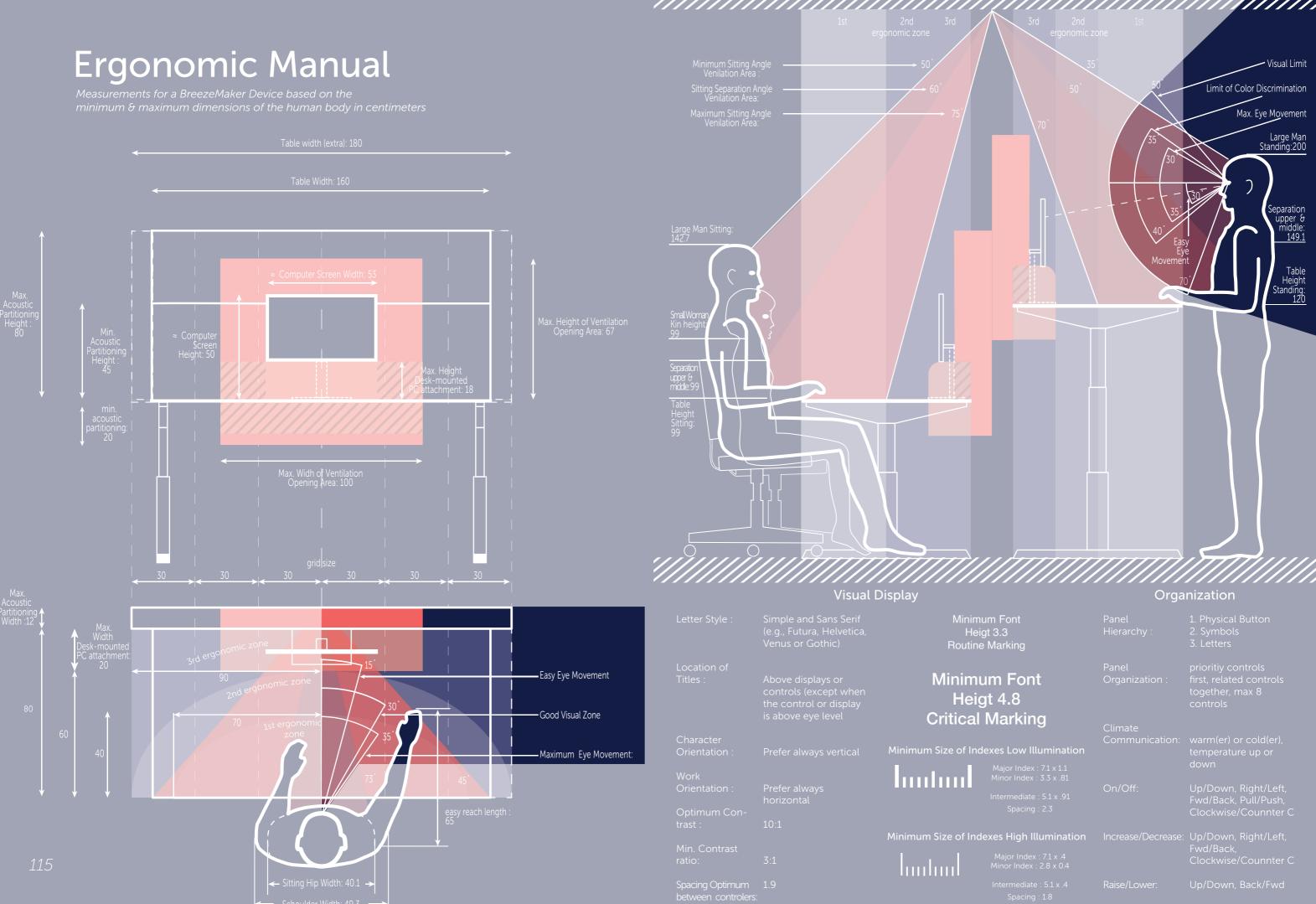
Variation 7

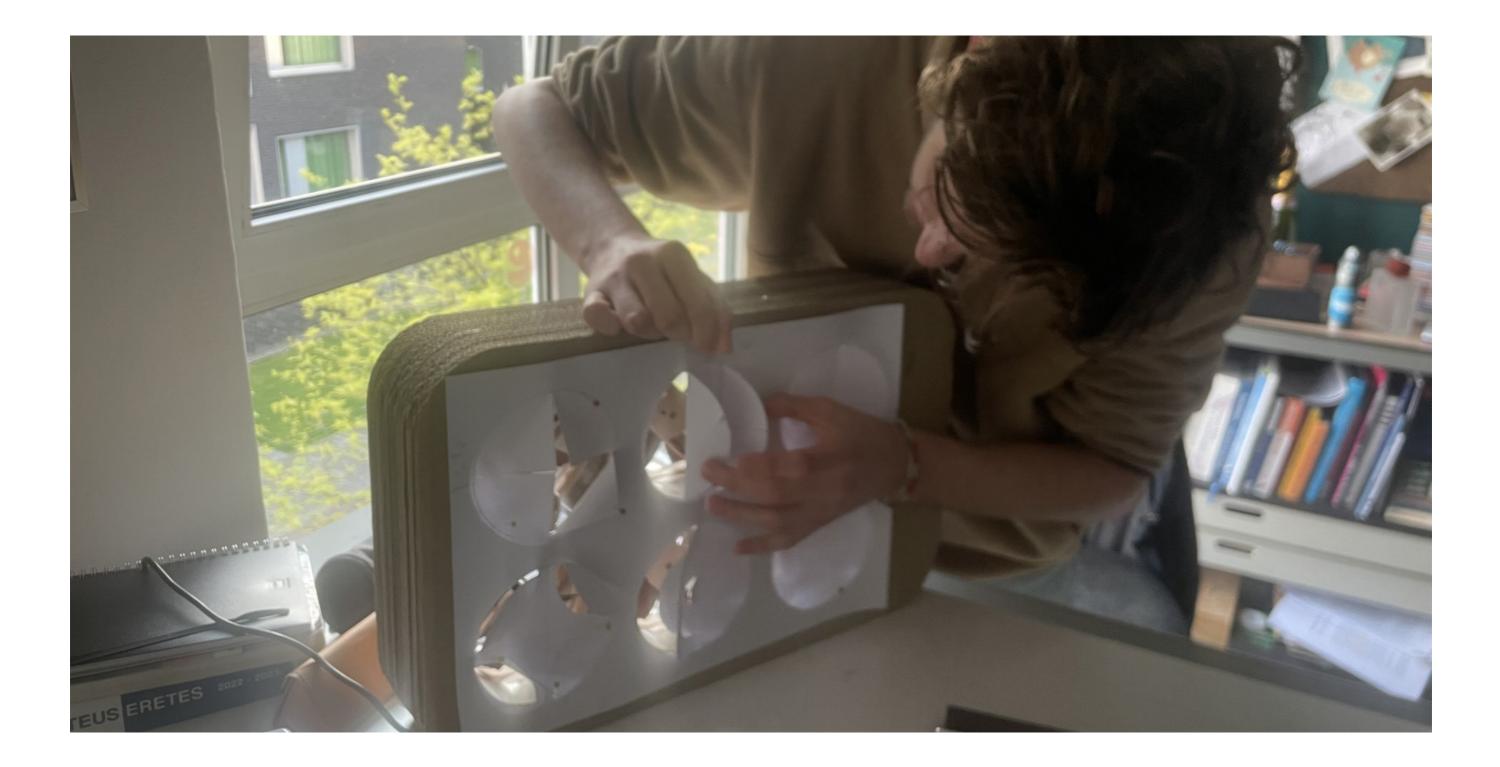
Physical Interface		~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~			
Finetuning				A REAL PROPERTY OF A REAL PROPER	
On/Off	on and alf		•		
Automatic preset funtion	on Afauto			HAND OPF ALTO	

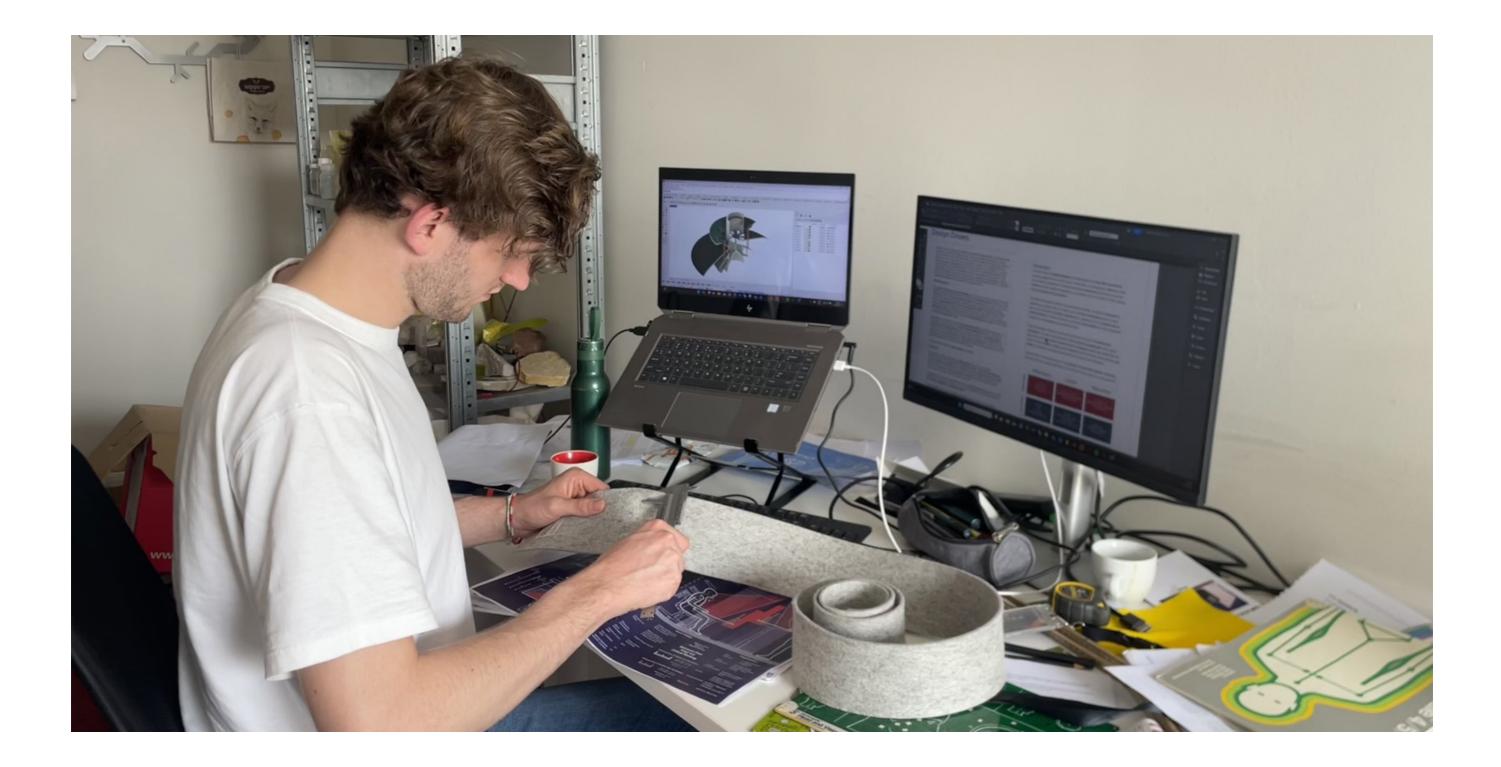


Physical Interface					
Finetuning				A STATE OF	
On/Off	on and off	0	•		
Automatic preset funtion	on auto			HAND OPF ALTO	







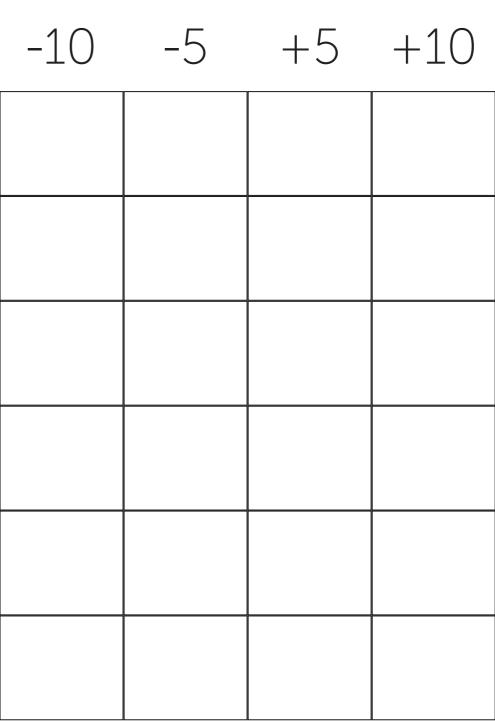


How do you determine which

variant is the best?

Harris profile

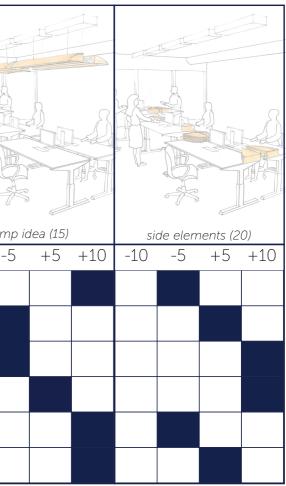
Design Criteria 1 Design Criteria 2 Design Criteria 3 Design Criteria 4 Design Criteria 5 Design Criteria 6



	-10	-5	+5	+1(
Silent operation				
Avoid Draft felt by Others				
Precize Adjustable per Body Part				
Visual & Tangible Feedback				
Cont. and Aesthic integration				
Flexibiltiy towards the office floorplans				



Airflow on Arms		ndar th	e desk (on(35)		full	3rd erg			flow	under p				under p		n (15)		lamp
	-10	-5	+5	+10	-10	-5	+5	+10	-10	-5	+5	+10	-10	-5	+5	+10	-10	-5	+5	+10	-10	-5
Noiseless																						
No Draft felt by Others																						
Precize Adjustable per Body Part																						
Visual & Tangible Feedback																						
Visually Integrated																						
Limitless office space Flexibllity																						



Deskmounted

Partition element

Ceiling mounted

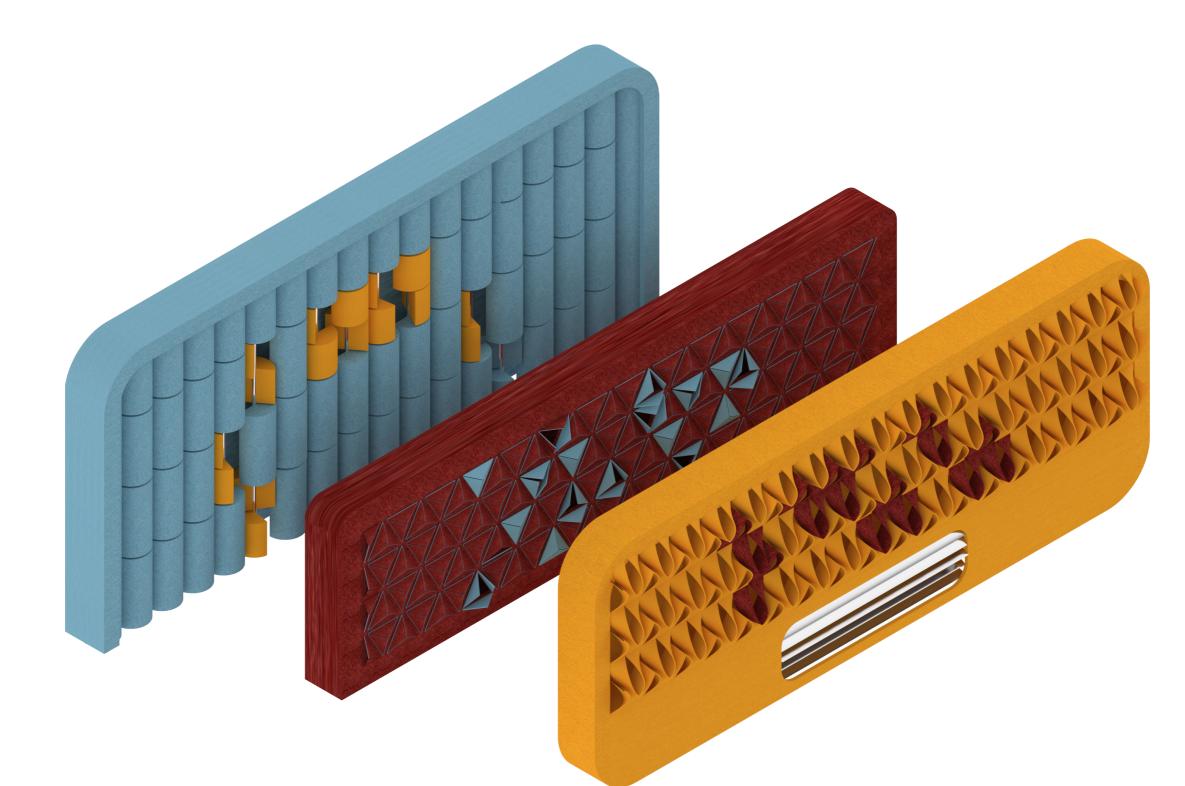


Deskmounted element

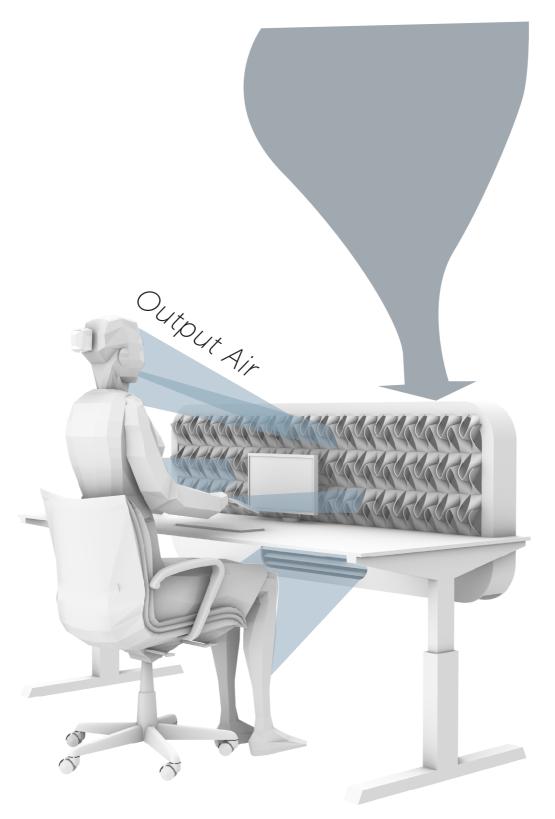




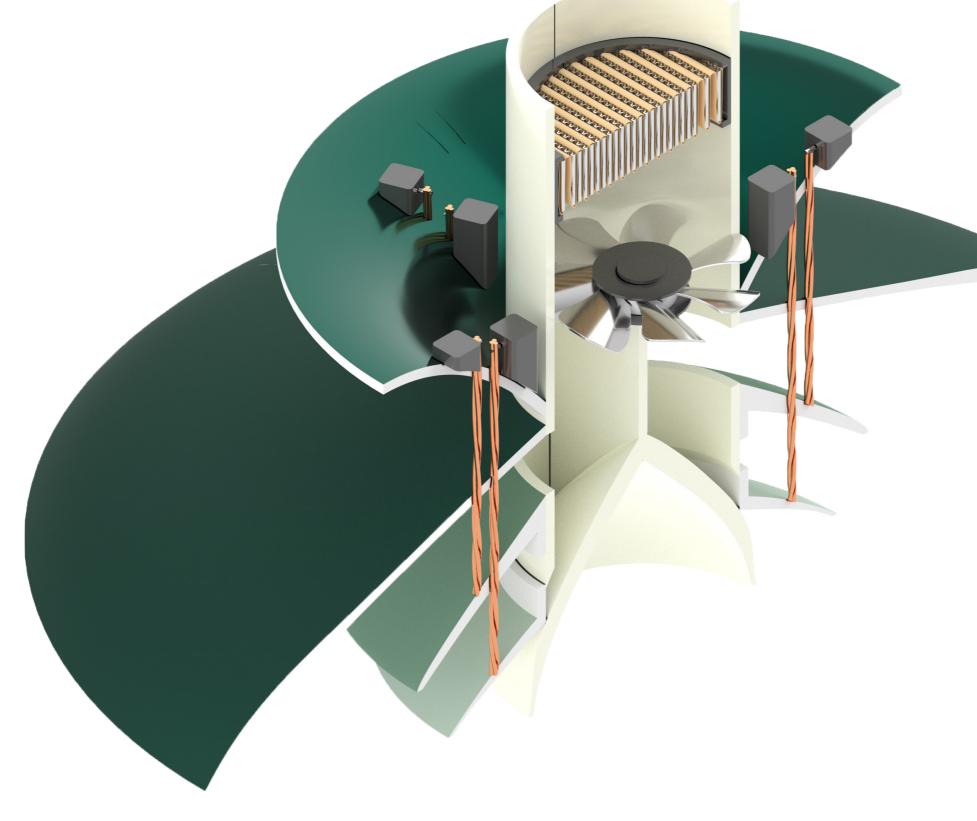
Partition element



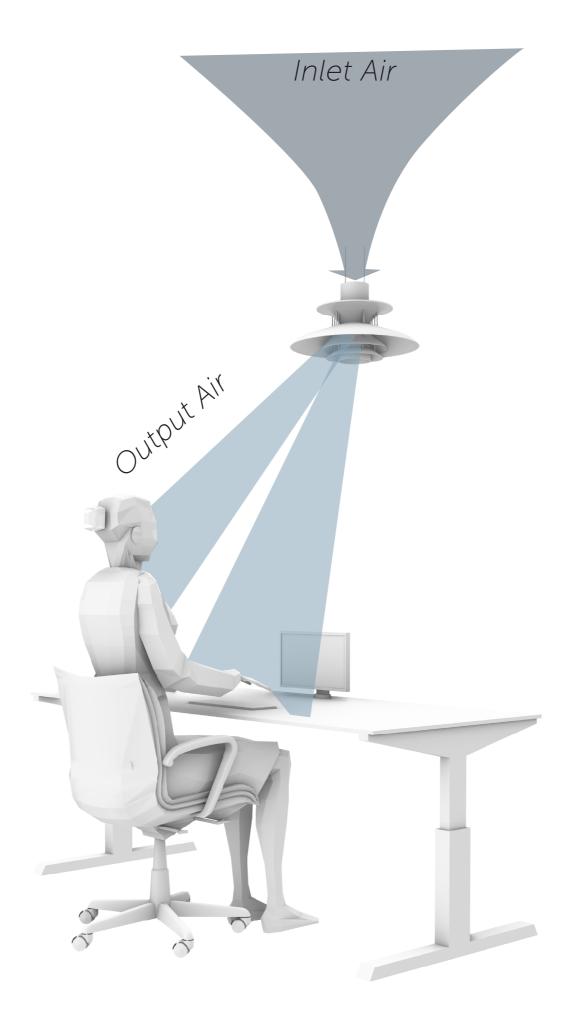
Inlet Air



Ceiling mounted element

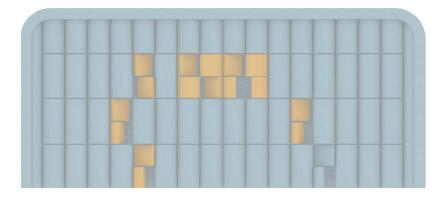




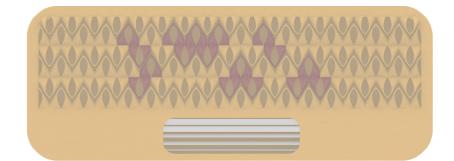




Final Design







Conclusion & Final Design

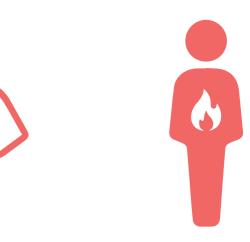
Research question

How can we develop an evidence-based framework to implement personalized air velocity for occupants in open-plan offices during summer and design an effective solution?

Perception Environmental

Behaviour

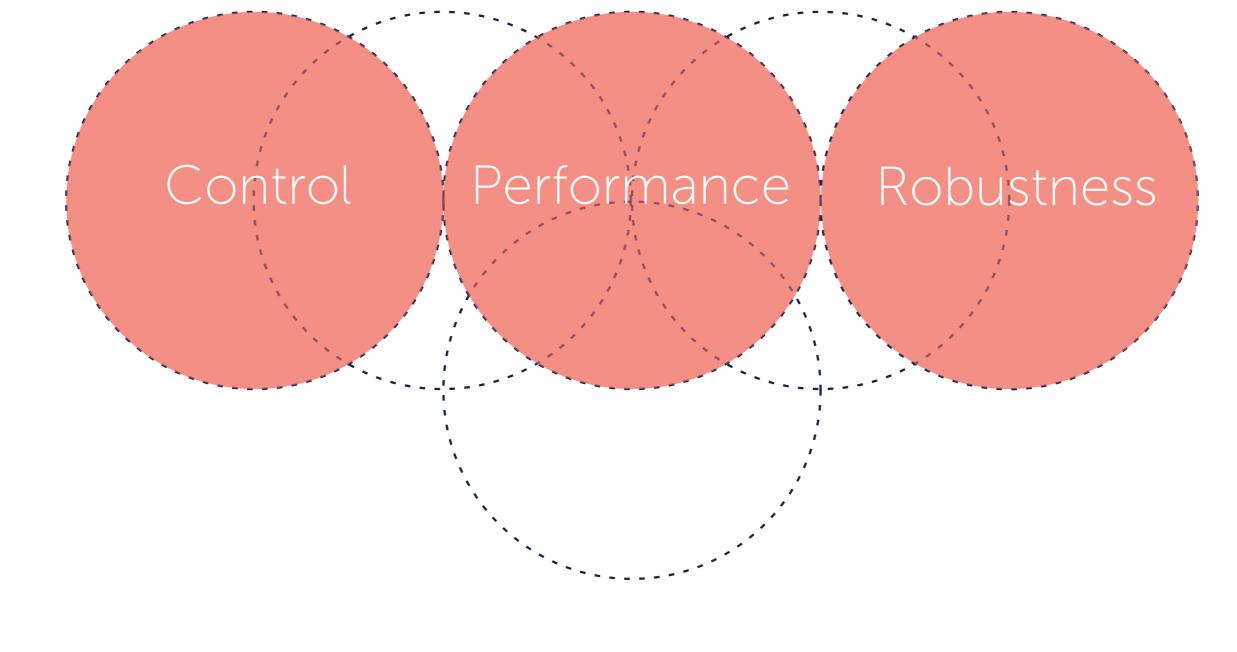
Operative Temperature (°C)	Relative Humidity (%)	Airspeed (m/s)	Clothing Insulation (clo)
24-30 °C	40 -60%	0.2 - 1.5 m/s	0.6 clo

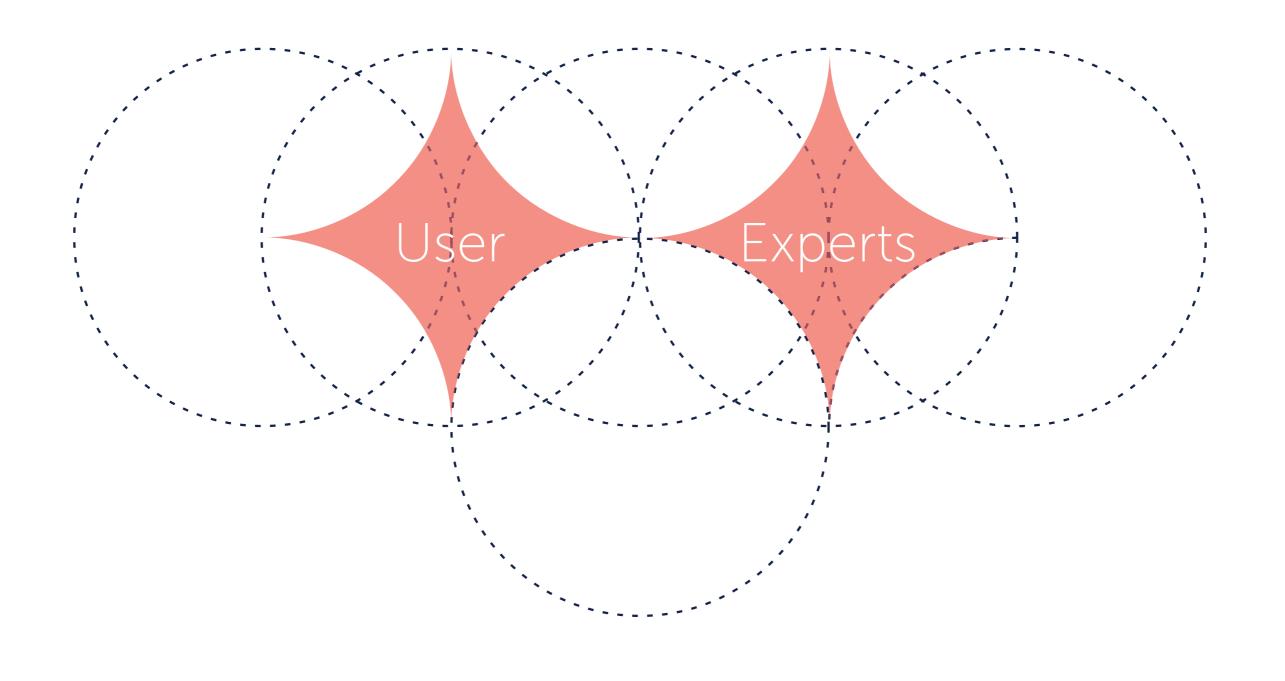


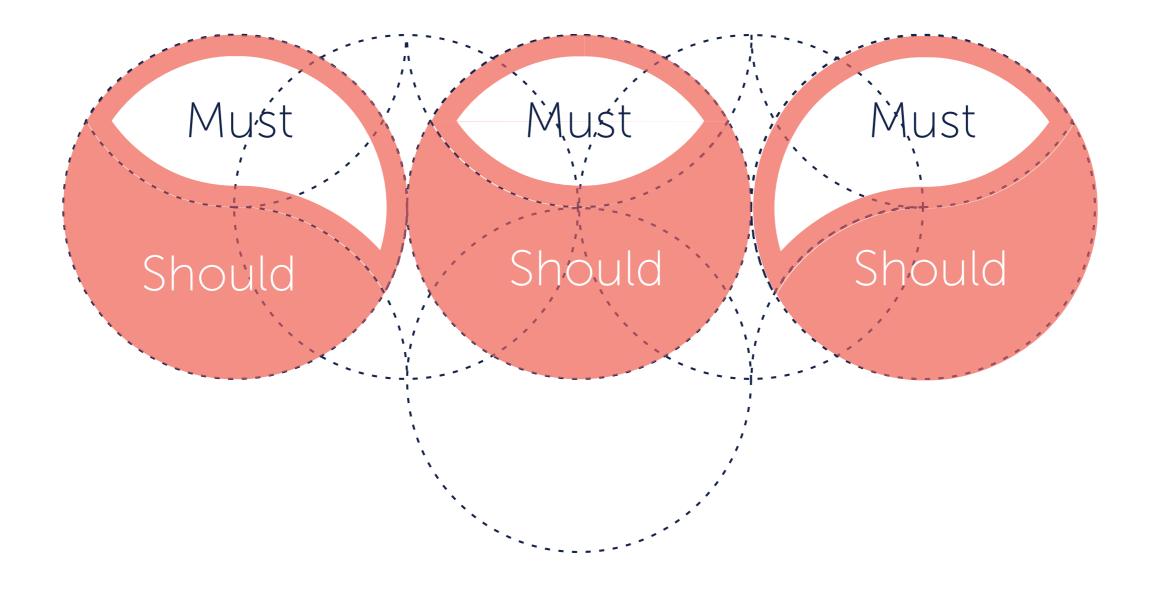


Metabolic Rate (met)

1 - 1.4 met





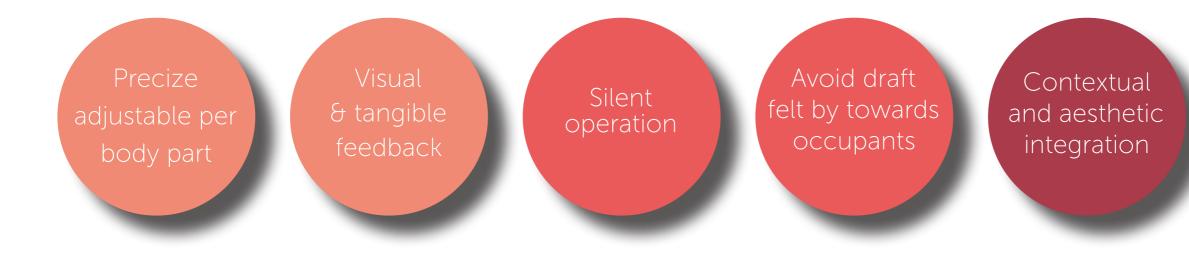


Criteria - N - I N - I - N Requirements Requirements Requirements ----Criteria Criteria Considerations Considerations Considerations



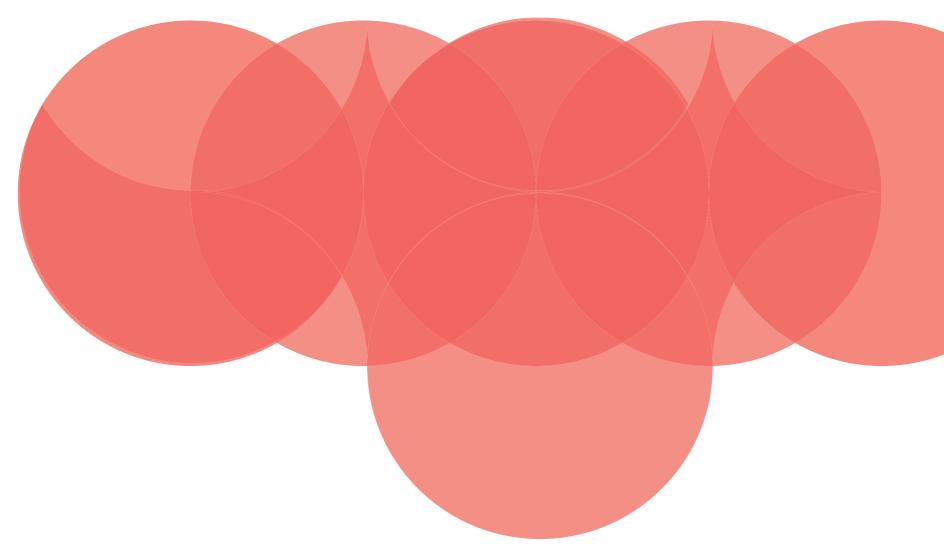
Control

Performance



Robustness

Flexibiltiy towards the office floorplans

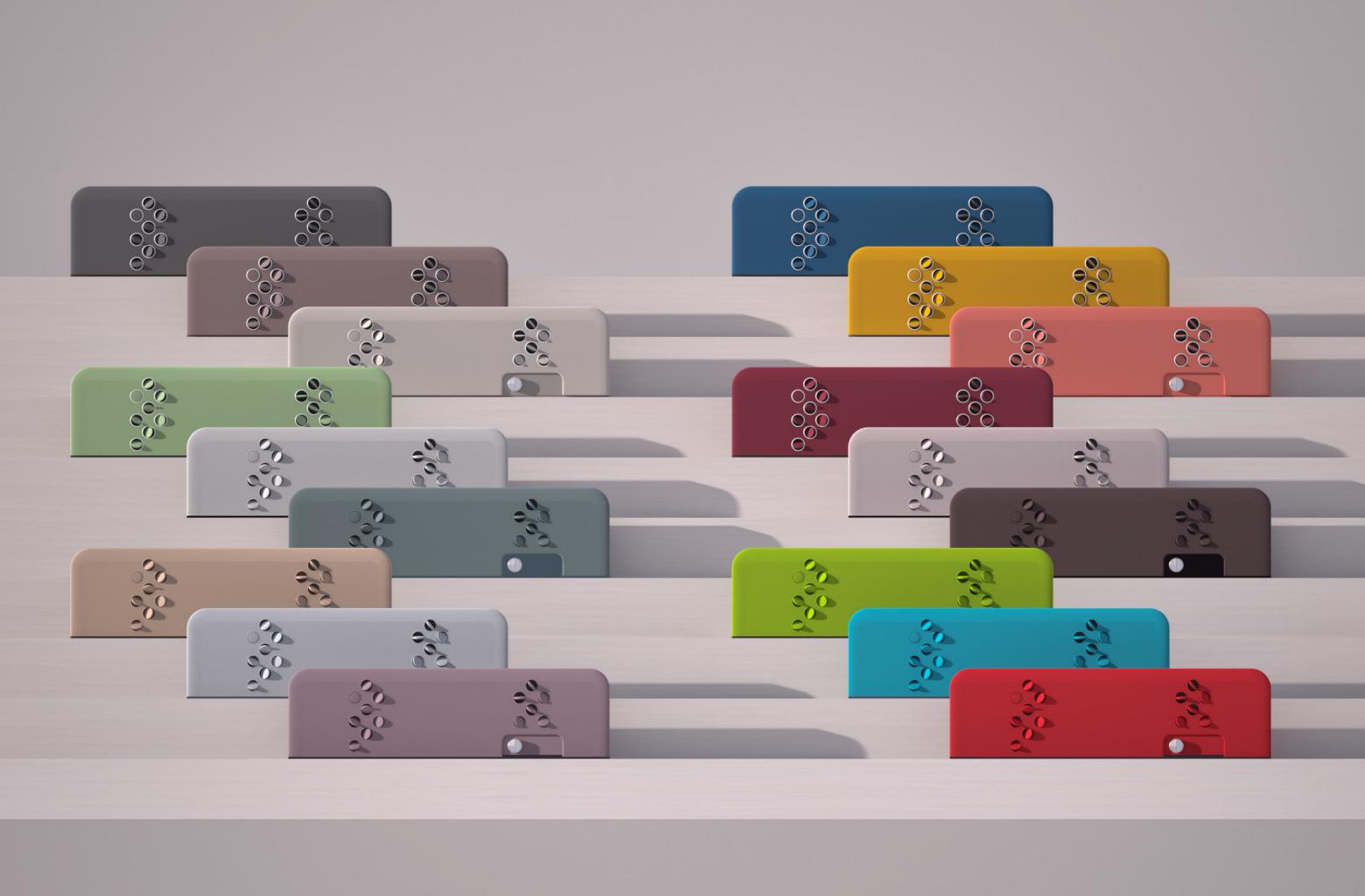


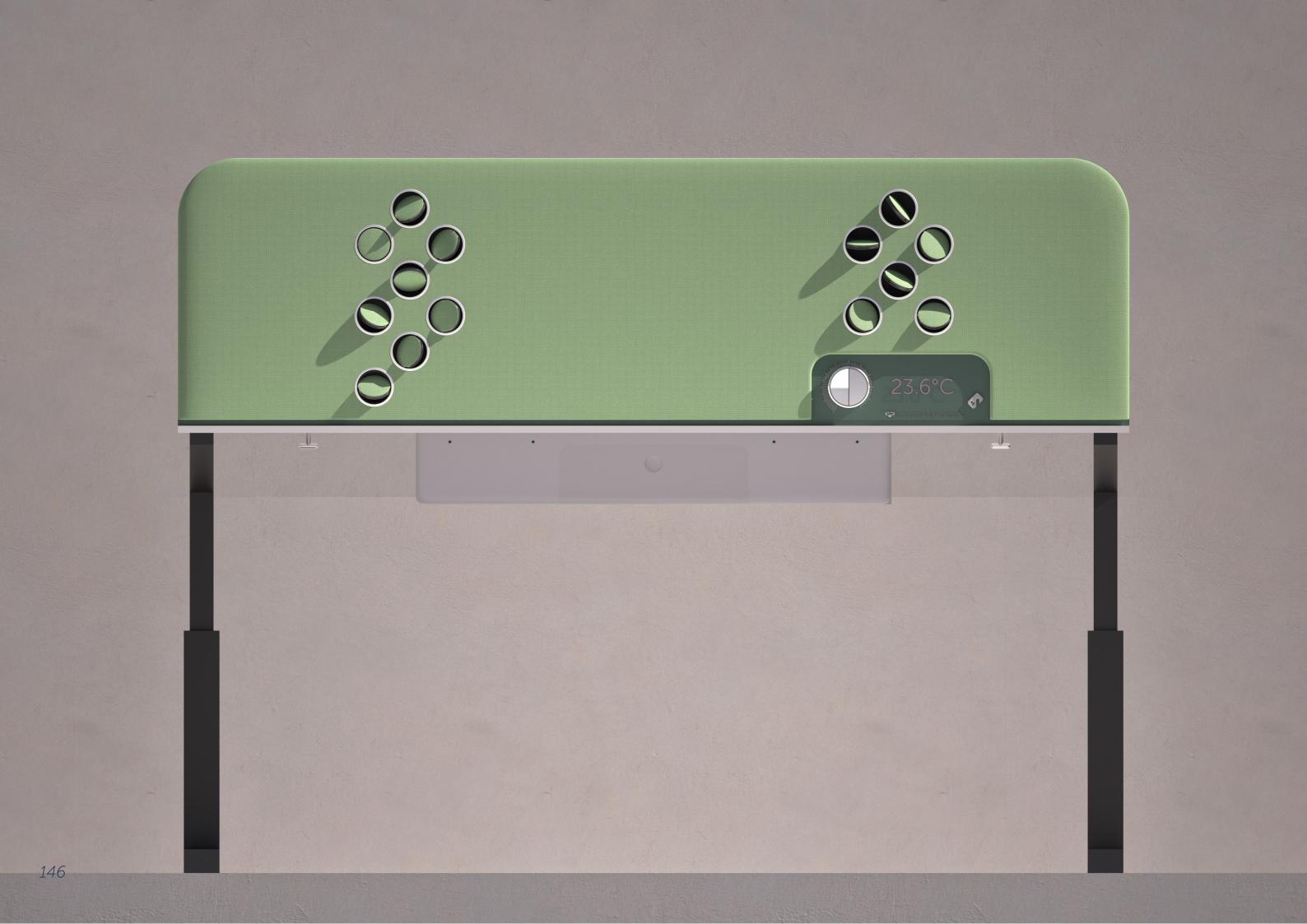


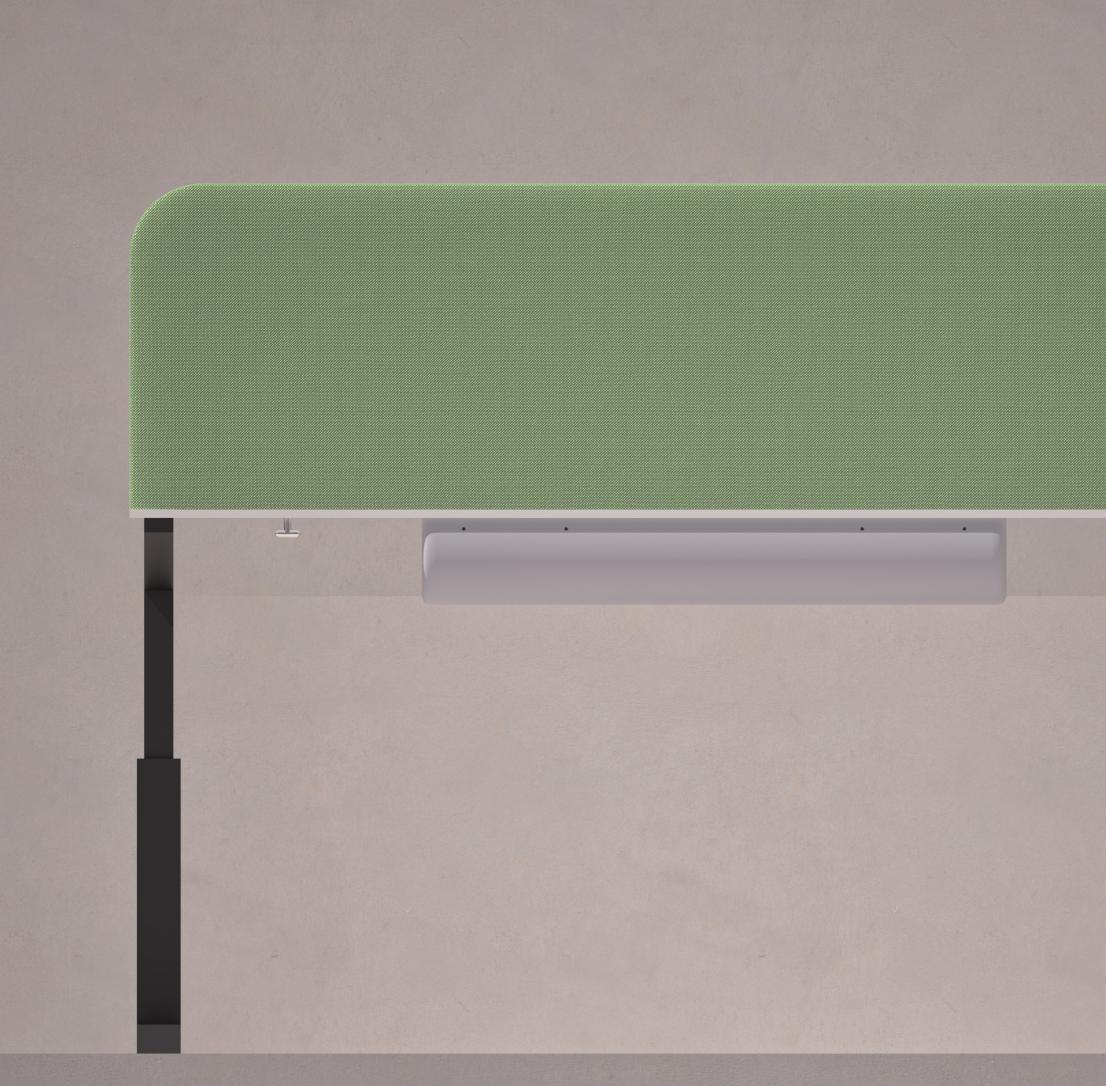




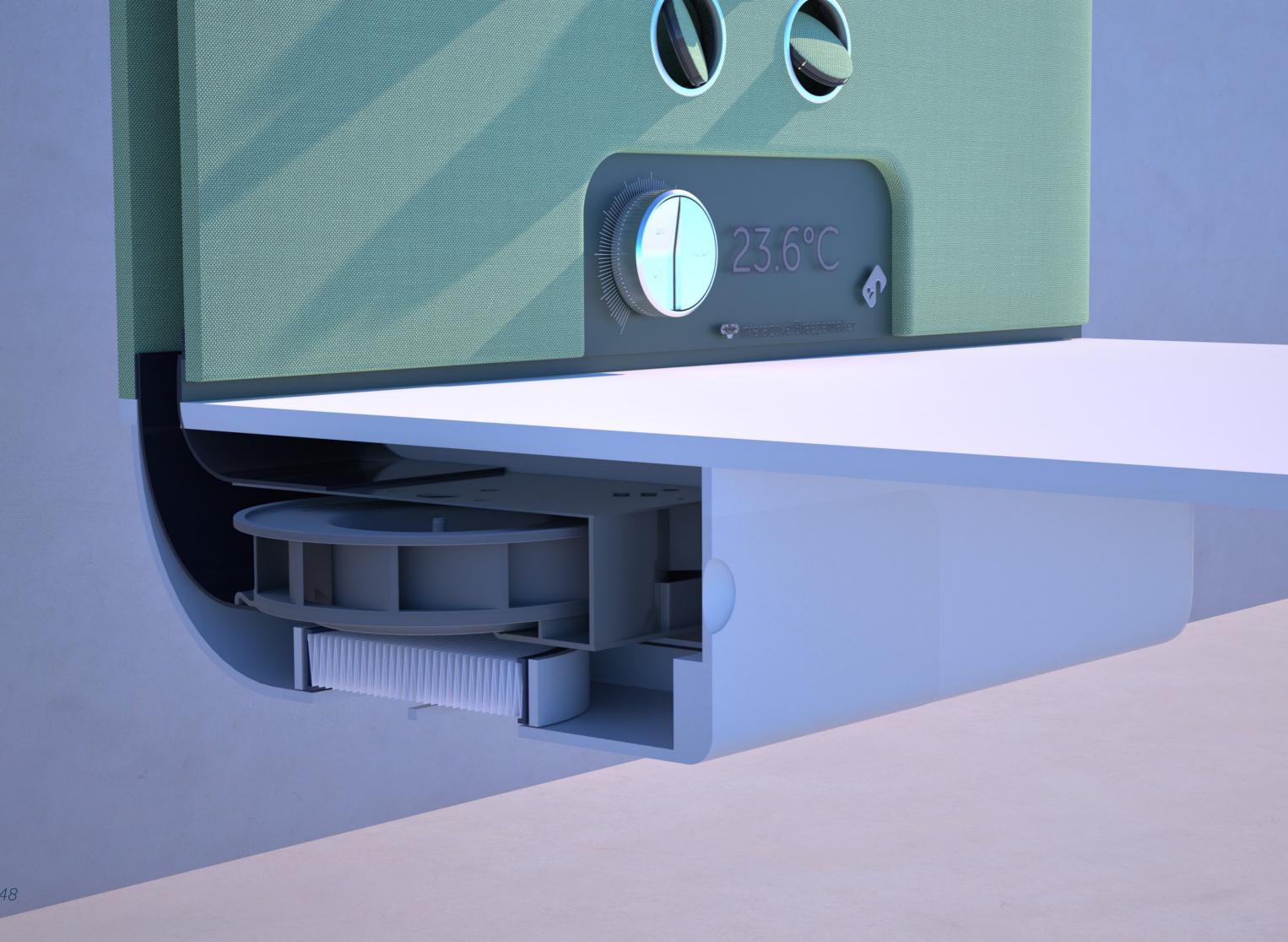


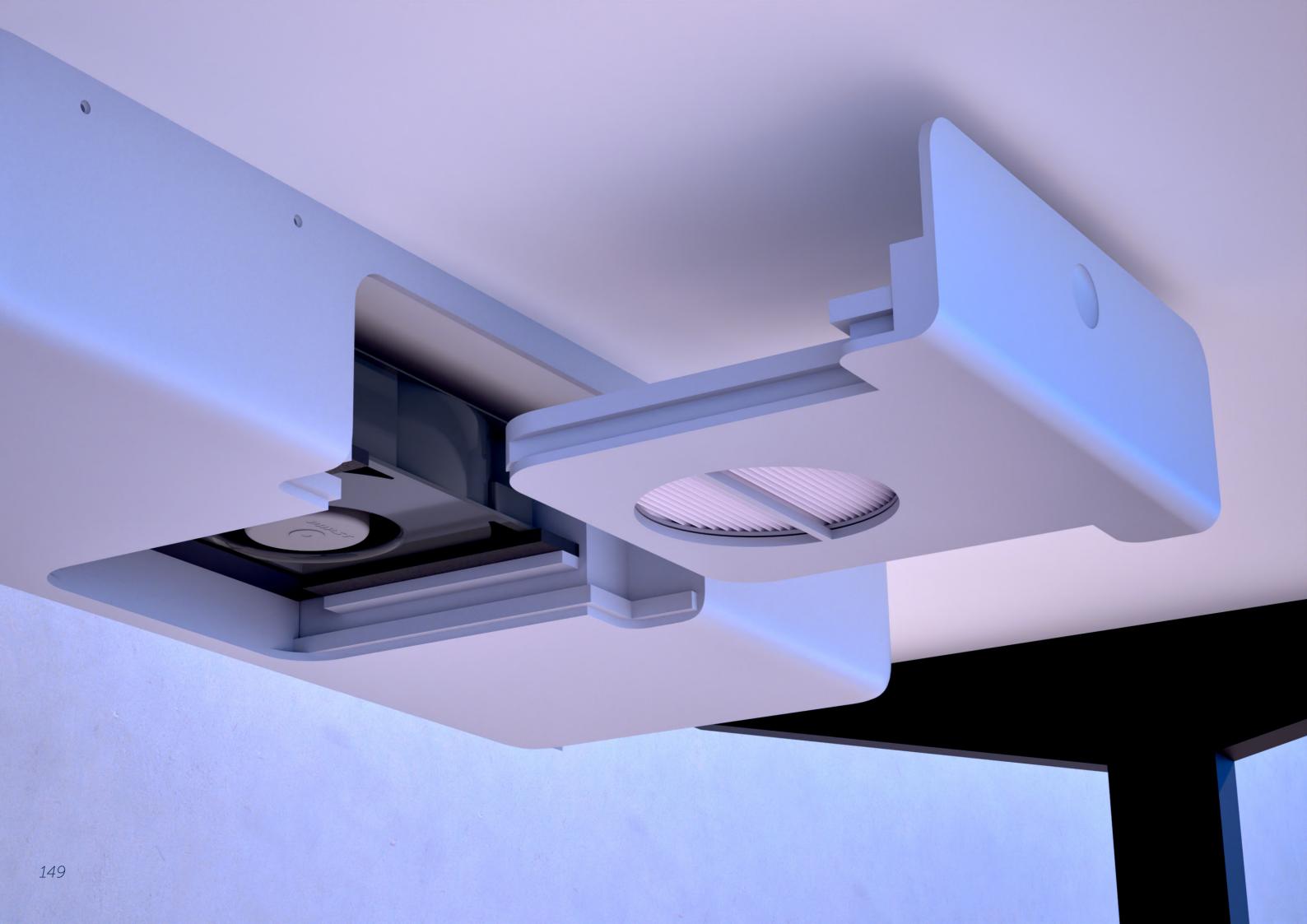


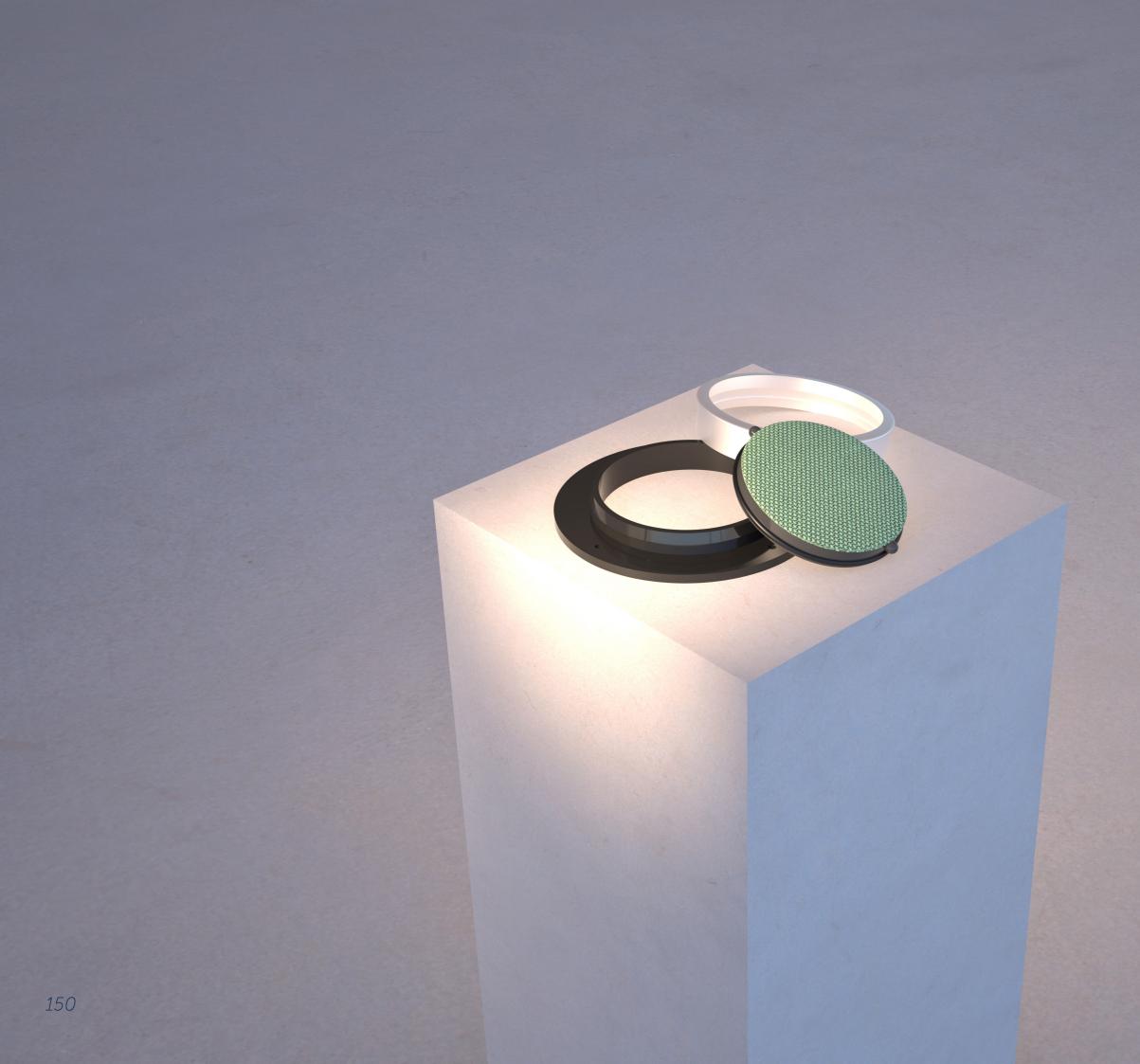






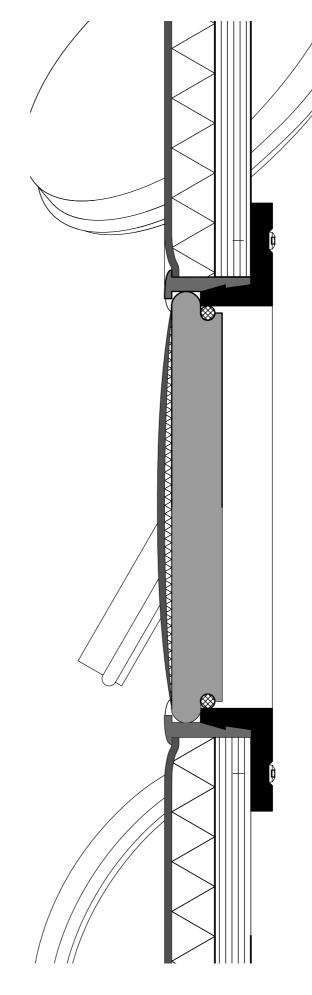




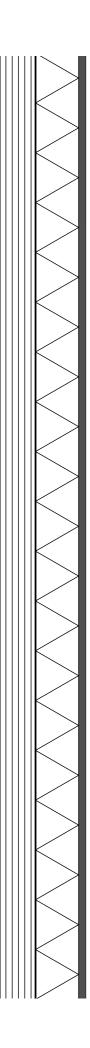


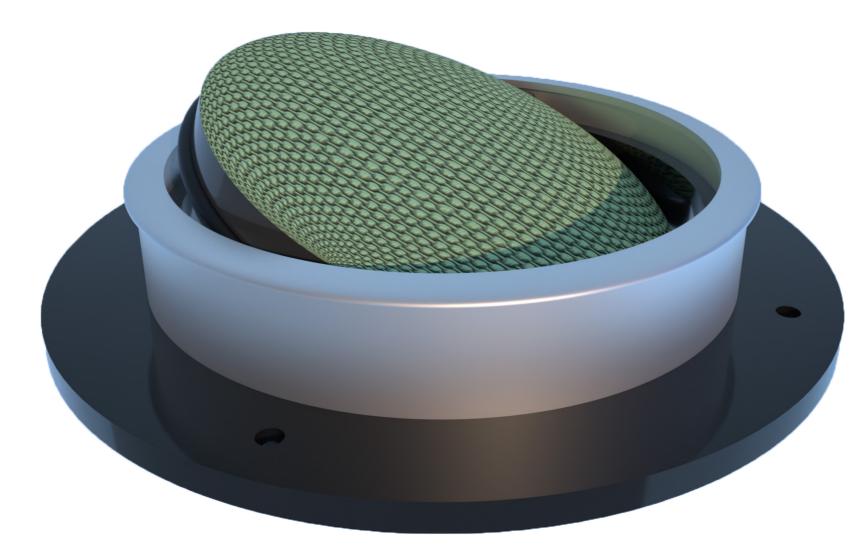


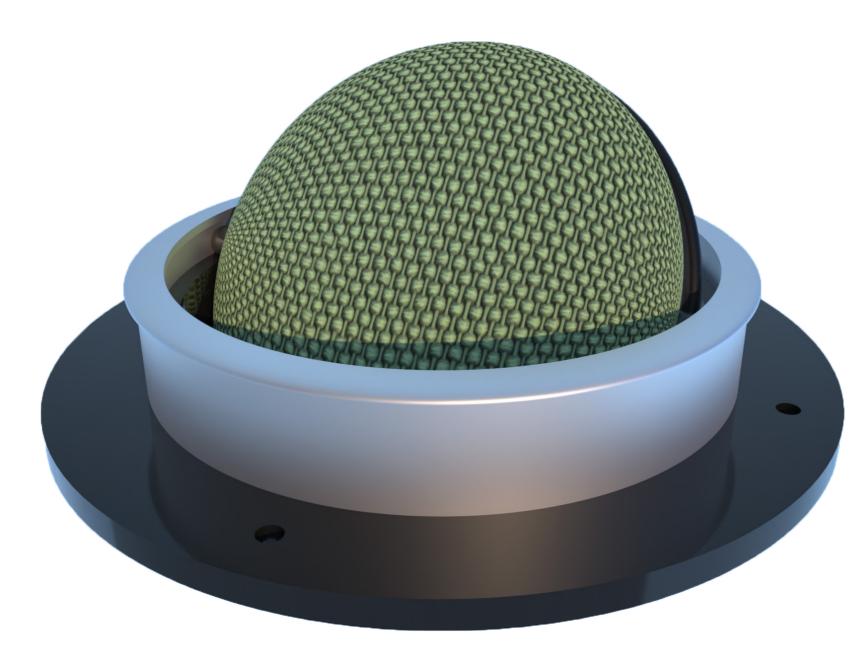


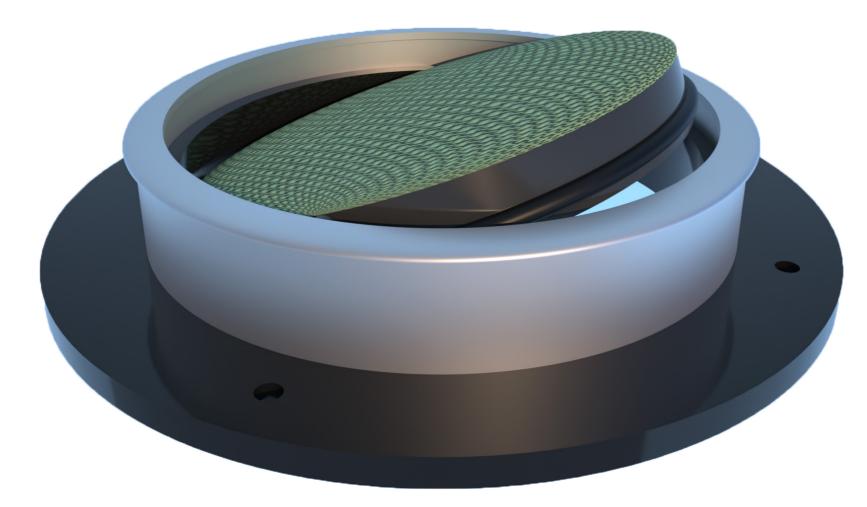






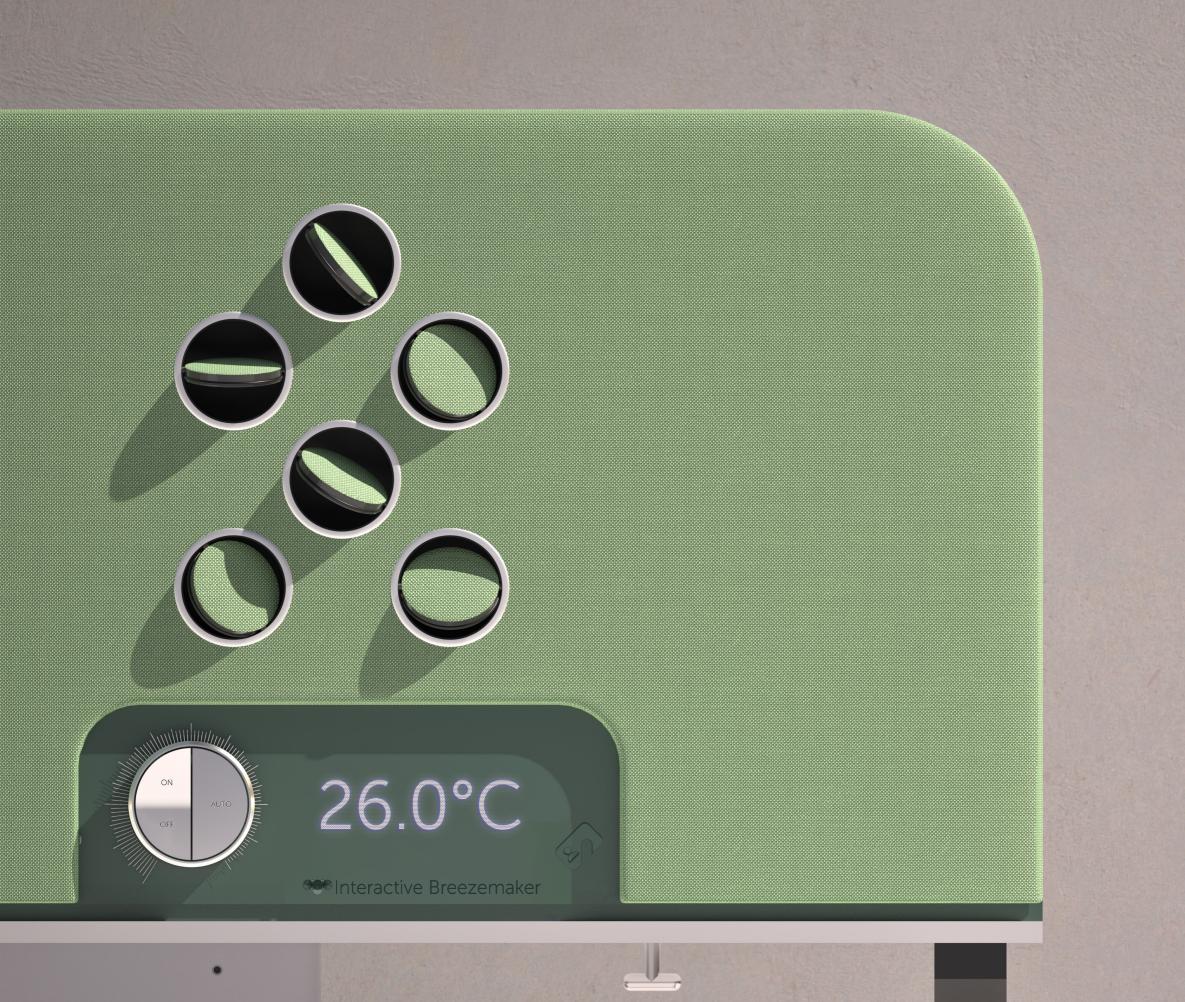














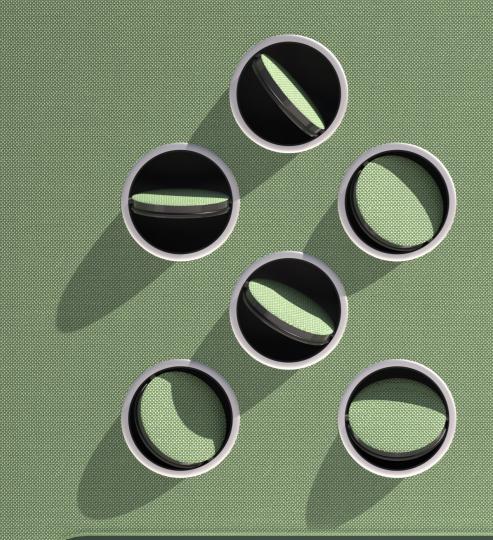


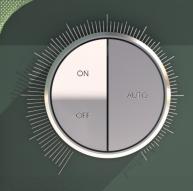












FUTURE RECOMMENDATIONS

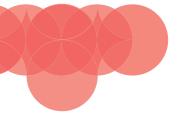
See Interactive Breezemaker



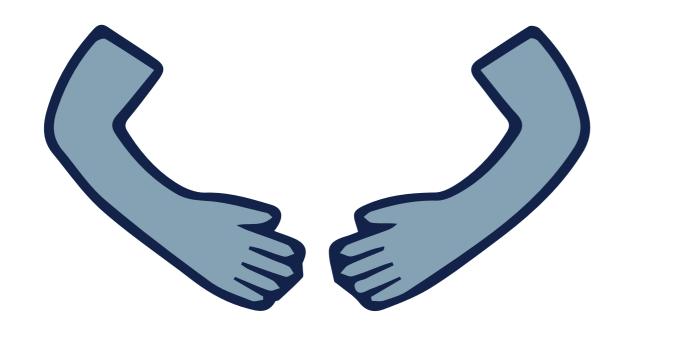


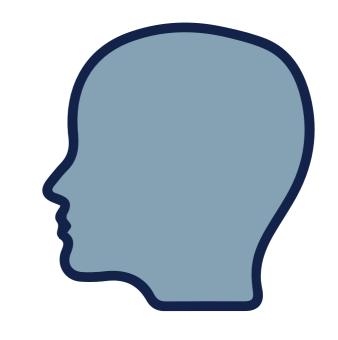


Interactive Breezemaker



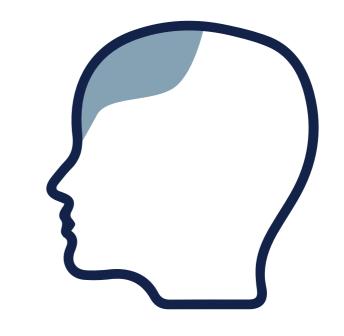
Targeting the wind

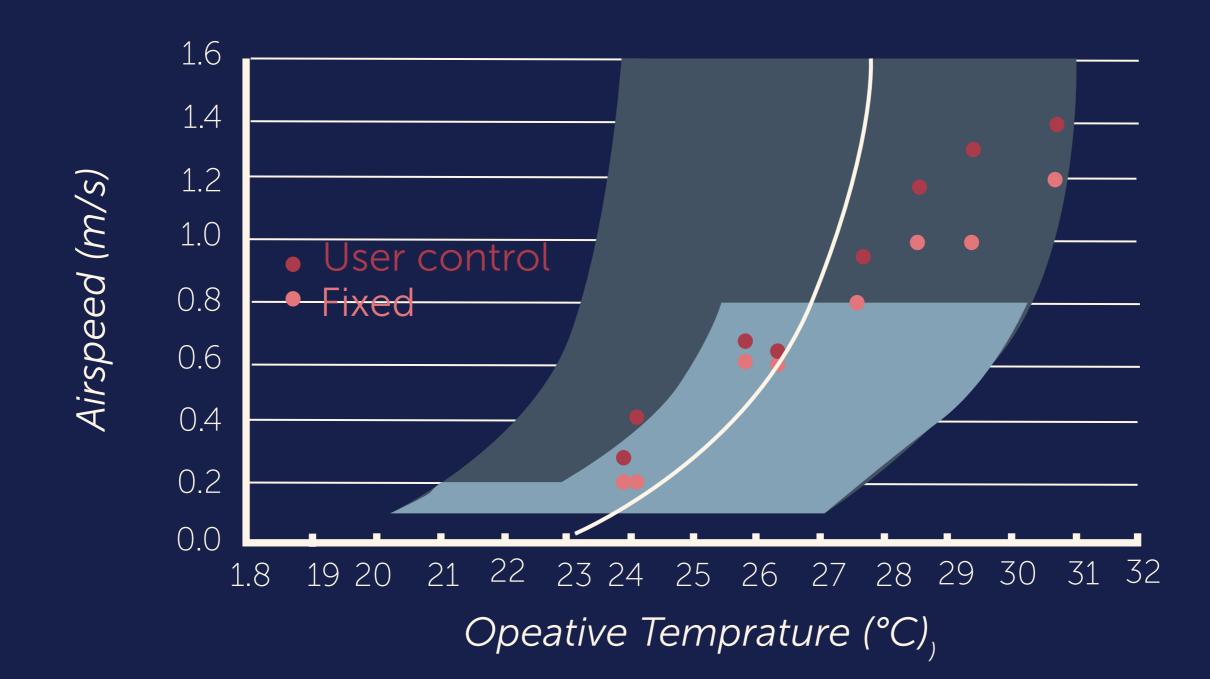




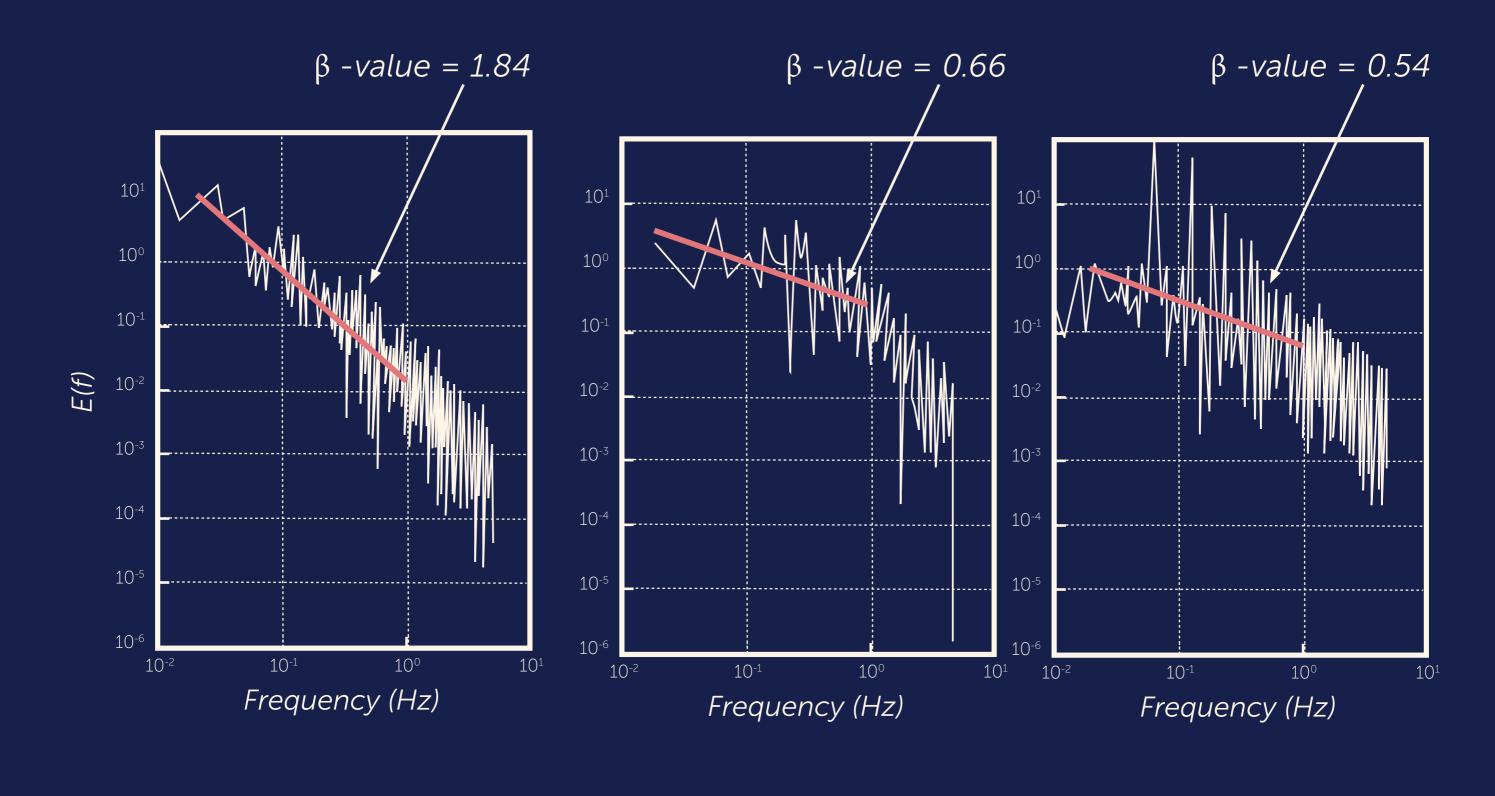
Targeting the wind







Test results projected onto the ASHRAE-55 standard (Zhai et al., 2017)

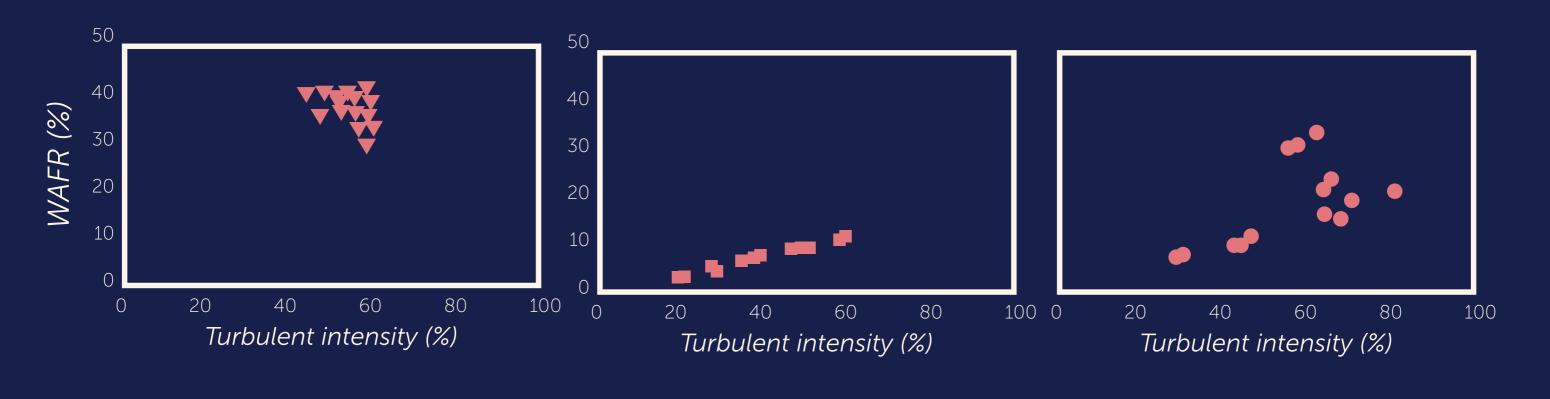


Comfortable natural wind

Uncomfortable natural wind

Mechanical wind

(Zeng et al., 2021)



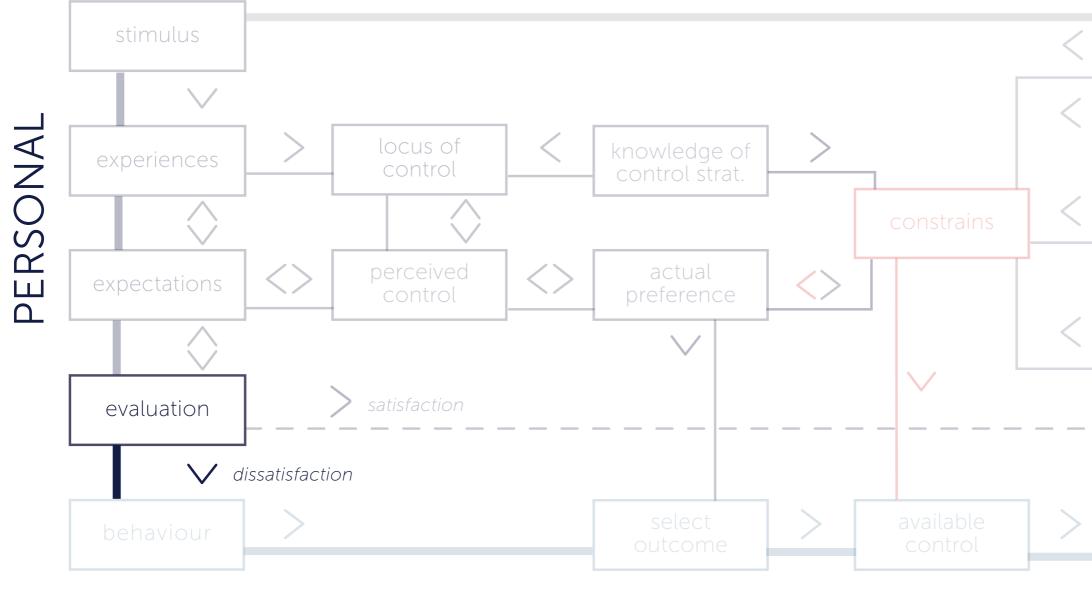
Natural wind

Axial fan

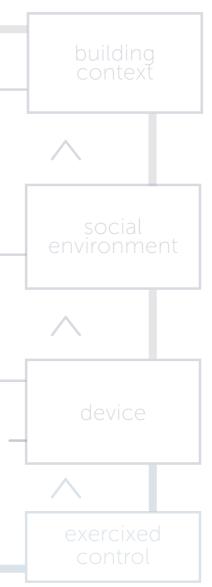
Wall airco

(Xie et al.,2023)





BEHAVIORAL



ENVIRONMENTAL









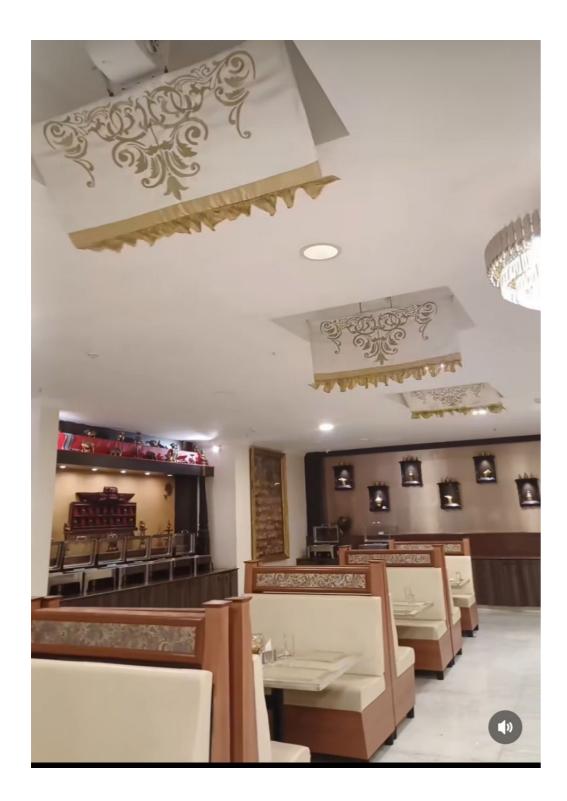




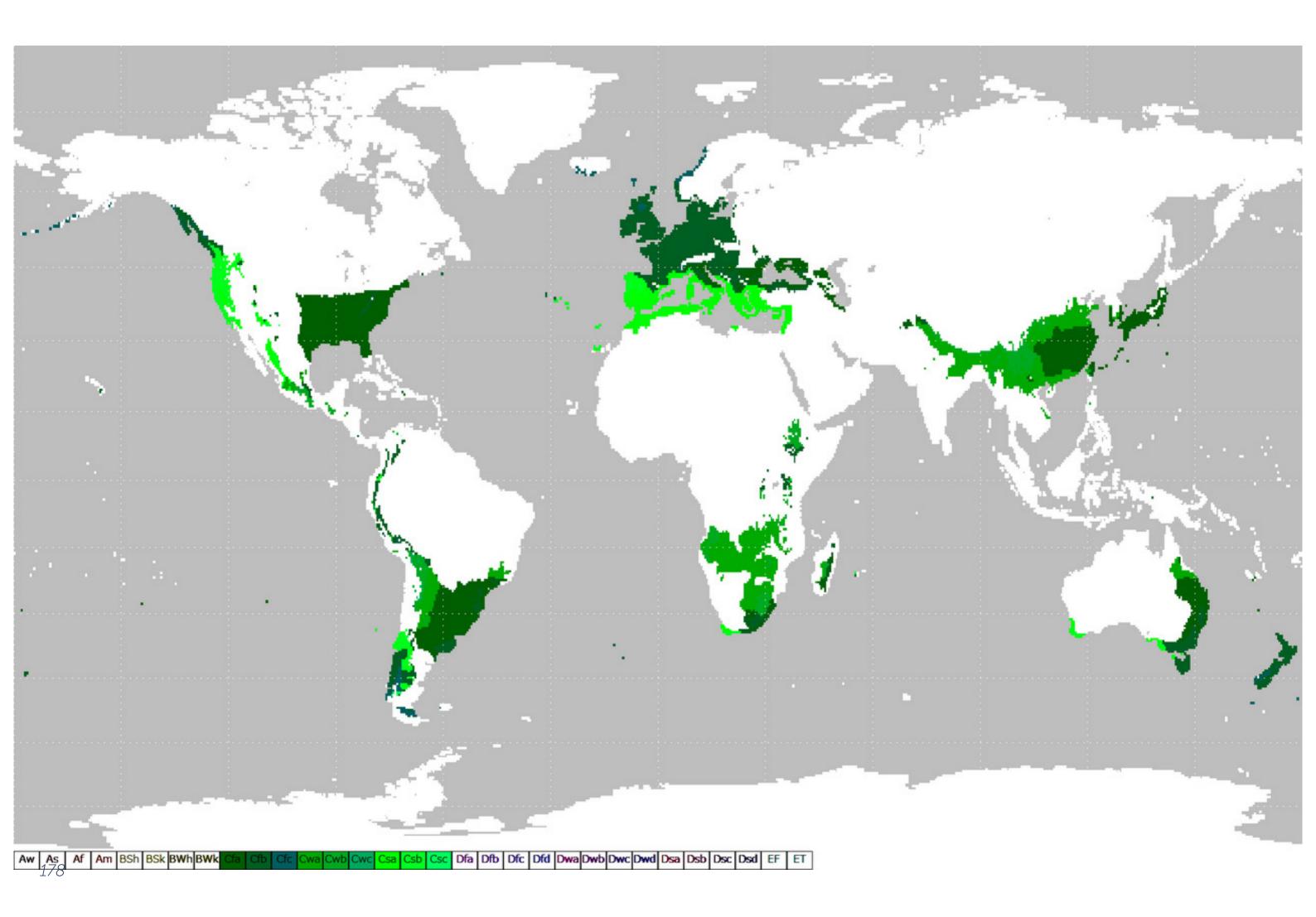




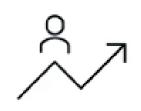






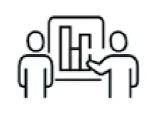






Productivity

Efficiency of an employee or group in performing their role and contribute to organisational goals



Meeting & collaboration

The ability of employees to meet up with other colleagues to share ideas, solutions and solve problems



Community & culture

The collective identity, shared values and mutual respect amongst employees in the workplace

Pride & enjoyment