

Interactive Breezemaker

*A Design Framework for
Personal Environmental Control Systems*













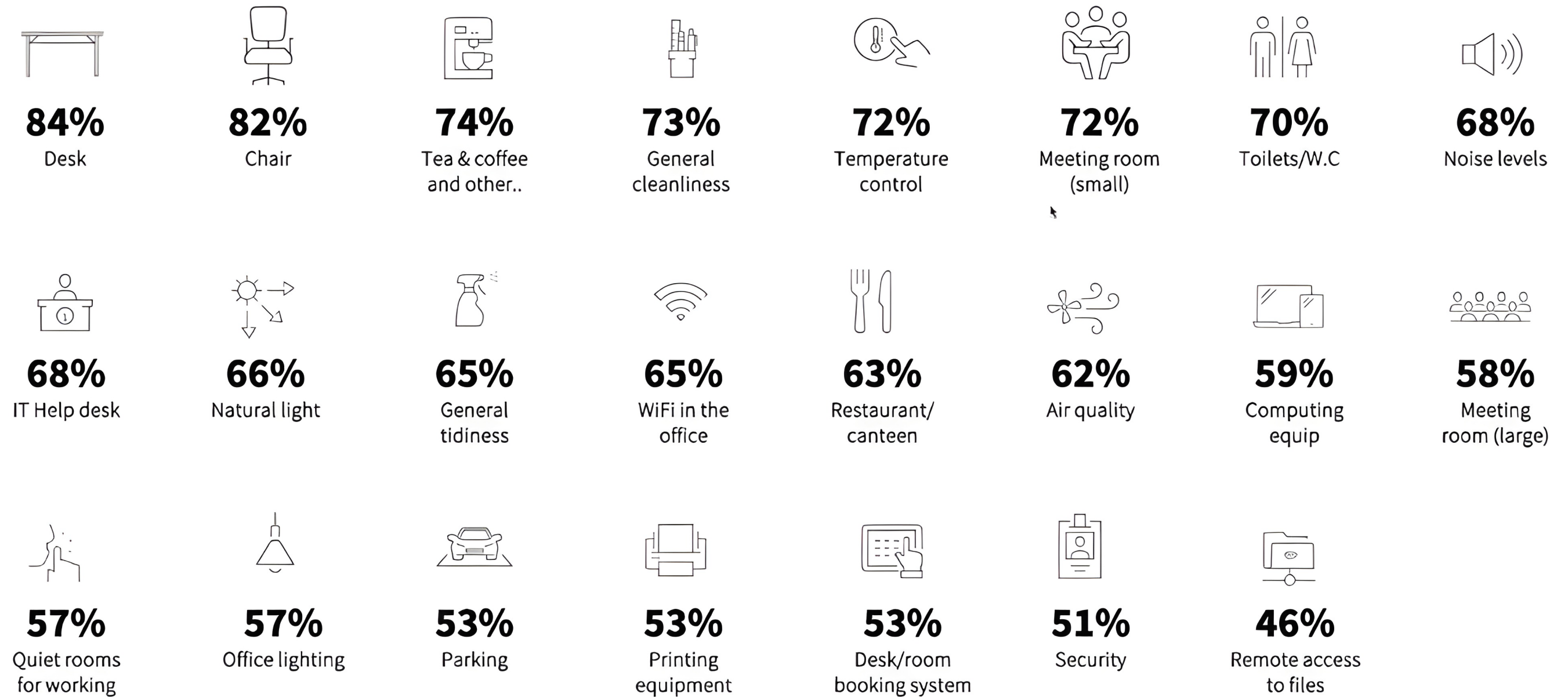
7 (Open-plan Office: Great for Photo Shoots, Terrible for Collaboration | Inside Nuclino, n.d.)

How do people
feel in these environments?

How would they rate their thermal comfort?

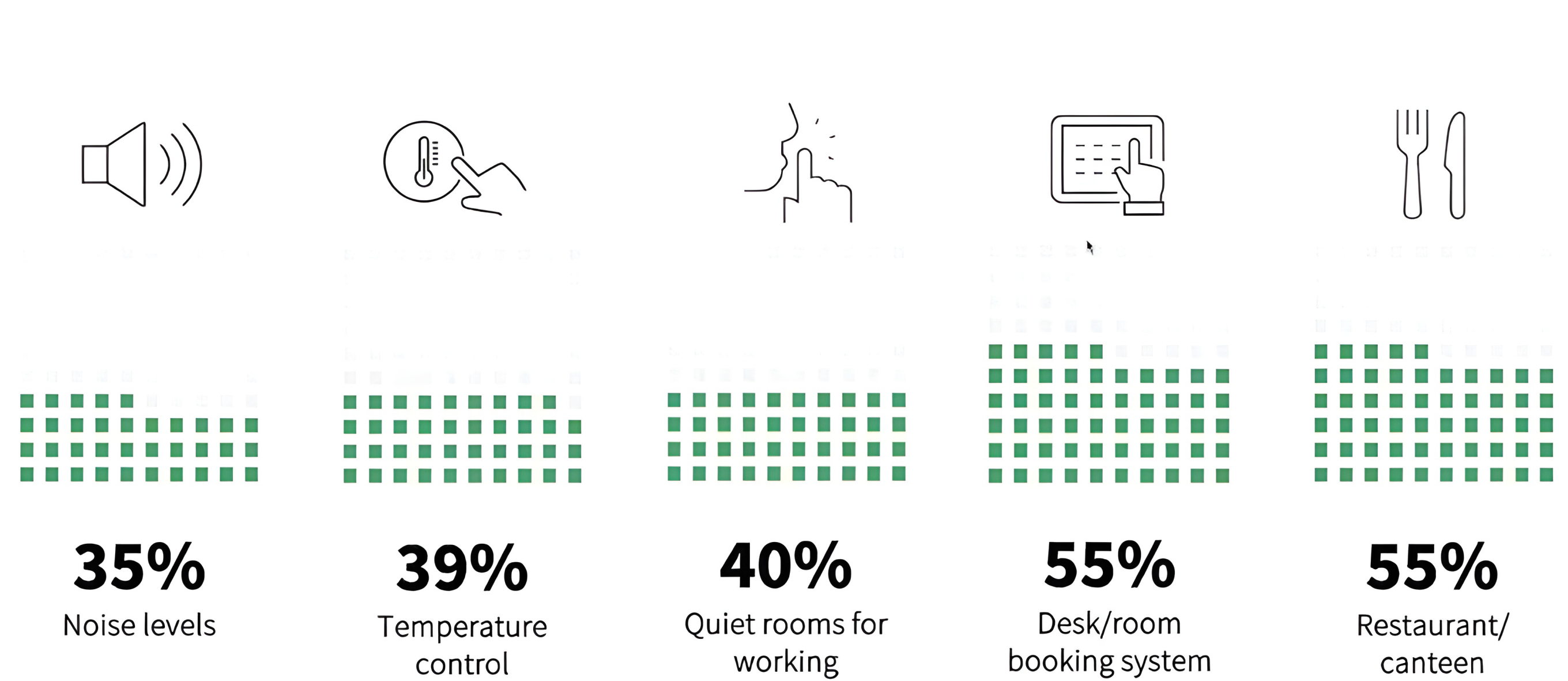
How
satisfied are they?

Importance of office features and services



(Leesman, 2024)

Employee satisfaction with critical features and services

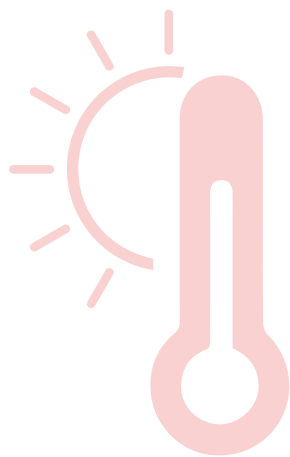


(Leesman, 2024)

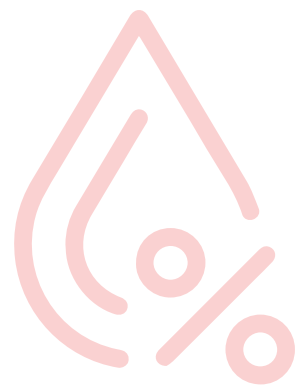
39% is satisfied about the temperature control
61% is not



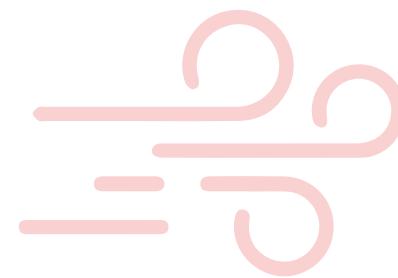
Air
Temperature
(°C)



Mean Radiant
Temperature
(°C)



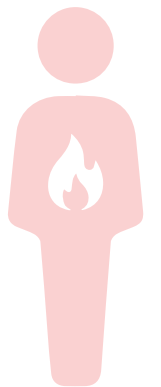
Relative
Humidity
(%)



Airspeed
(m/s)



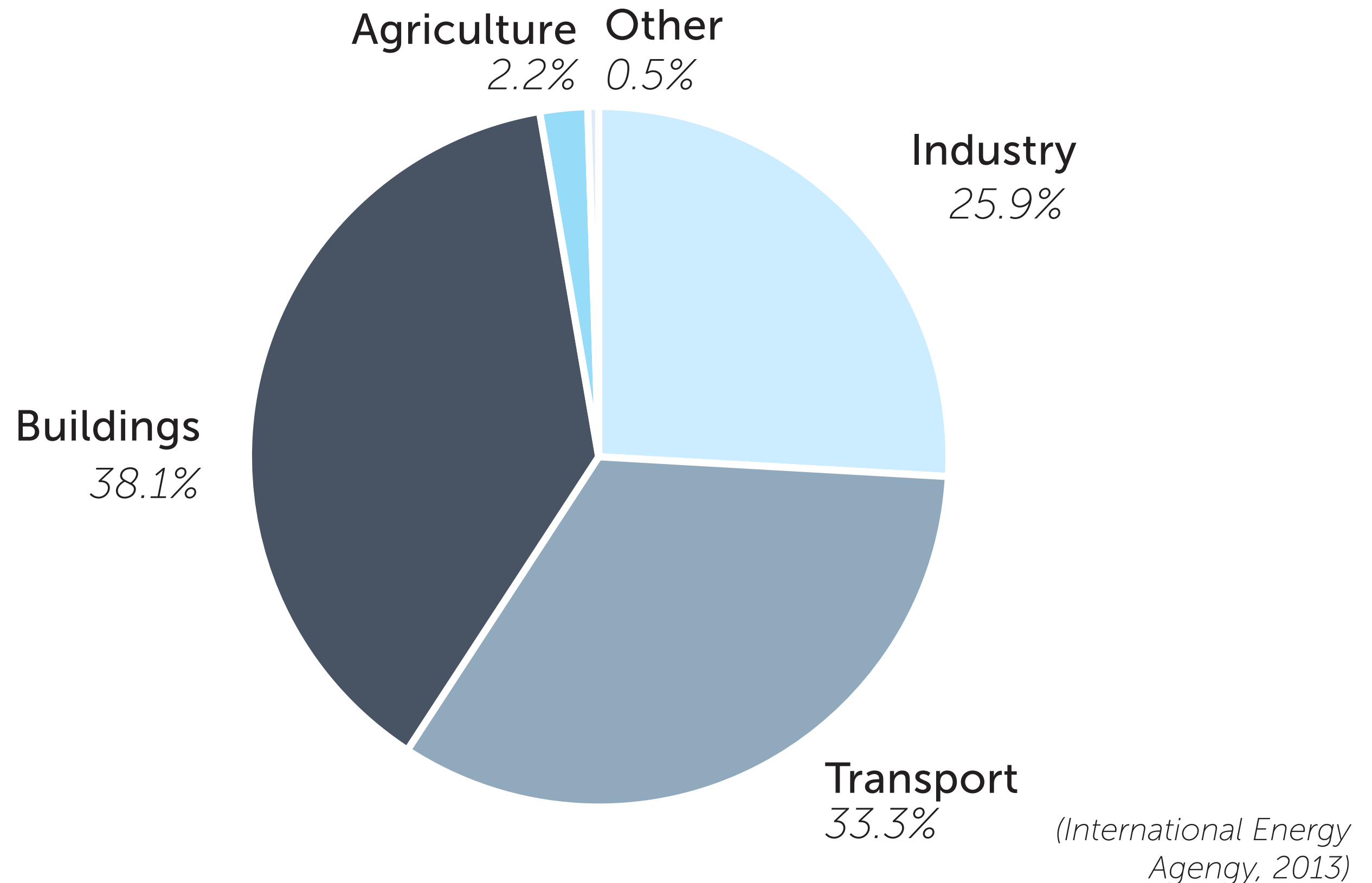
Clothing
Insulation
(clo)



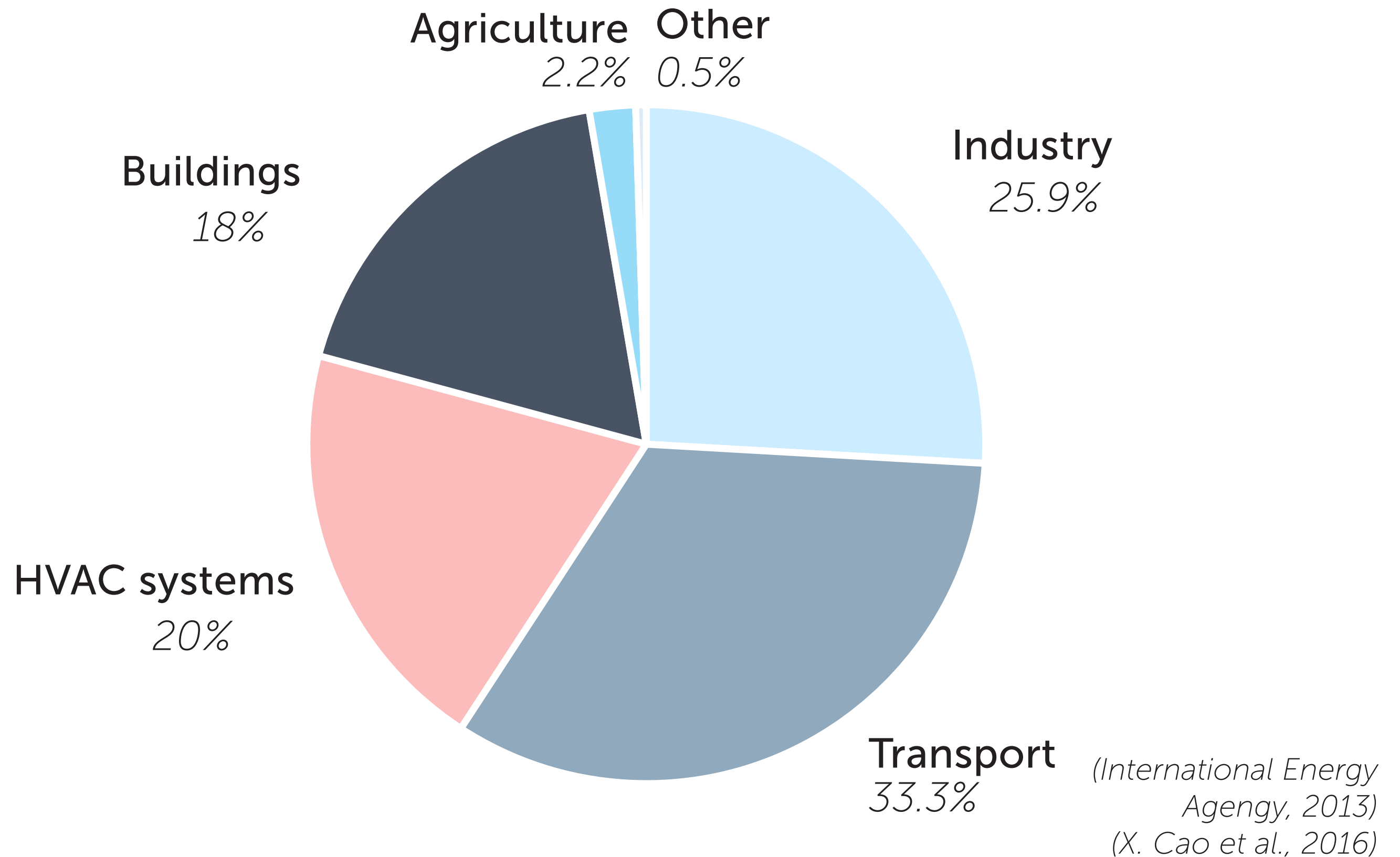
Metabolic
Rate
(met)



Primary energy consumption in the U.S. and EU



Primary energy consumption in the U.S. and EU







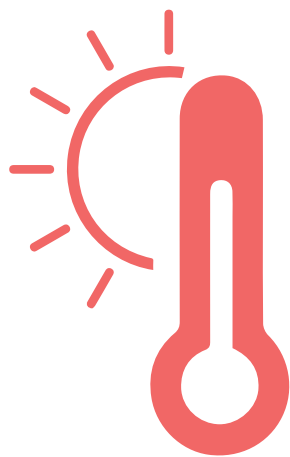




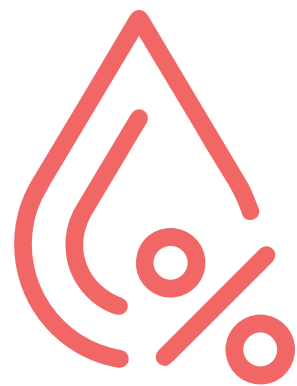
Is there a way to provide people with more personal control over the temperature in a more effective and energy-efficient manner?



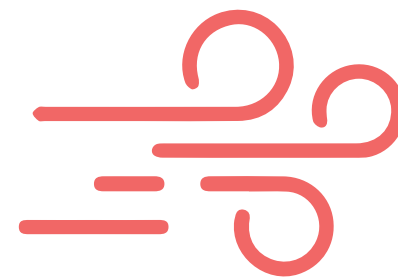
Air
Temperature
(°C)



Mean Radiant
Temperature
(°C)



Relative
Humidity
(%)



Airspeed
(m/s)



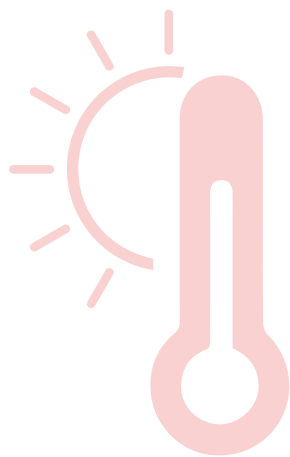
Clothing
Insulation
(clo)



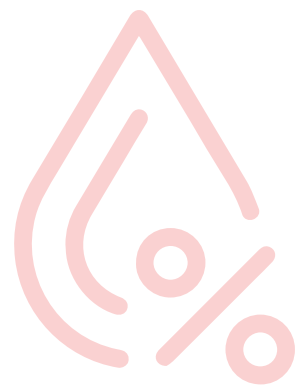
Metabolic
Rate
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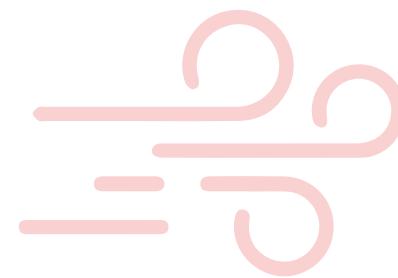
Air
Temperature
(°C)



Mean Radiant
Temperature
(°C)



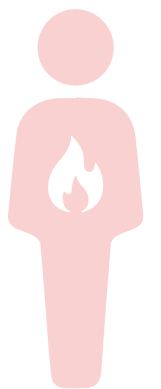
Relative
Humidity
(%)



Airspeed
(m/s)

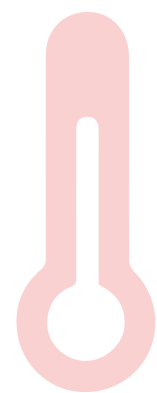


Clothing
Insulation
(clo)

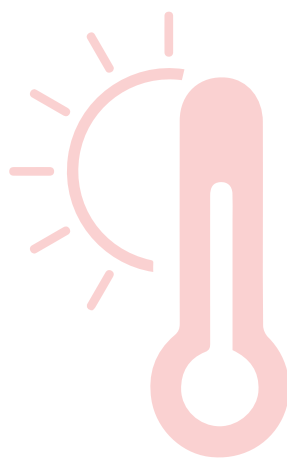


Metabolic
Rate
(met)





Air
Temperature
(°C)



Mean Radiant
Temperature
(°C)



Relative
Humidity
(%)



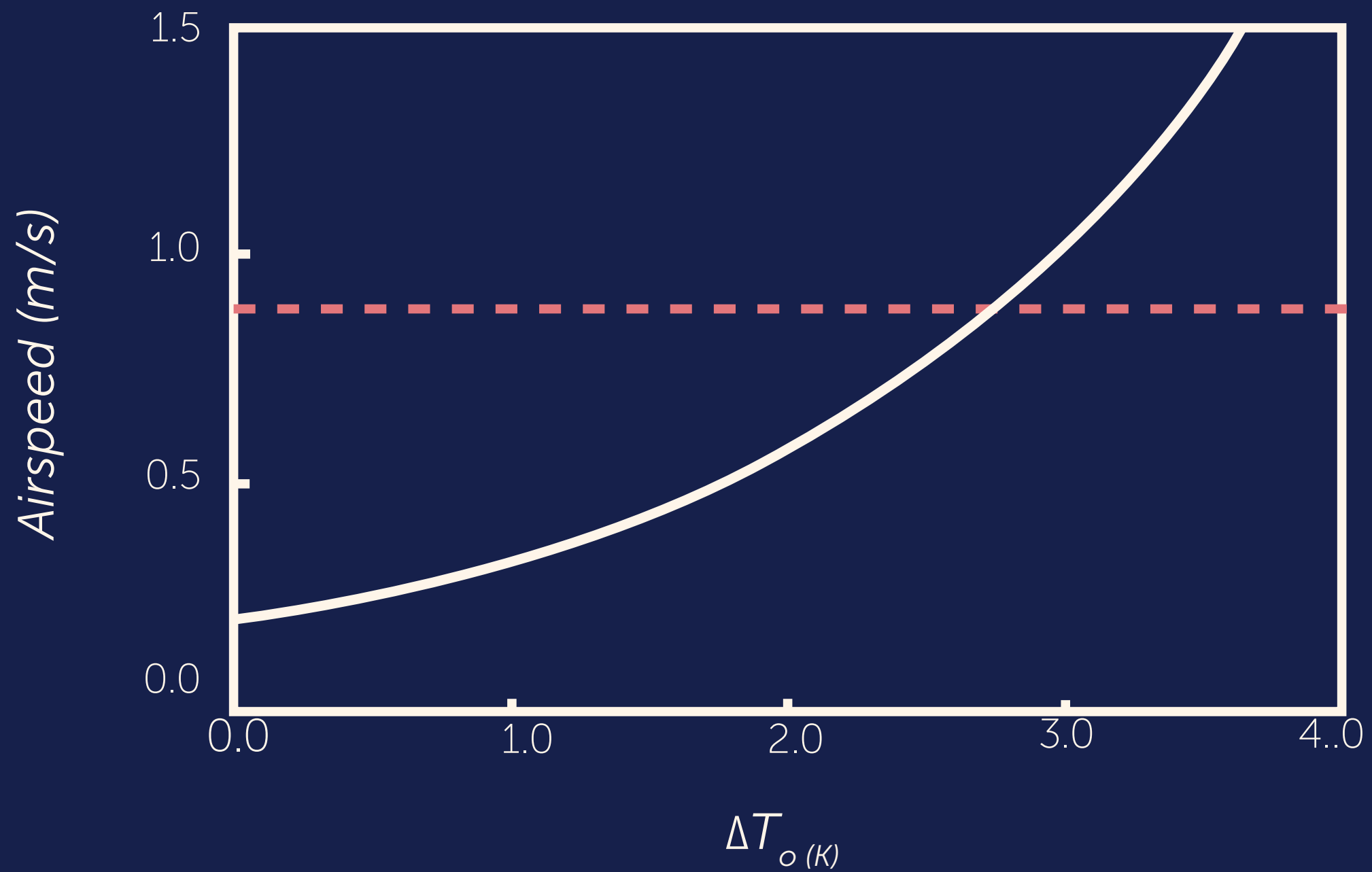
Airspeed
(m/s)

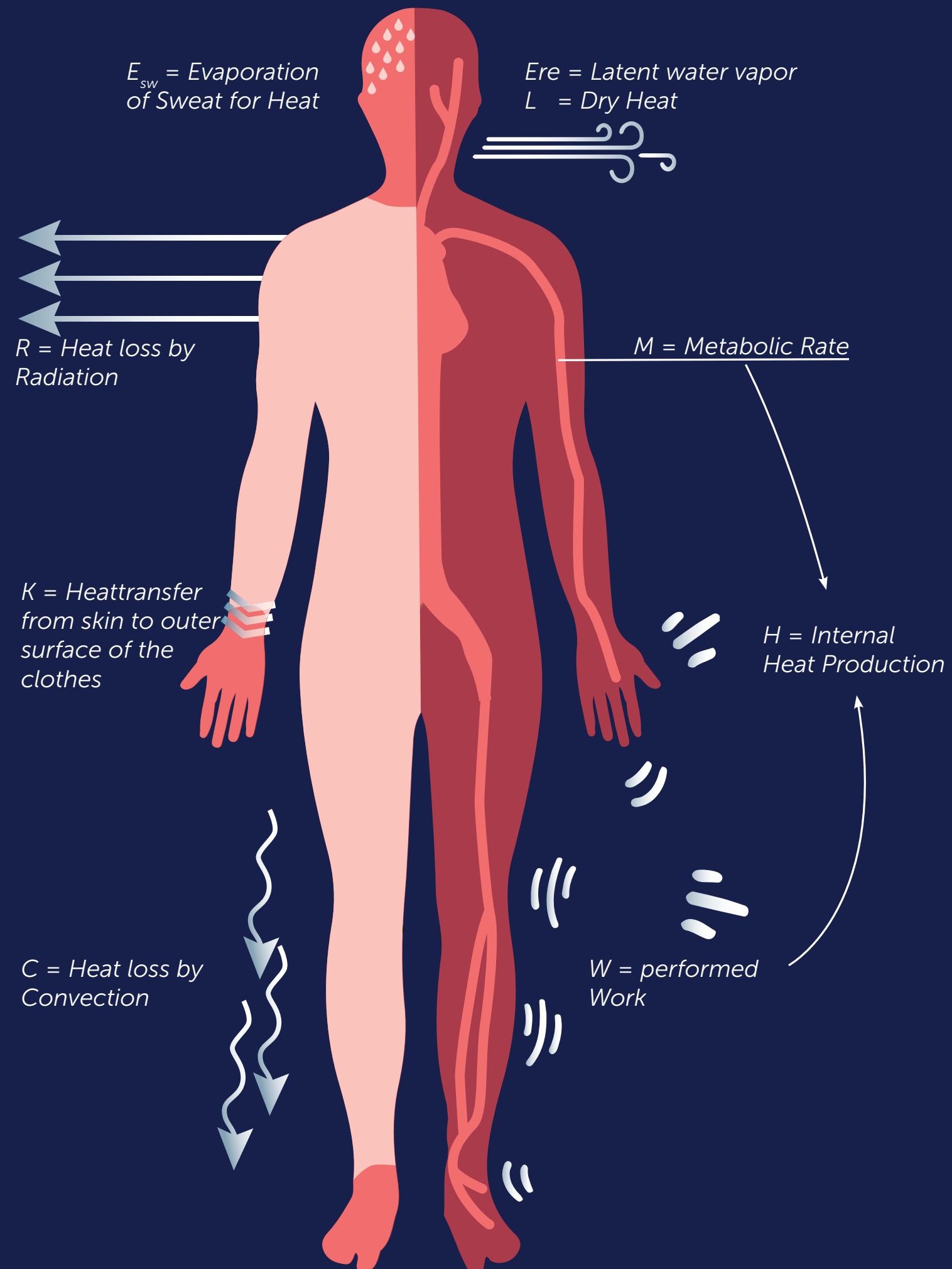


Clothing
Insulation
(clo)



Metabolic
Rate
(met)





Problem statement

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Develop an evidence-based framework for personalized air velocity for occupants in open-plan offices in a temperate maritime climate, aimed at enhancing comfort and productivity, and illustrate this through an effective design solution.

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*Develop an evidence-based framework for personalized air velocity for occupants in open-plan offices in a temperate maritime climate, aimed at enhancing comfort and productivity, and illustrate this through an **effective design solution**.*

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

Methodology

Literature Review



Interviews

Methodology

Literature Review



Interviews



Framework

Methodology

Literature Review



Interviews



Framework



Application of the Framework

Methodology

Literature Review



Interviews



Framework



Application of the Framework



Conclusion

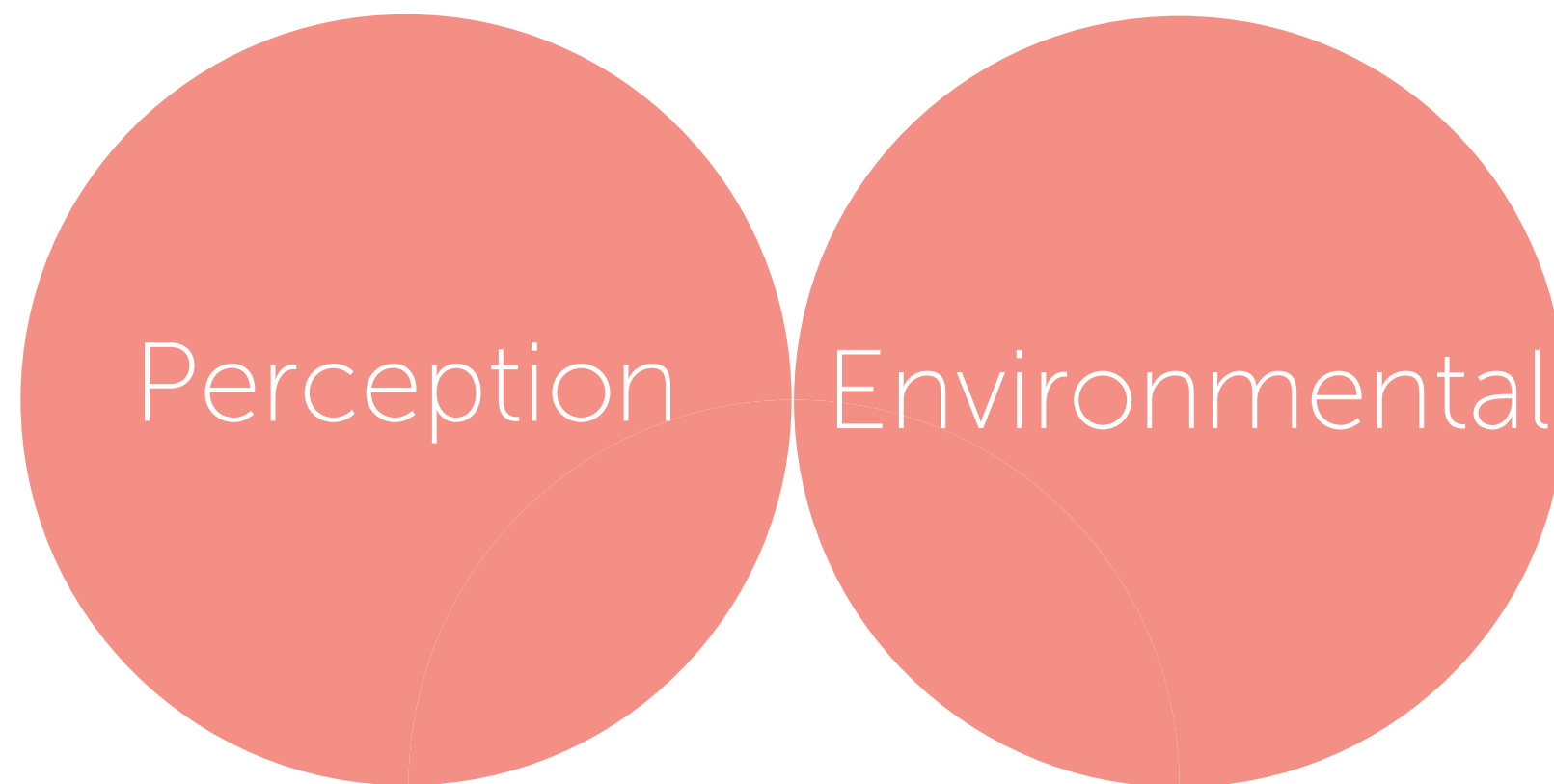
Literature review

Perceived Control

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

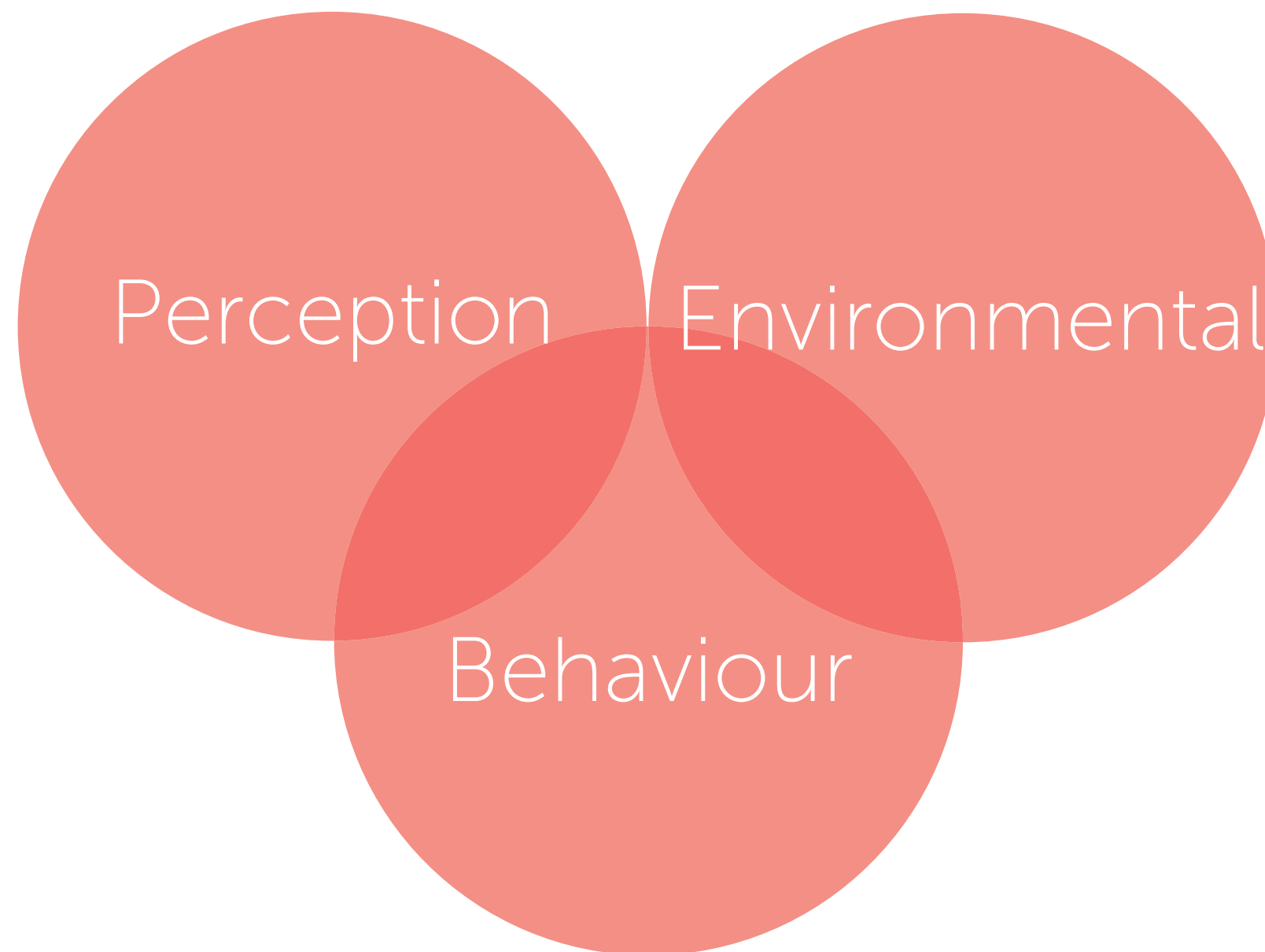
Conceptual model perceived control

simplified

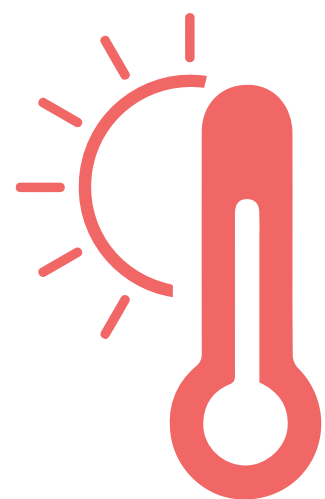


Conceptual model perceived control

simplified

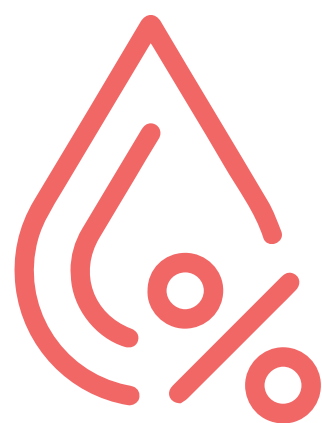


Environmental



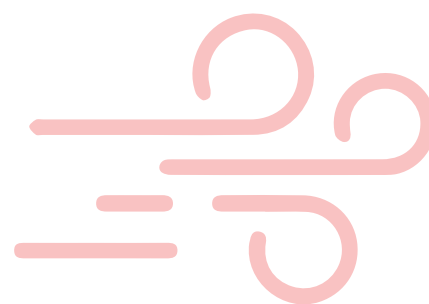
Operative
Temperature
(°C)

24-30 °C



Relative
Humidity
(%)

40 -60%



Airspeed
(m/s)



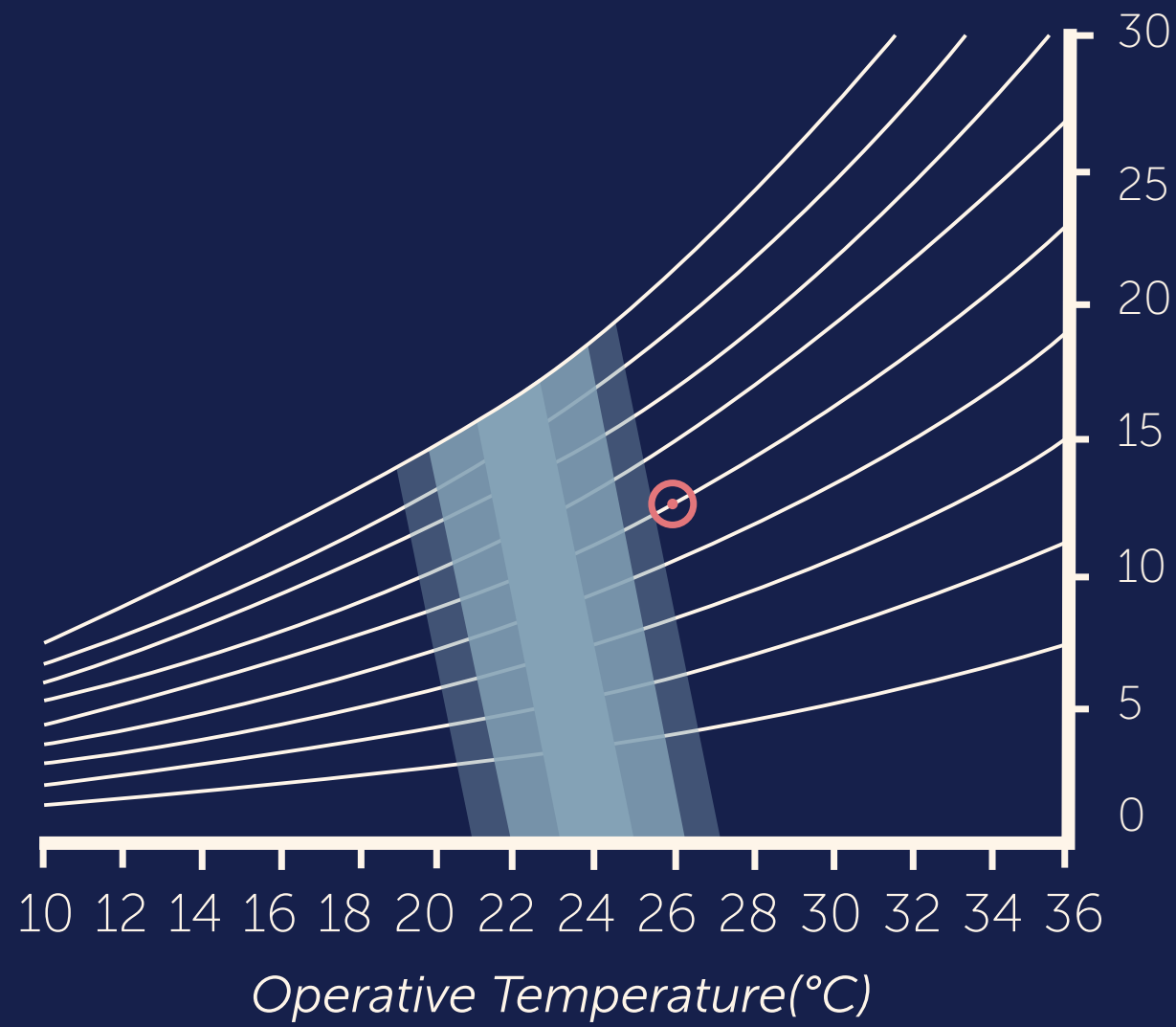
Clothing
Insulation
(clo)

0.6 clo

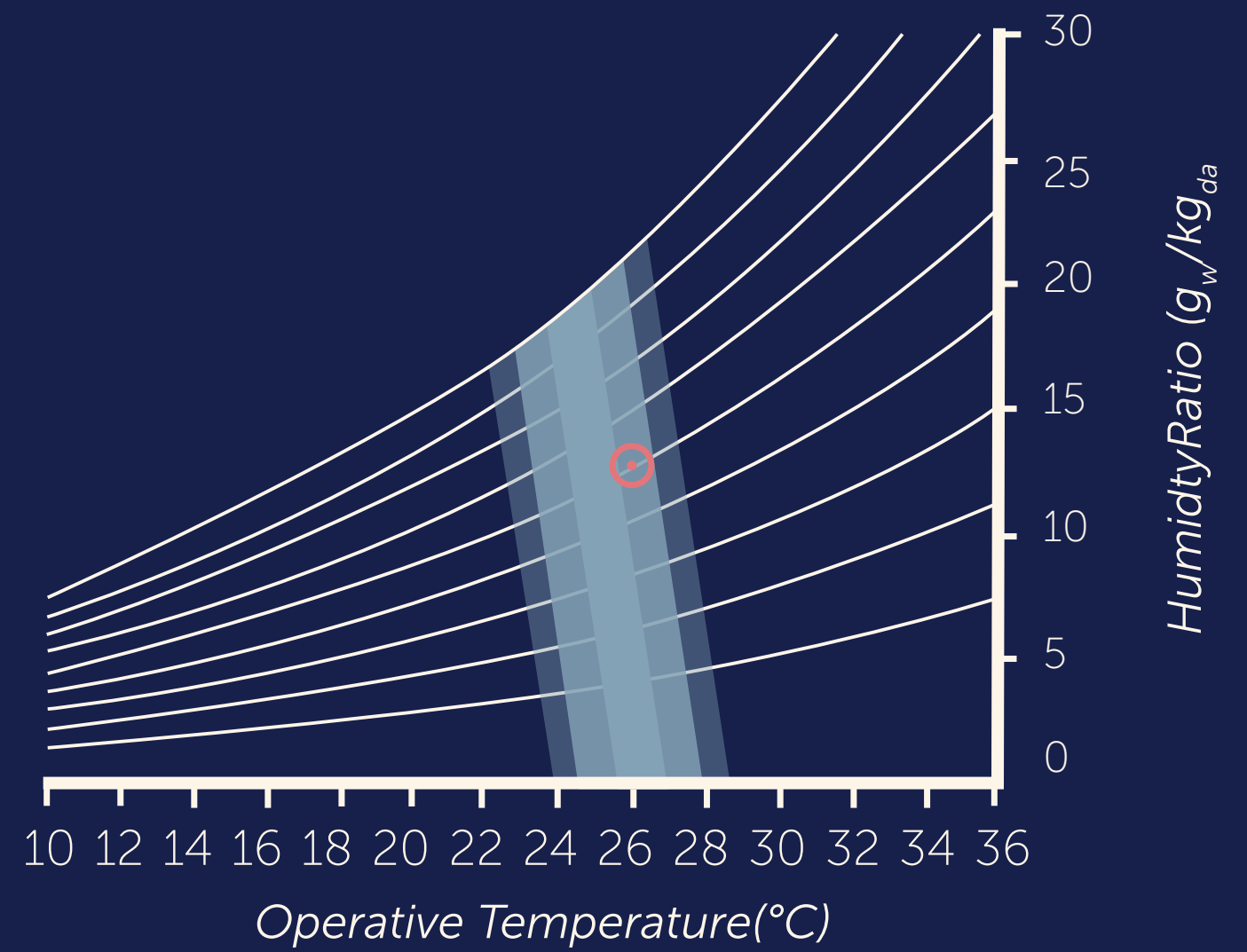


Metabolic
Rate
(met)

1 - 1.4 met

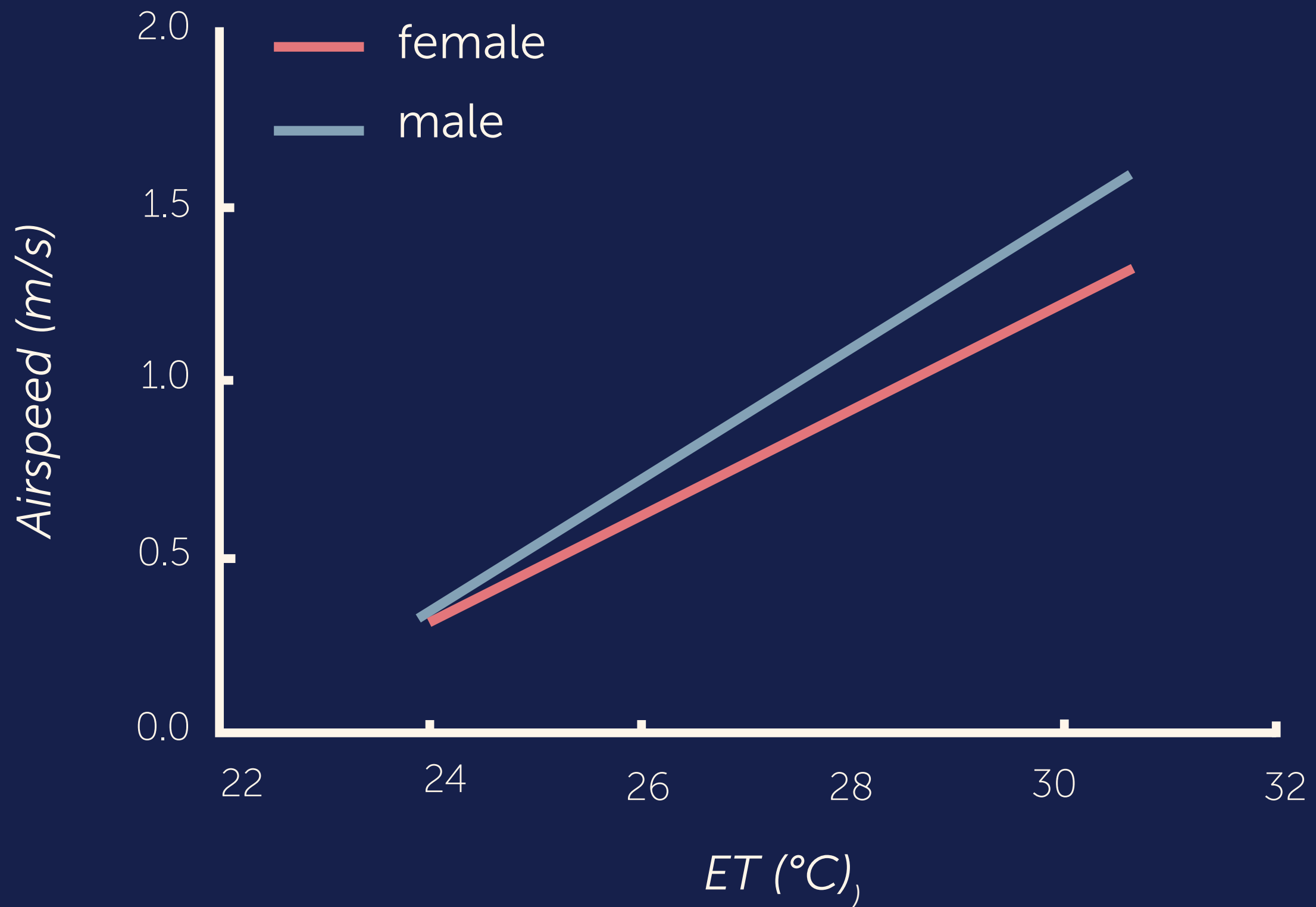


0 m/s



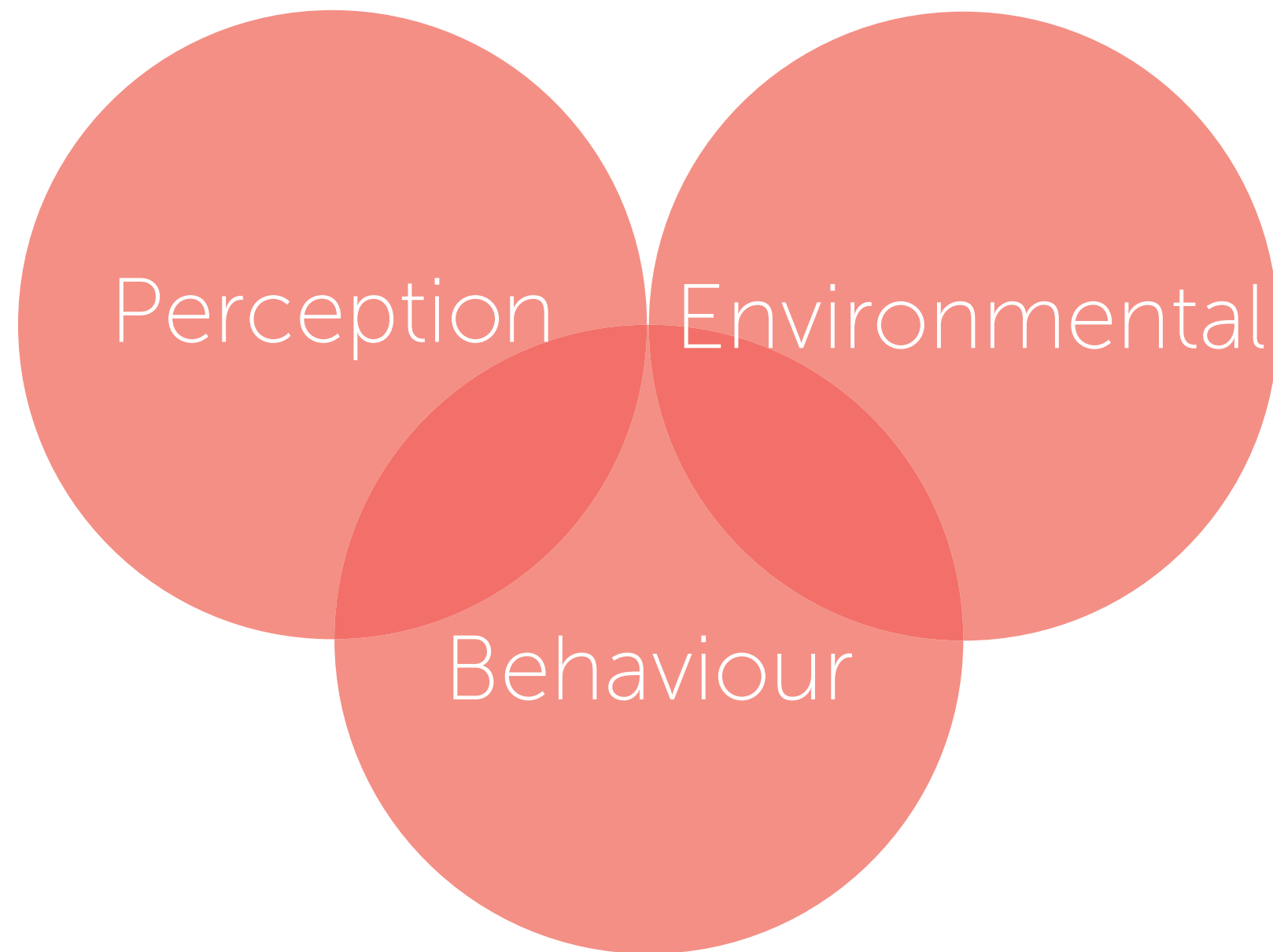
0.7 m/s

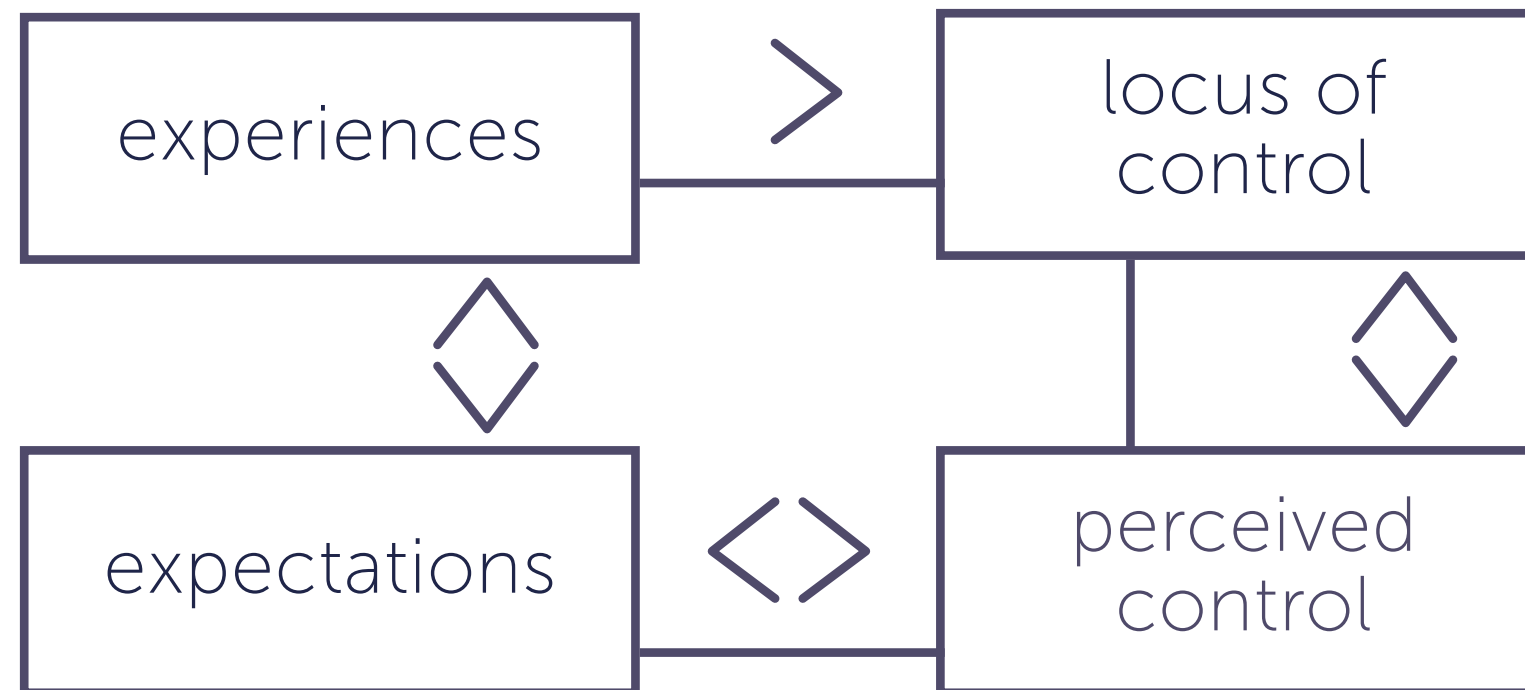
1.4 met , 60%



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

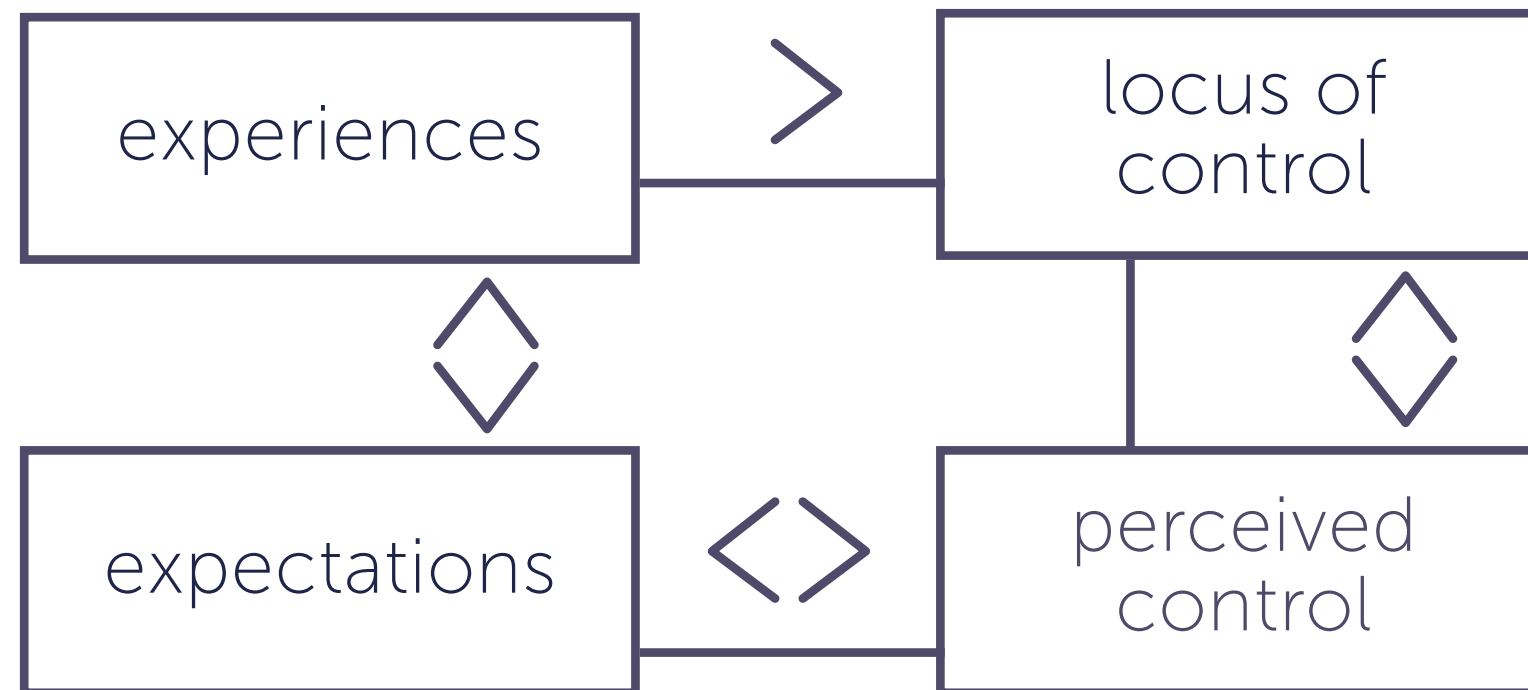
So give someone control over the airspeed
and done?



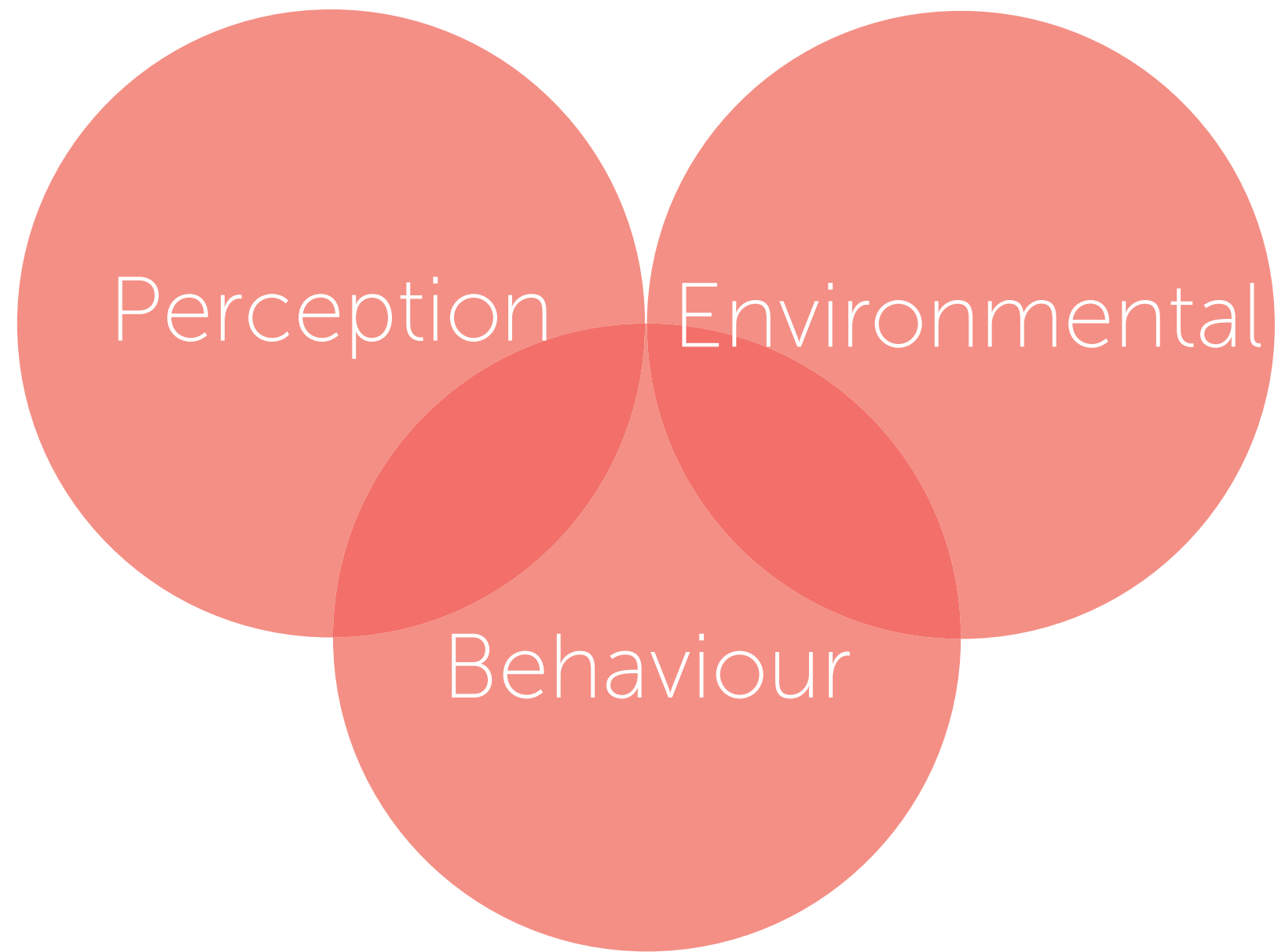


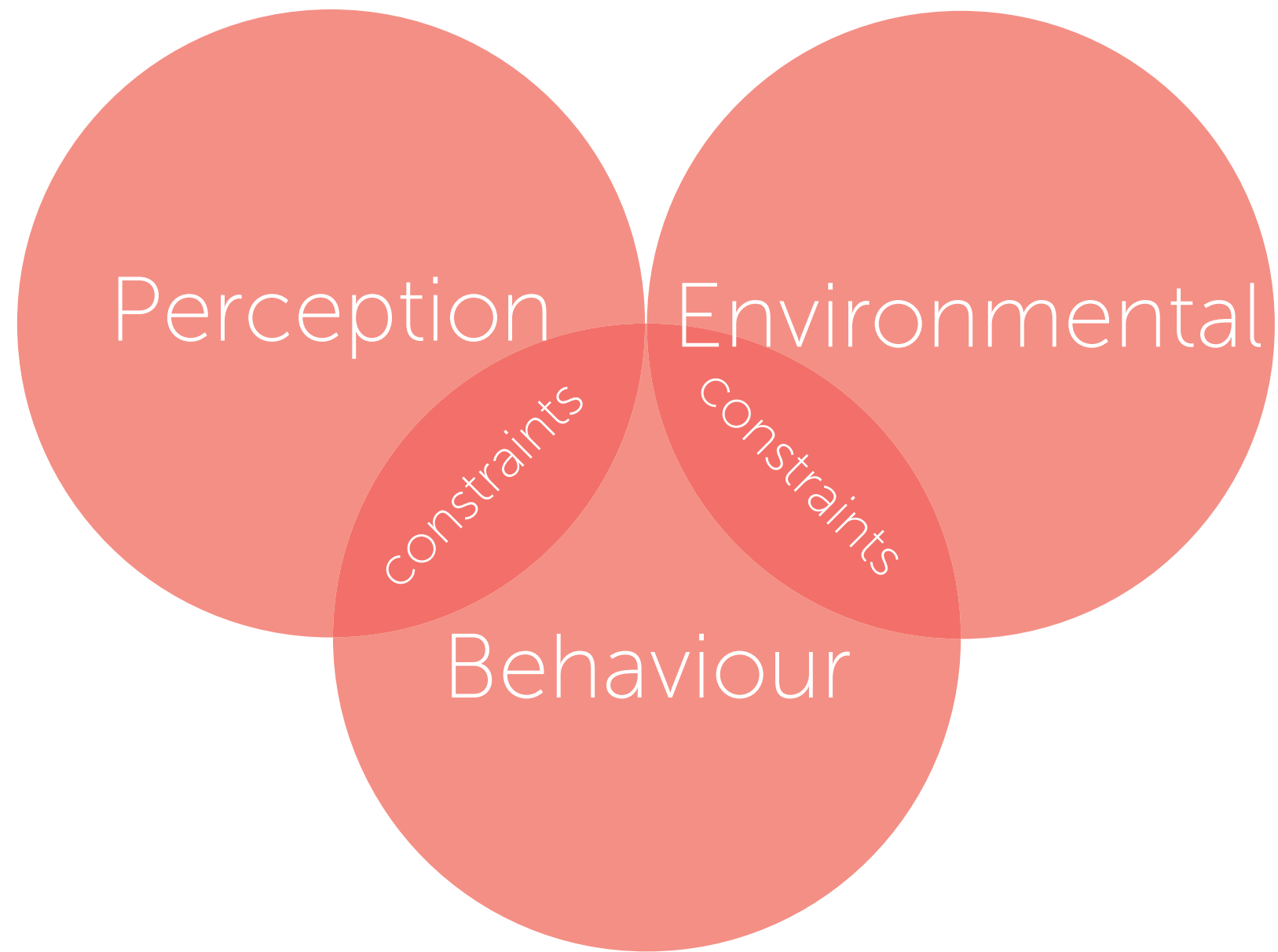
Locus of control

- *Internal locus of Control*
- *External locus of Control*



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





Knowlegde gap:

*What are the **user experiences** and **expectations** regarding a personal environmental control system utilizing elevated airspeed, and what is the expert insight and expertise concerning its implementation?*

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*What are the **user experiences** and **expectations** regarding a personal environmental control system utilizing elevated airspeed, and what is the expert insight and expertise concerning its implementation?*

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*What are the user experiences and expectations regarding a personal environmental control system **utilizing elevated airspeed**, and what is the expert insight and expertise concerning its implementation?*

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Knowlegde gap:

*What are the user experiences and expectations regarding a personal environmental control system utilizing elevated airspeed, and what is the expert insight and expertise concerning its **implementation?***

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.)



standing fan

(Ubuy Netherlands, n.d.)



bladeless
ceiling fan

(O'Donnell, 2024)



ceiling fan

(Asahi Home Appliances, 2023)



Dyson purifier

(Dyson, 2024)



openable
window

(40 Mm Openable Window, n.d.)



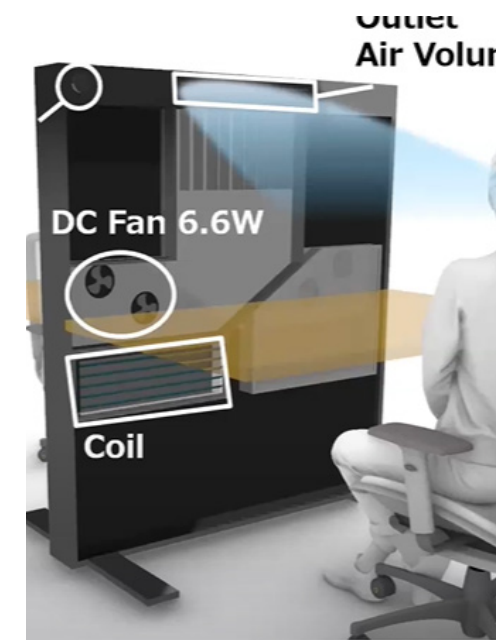
climate ceiling
TNO

(TNO, 2014.)



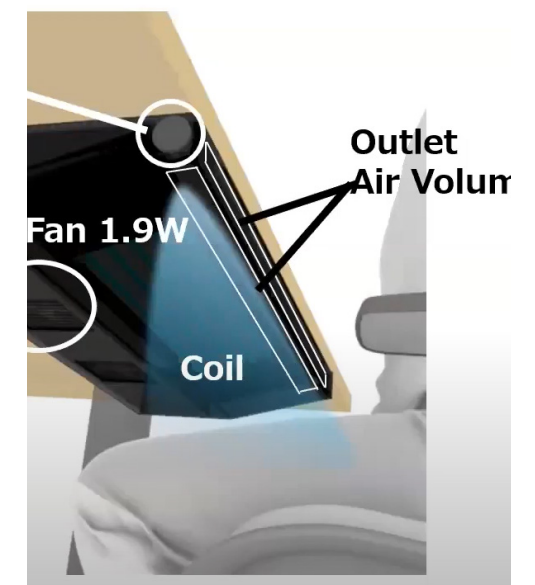
climate table
Ahrend

(DESKs | Ahrend, n.d.)



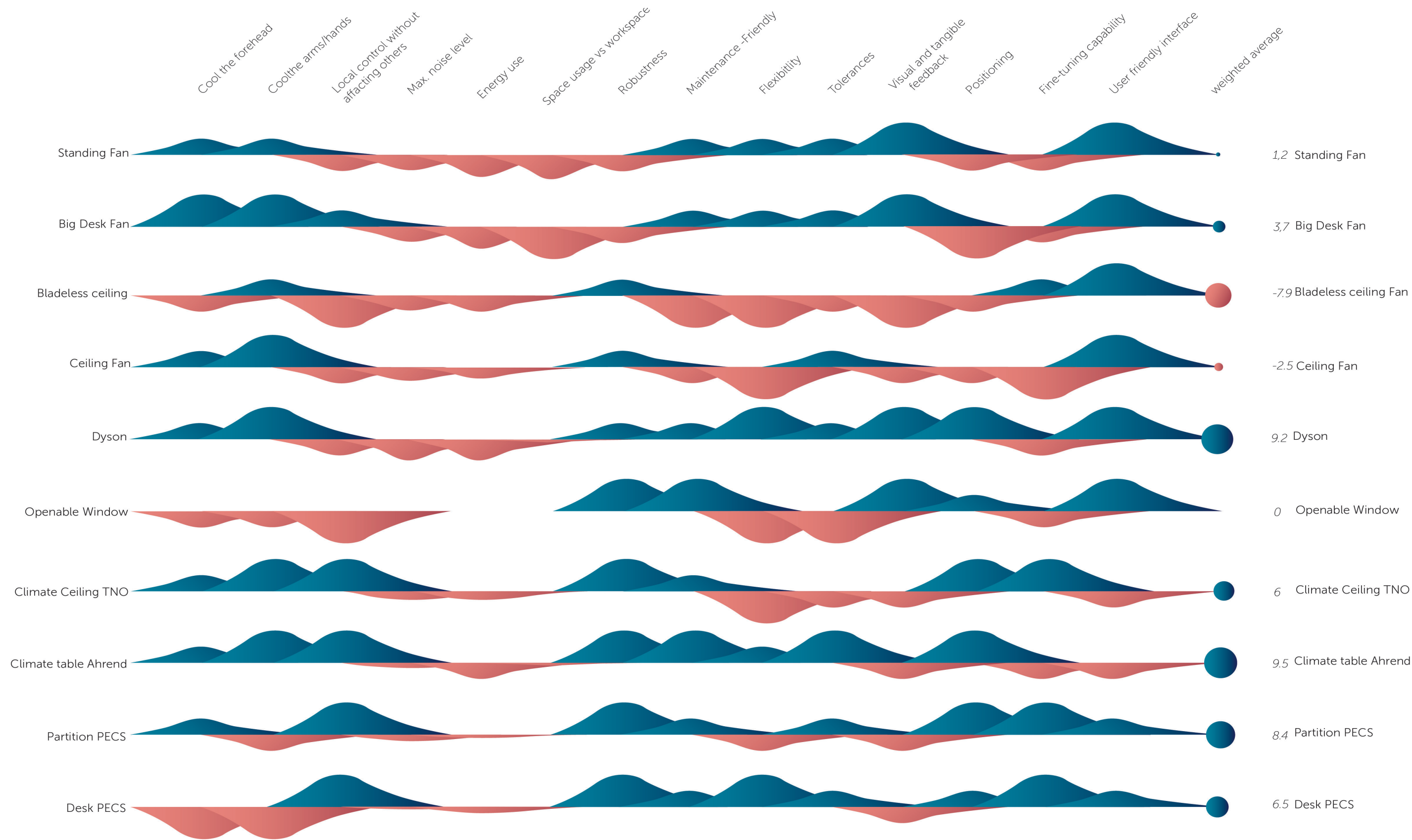
partition PECS

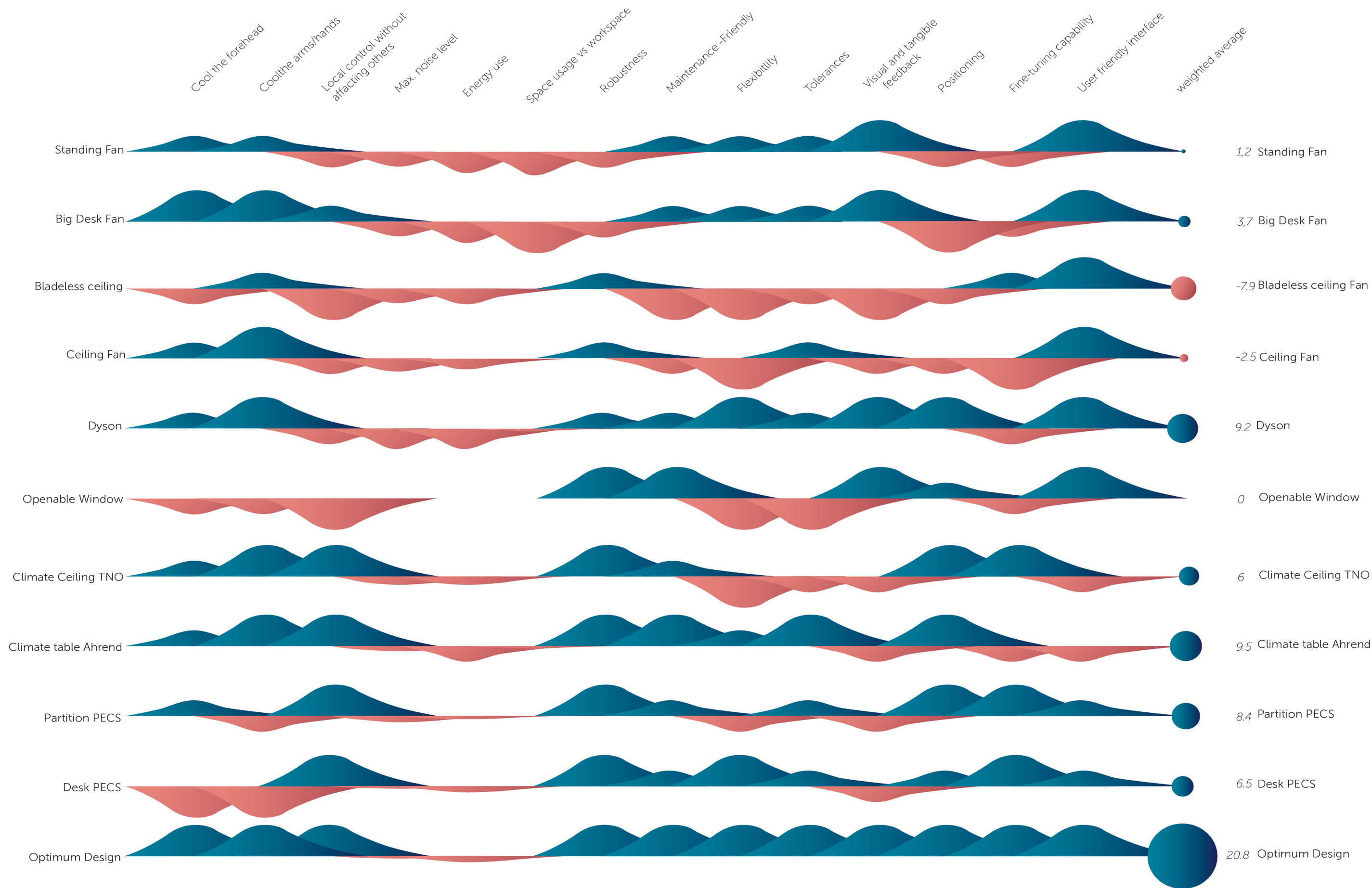
(INIVE, 2023)



desk PECS

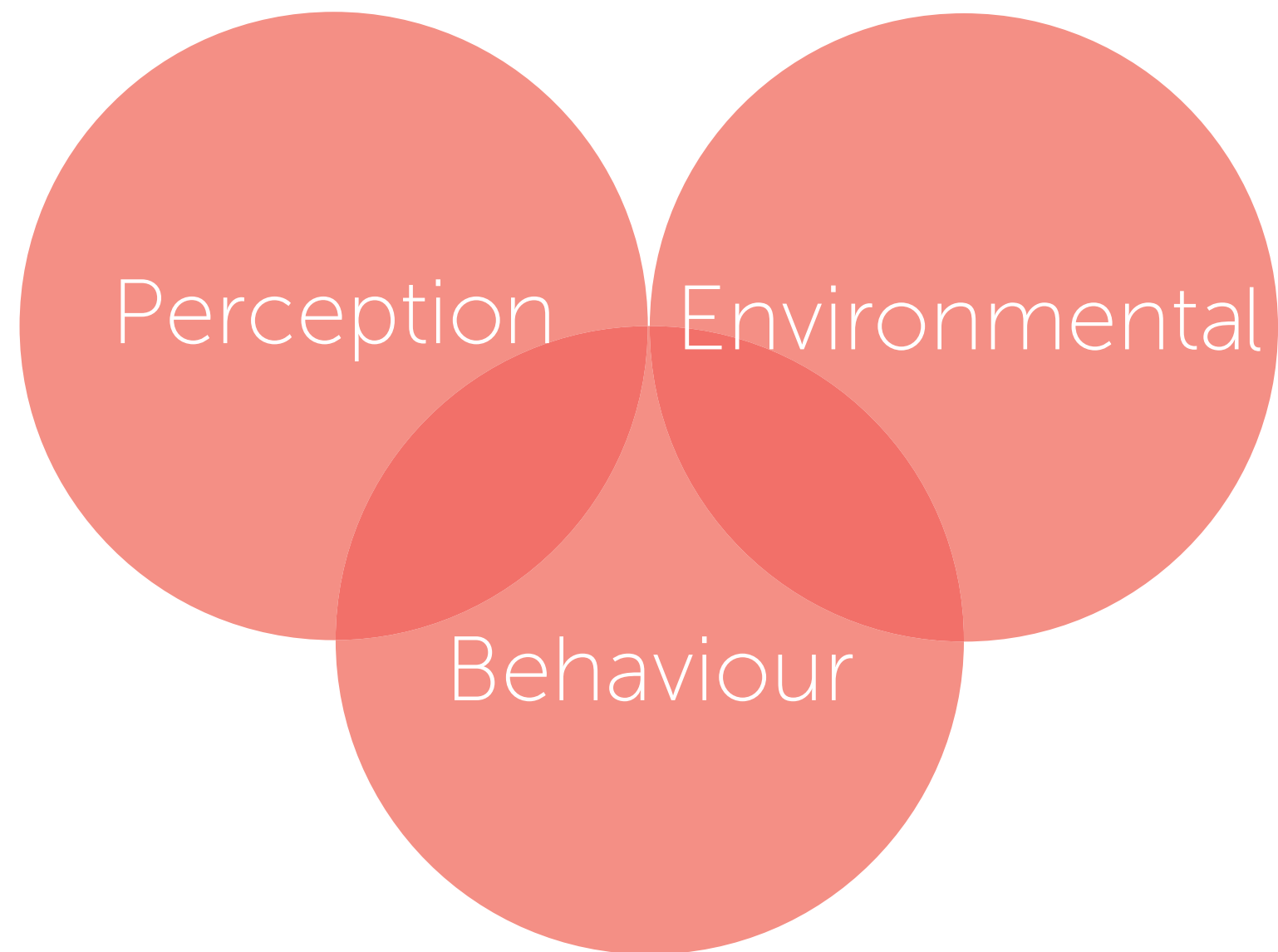
(INIVE, 2023)

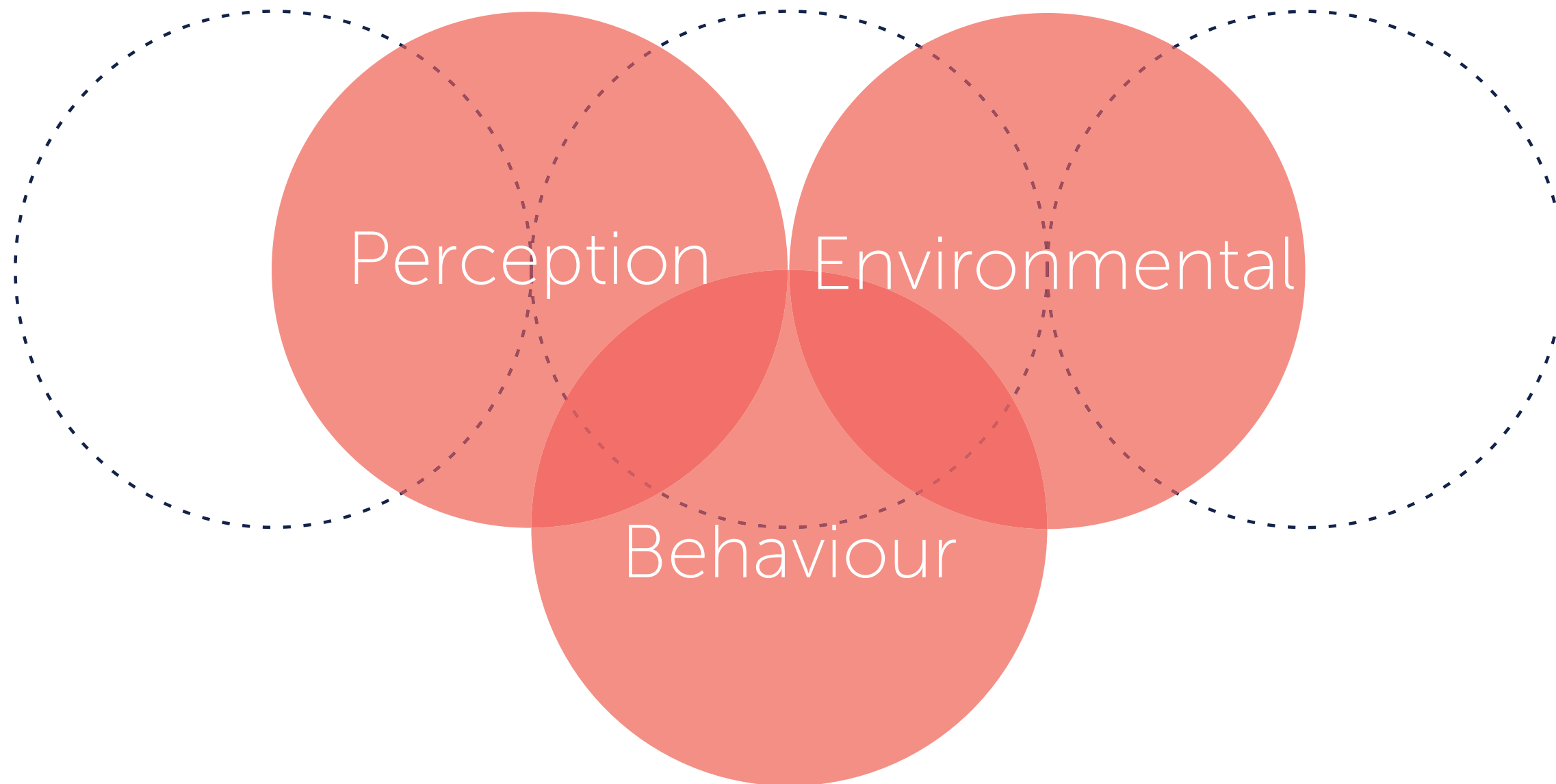


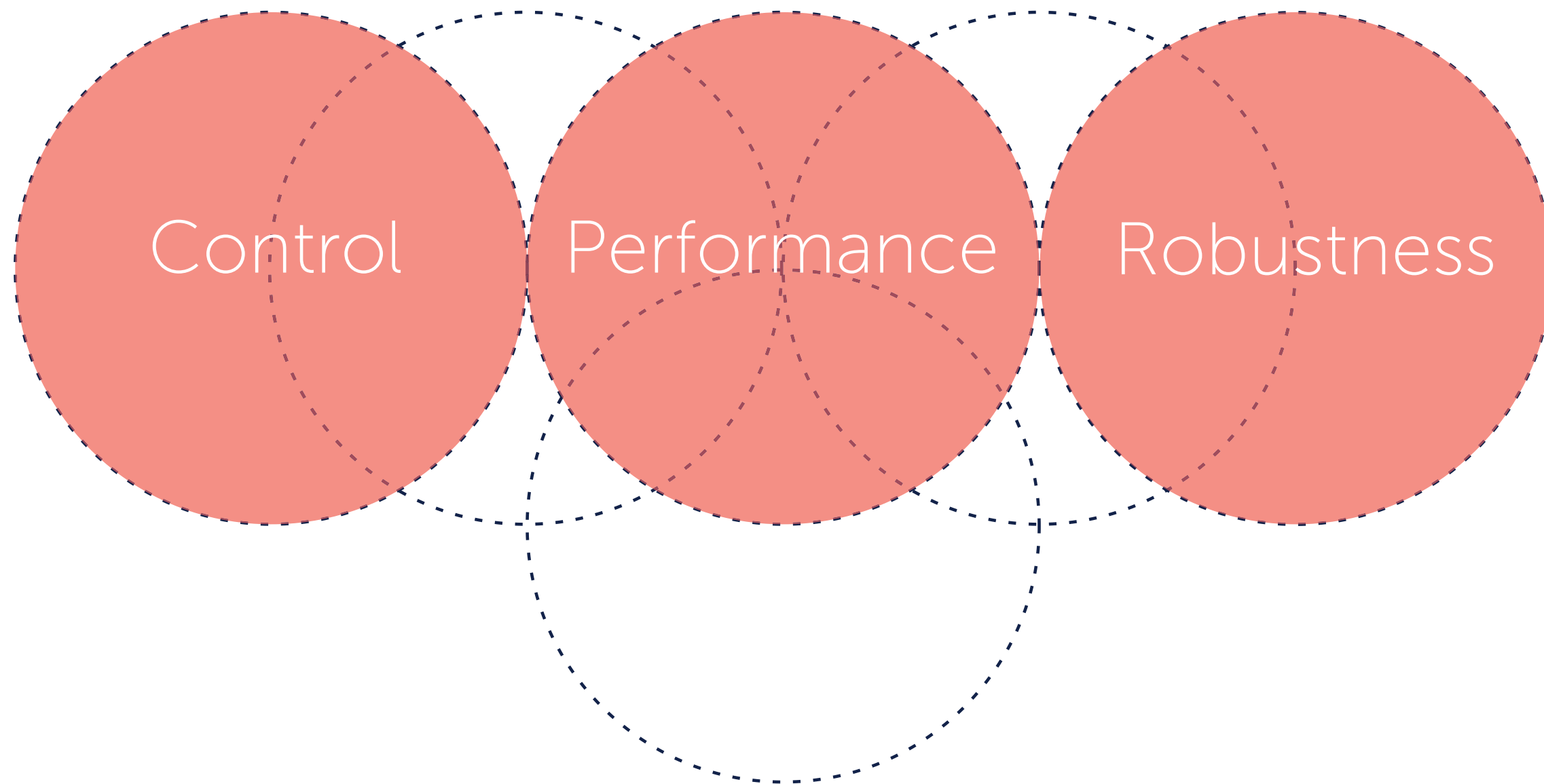


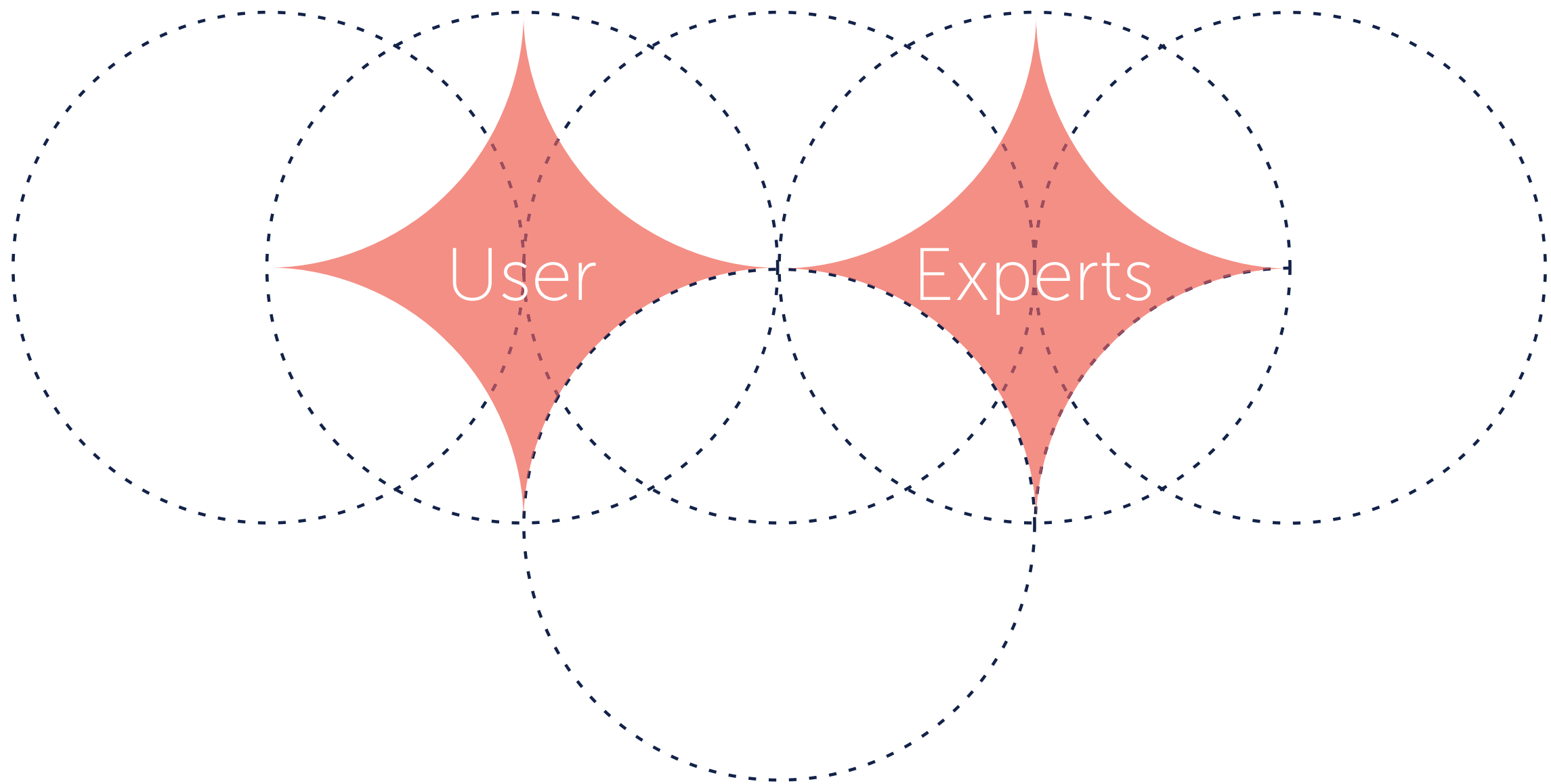
Still a lot of room for improvement.....

Interviews





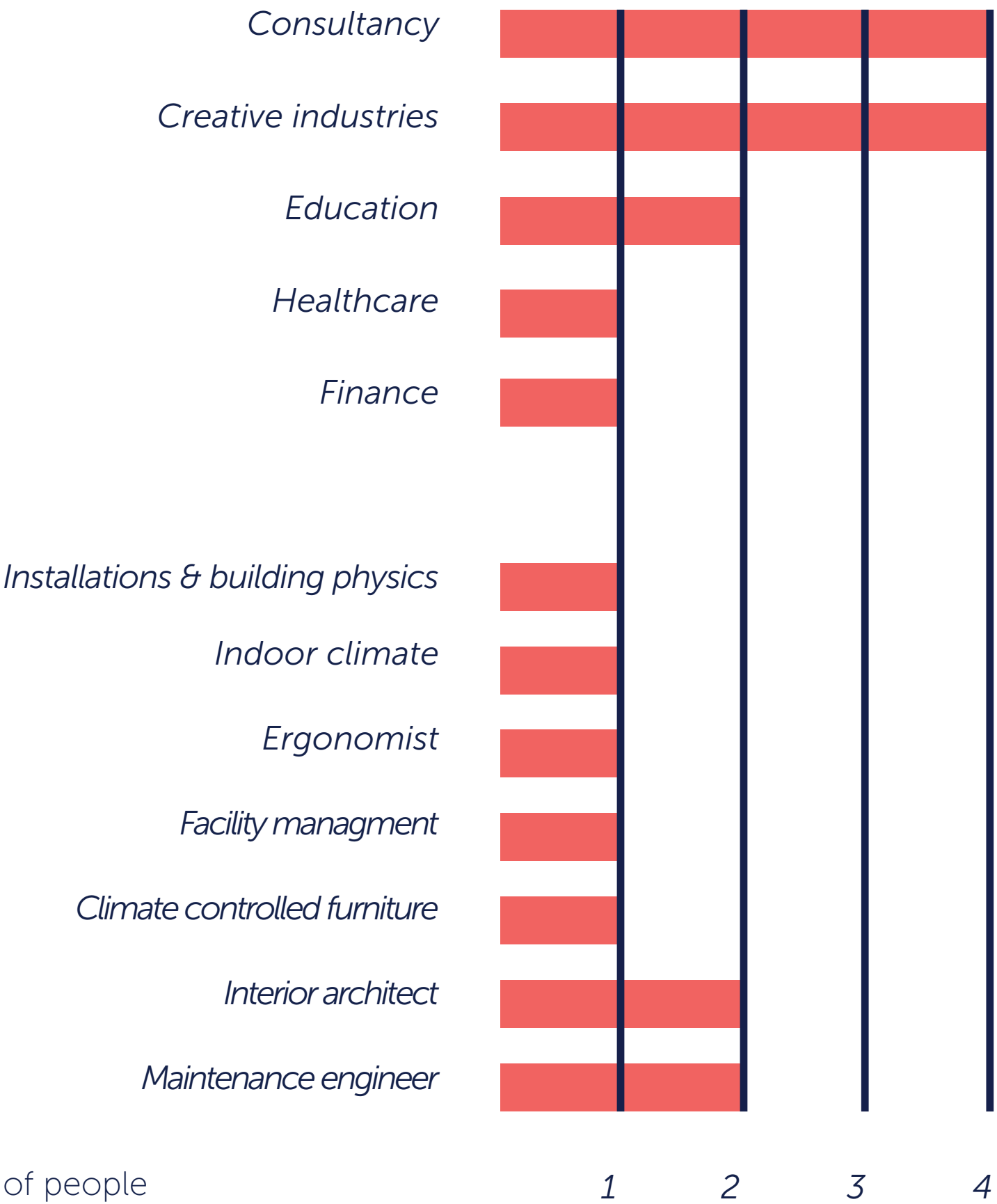




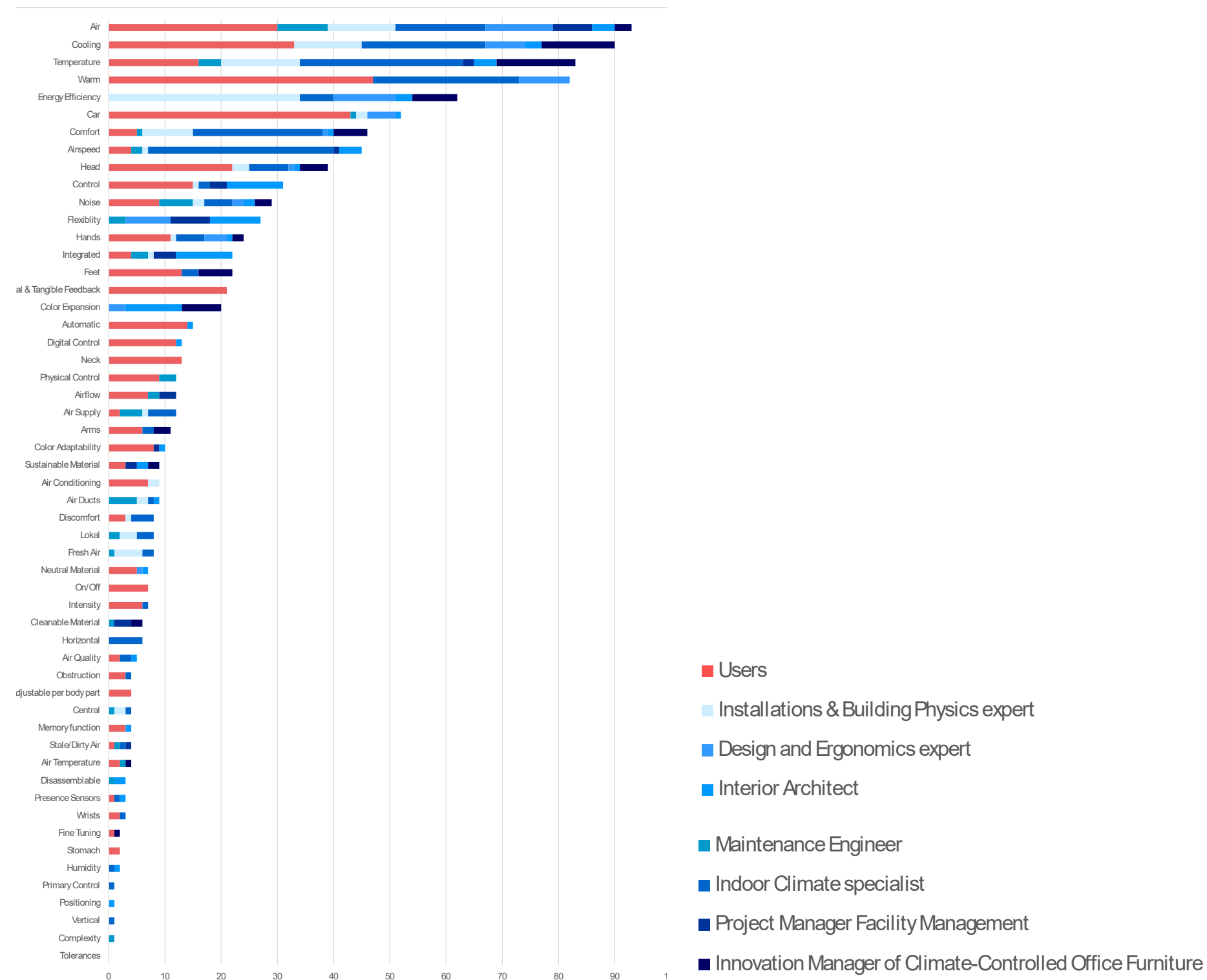
Respondents

User backgrounds

Expert backgrounds



Frequency analysis

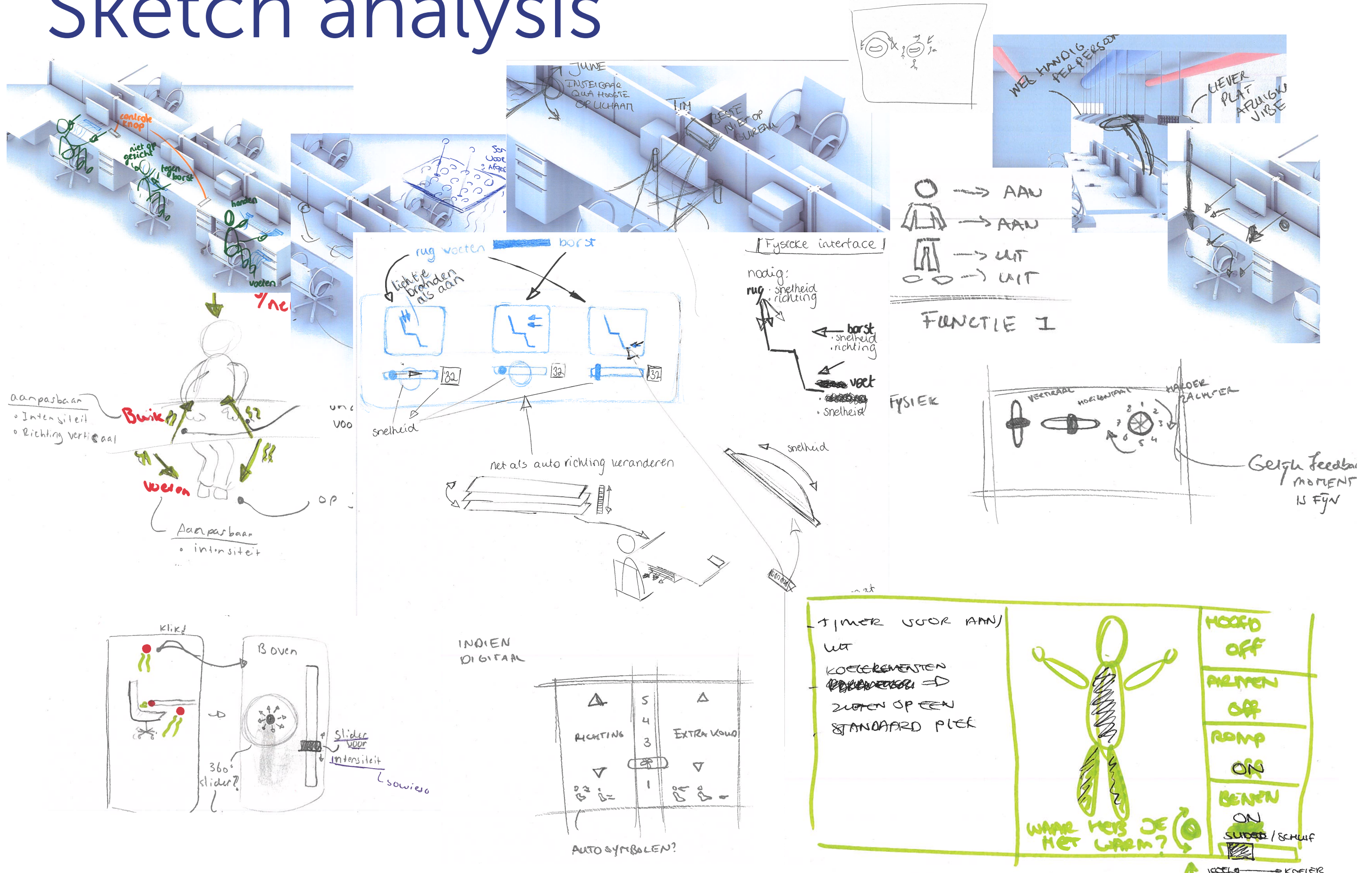


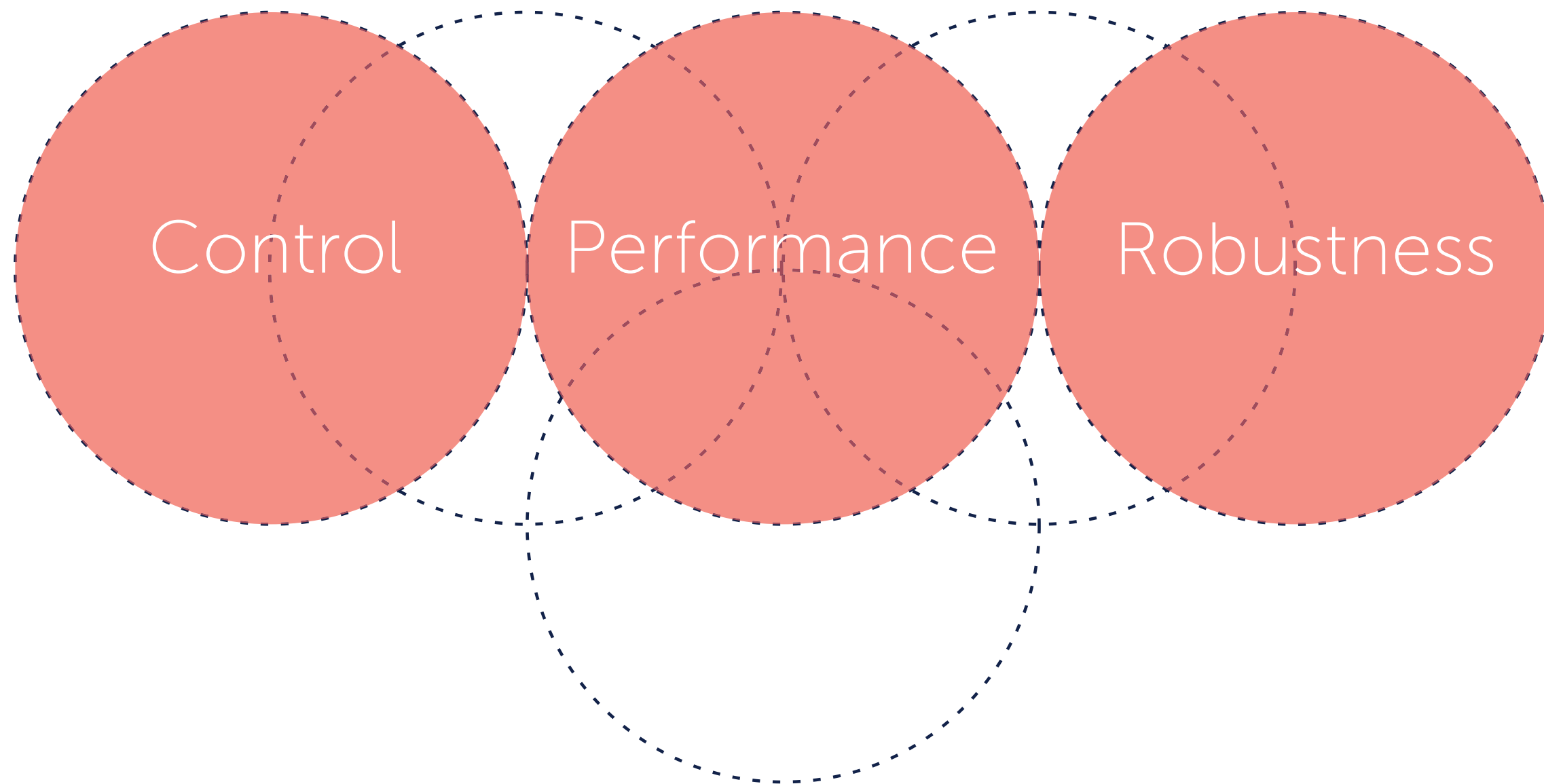
Qualitative analysis

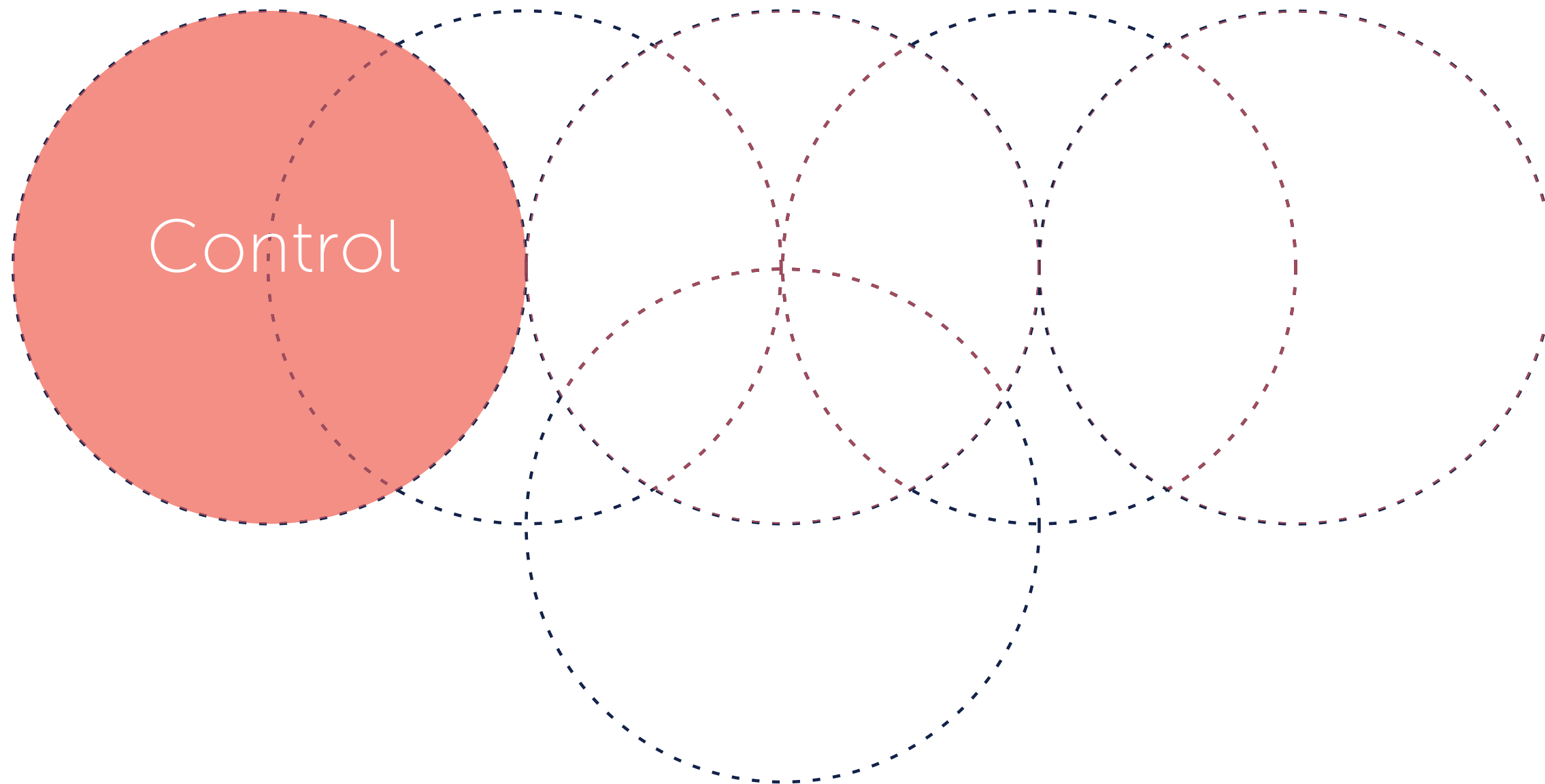
[illegible]

Criteria	Frequency									Interpretation and Specification
	U	ME	IBP	IC	DE	FM	IA	IM	Total	

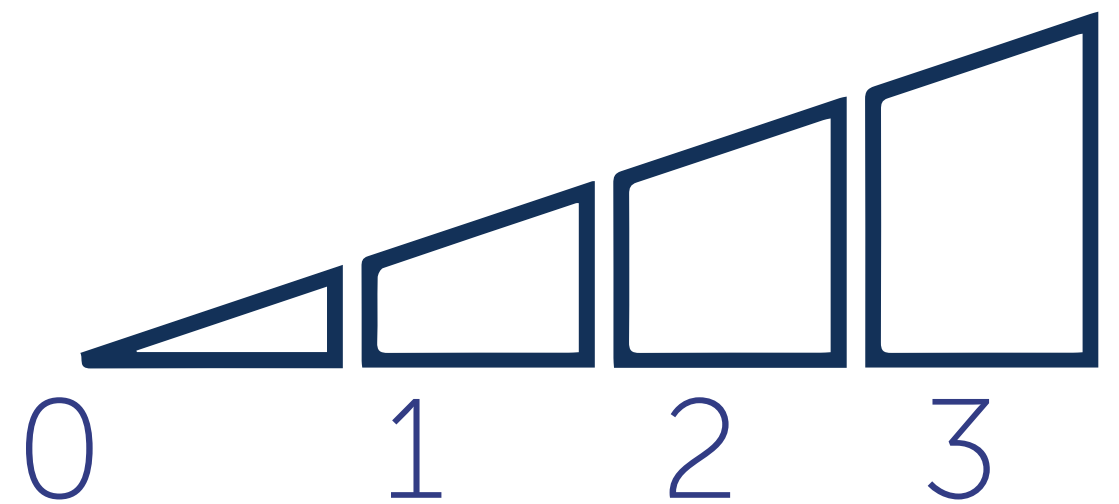
Sketch analysis



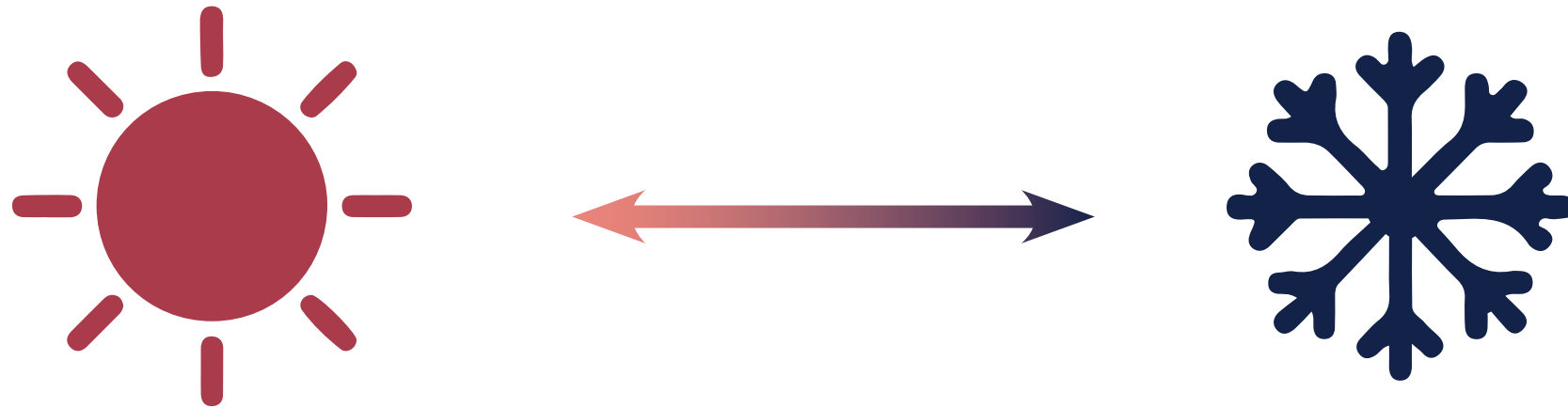


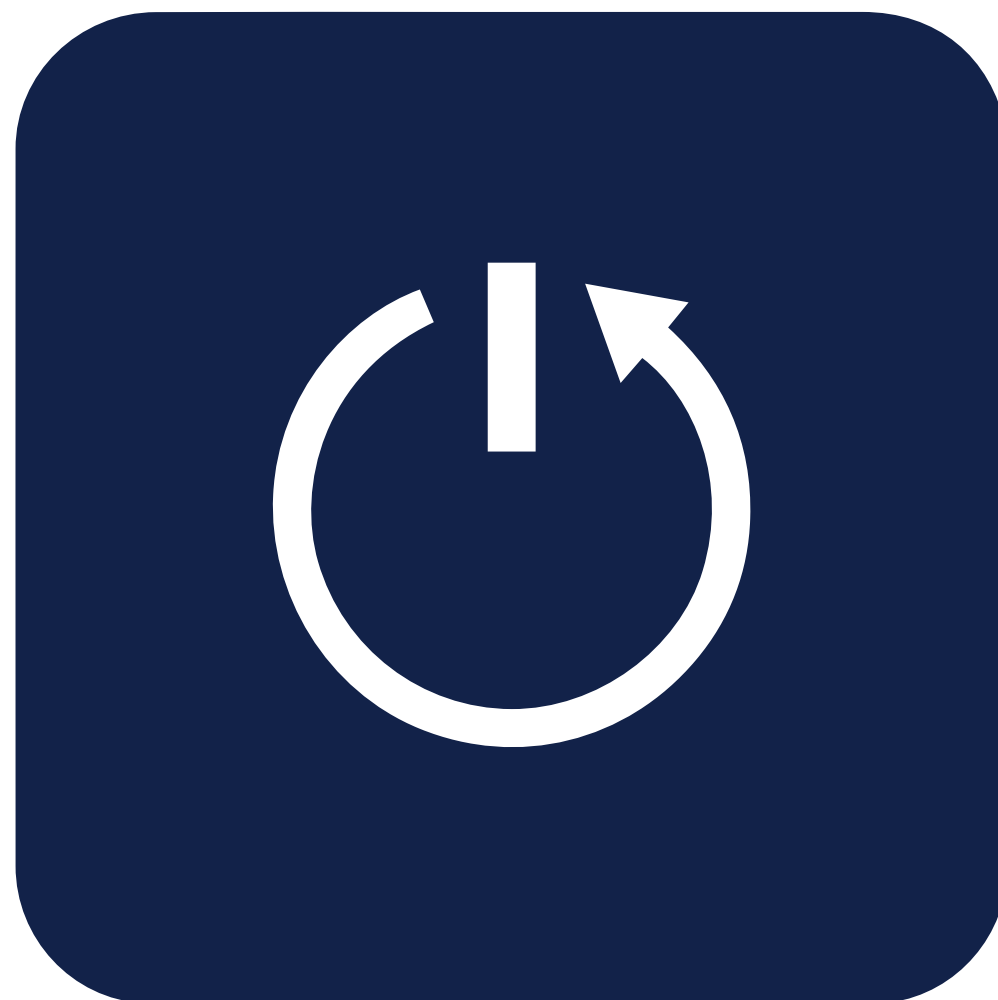


Intensity



Communication





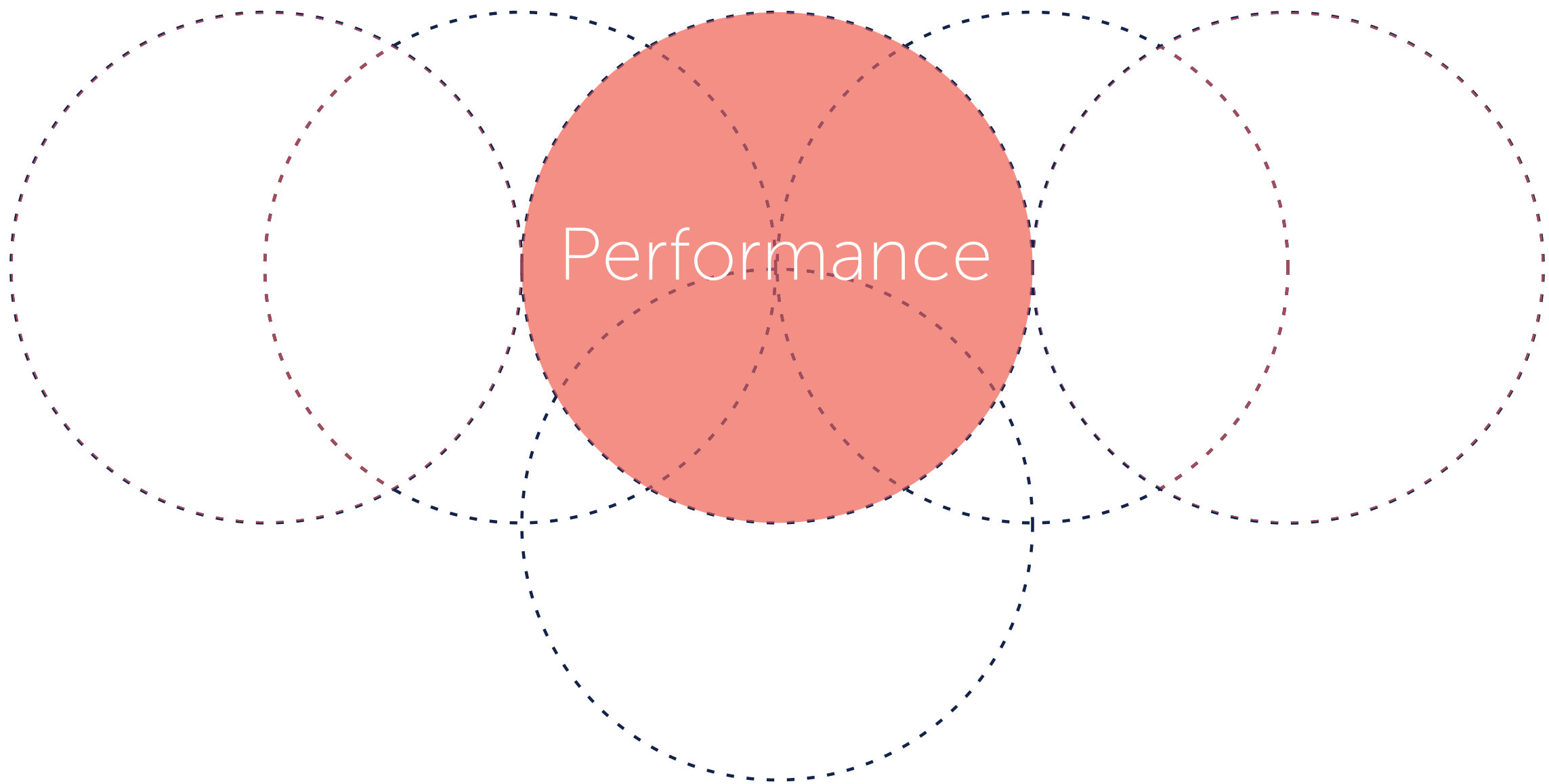
AUTO ON/OFF

Responsiveness



Responsiveness

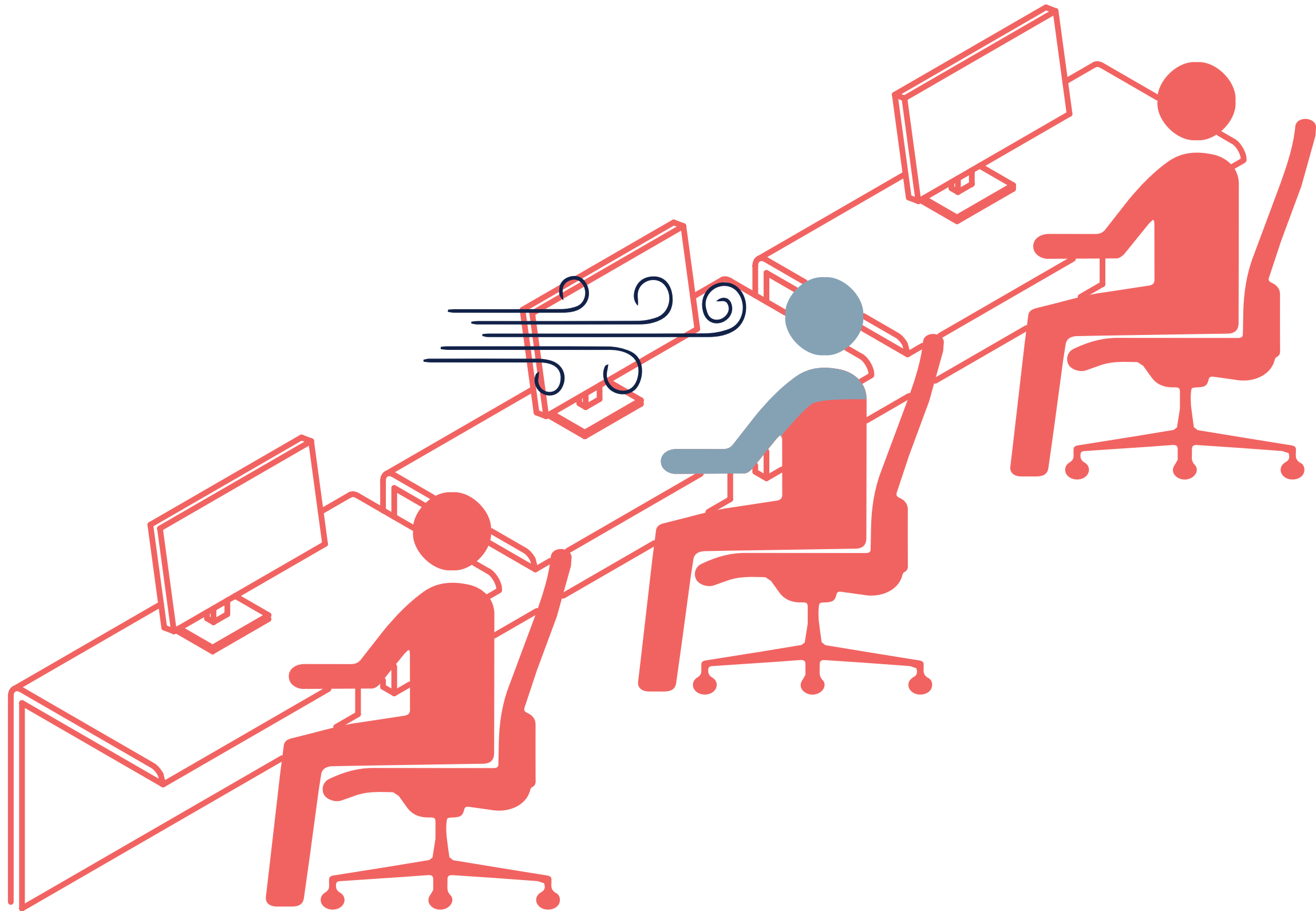




Draft felt by other occupants



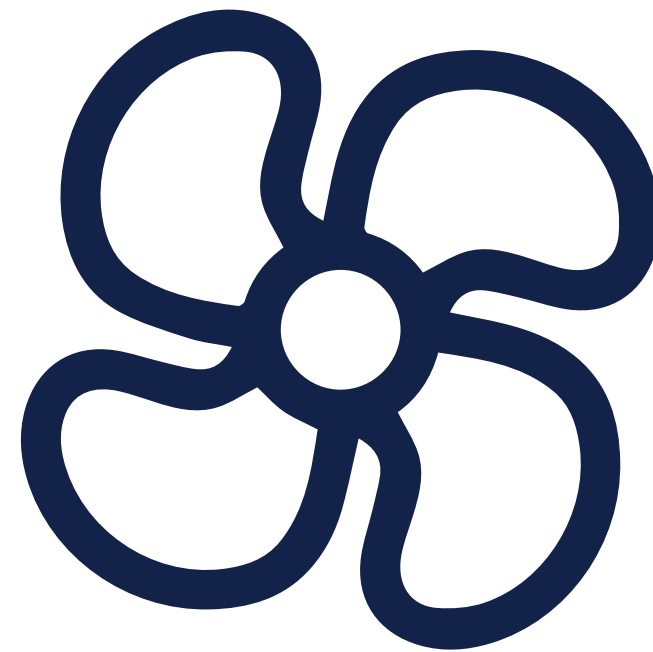
Draft felt by other occupants

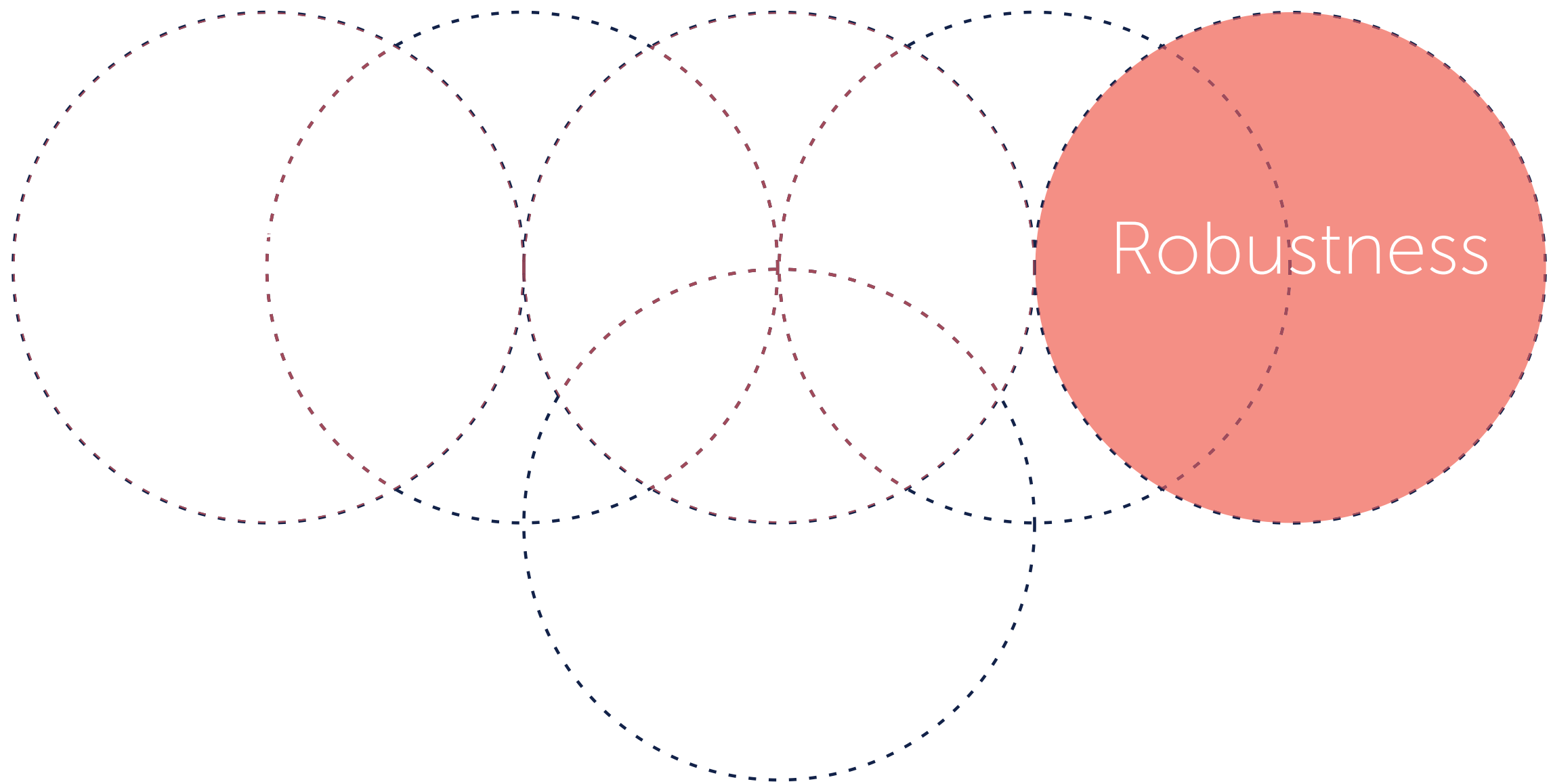


Draft felt by other occupants

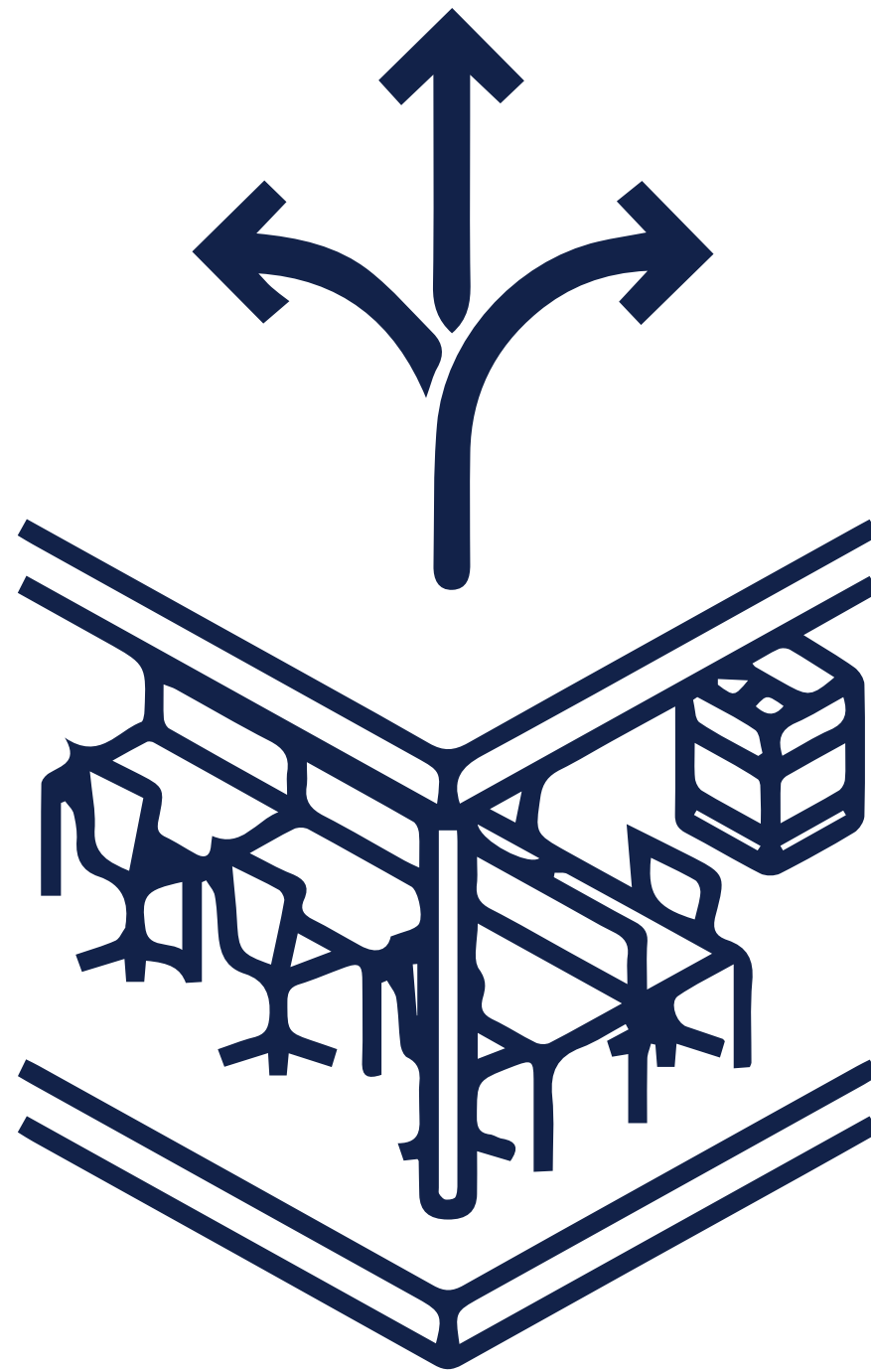


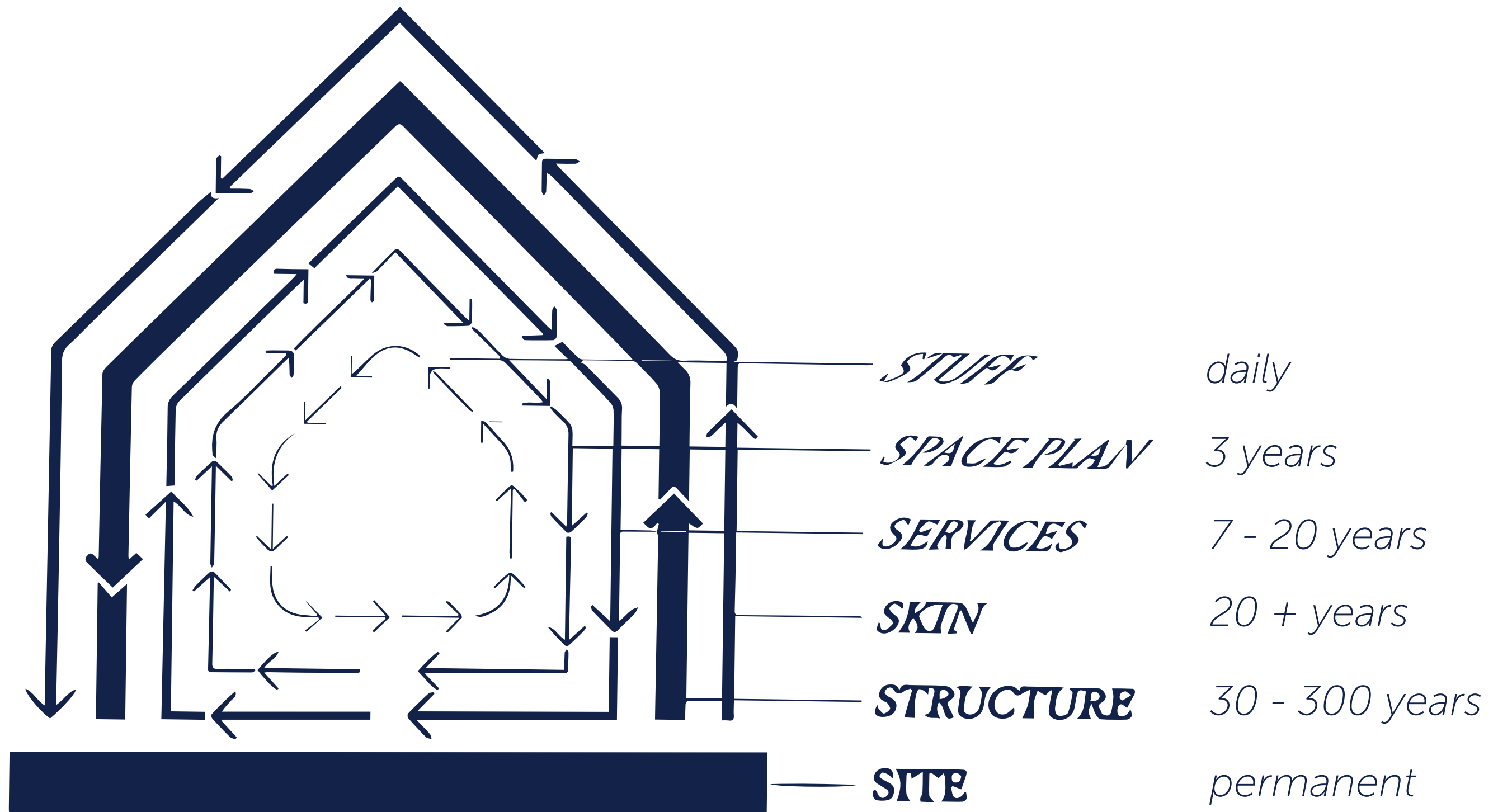
Noise





Flexibility of floorplan





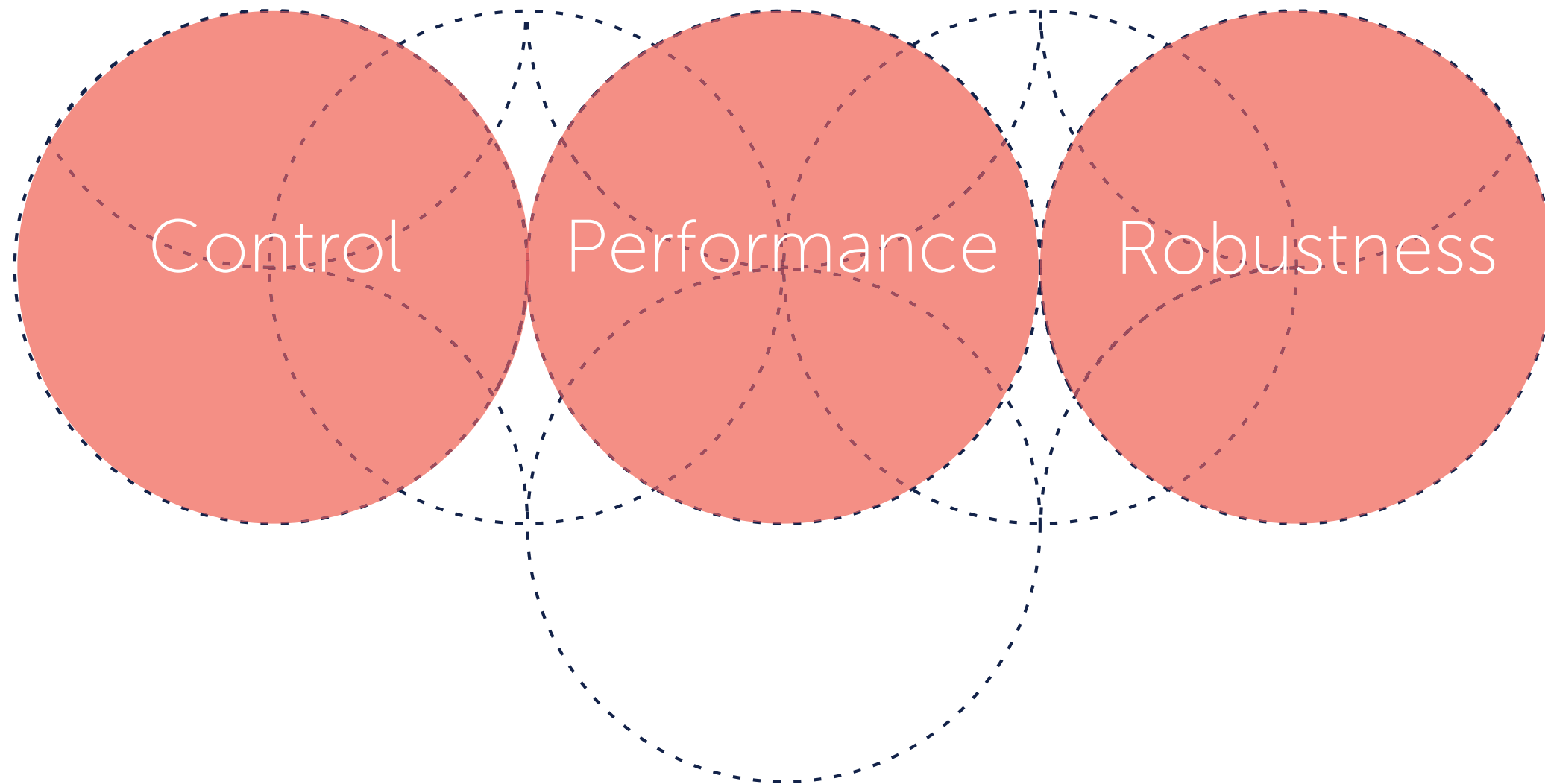
(Brand, 1994)

Contextual and aesthetic integration



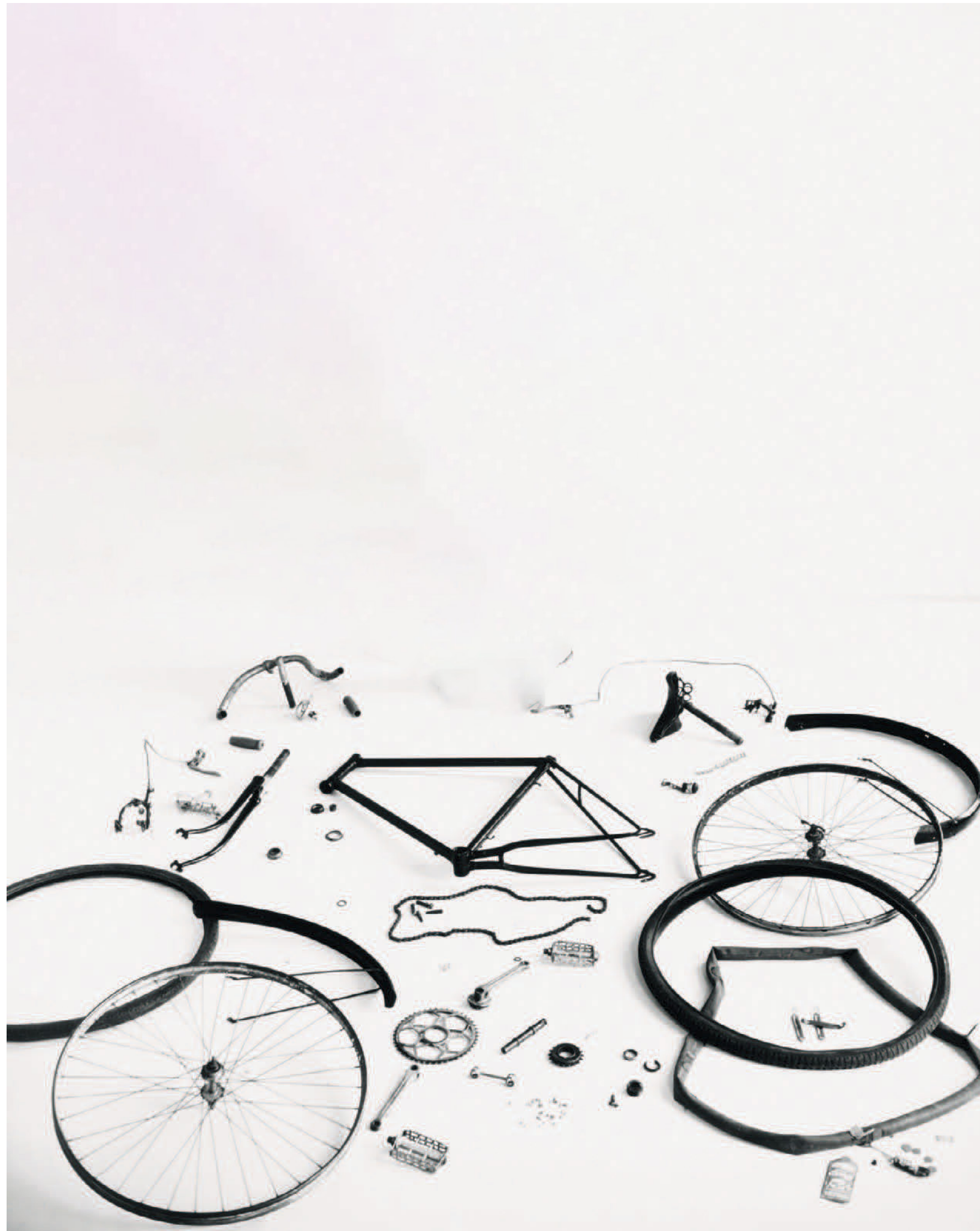
(Melikov, 2007)





All factors have been identified, so we can start
designing

Framework







Drivers, Criteria, Requirements, and Considerations

Control

Performance

Robustness

Precize adjustable per body par

Visual & tangible feedback

Silent operation

Avoid draft felt by towards occupants

Contextual and aesthetic integration

Flexibiltiy towards the office floorplans

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 for easy maintenance to be done by non-experts

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 for ease of dissassembly

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

Design means to prevent dirt accumulation

Add memory capability function

Provide a digital interface

Design means for targeting airflow on feet

Provide automatic control of airspeed

Design the PEC as a detachable element from the building

Provide means for adjusting for personal selection of settings

Add presence sensors

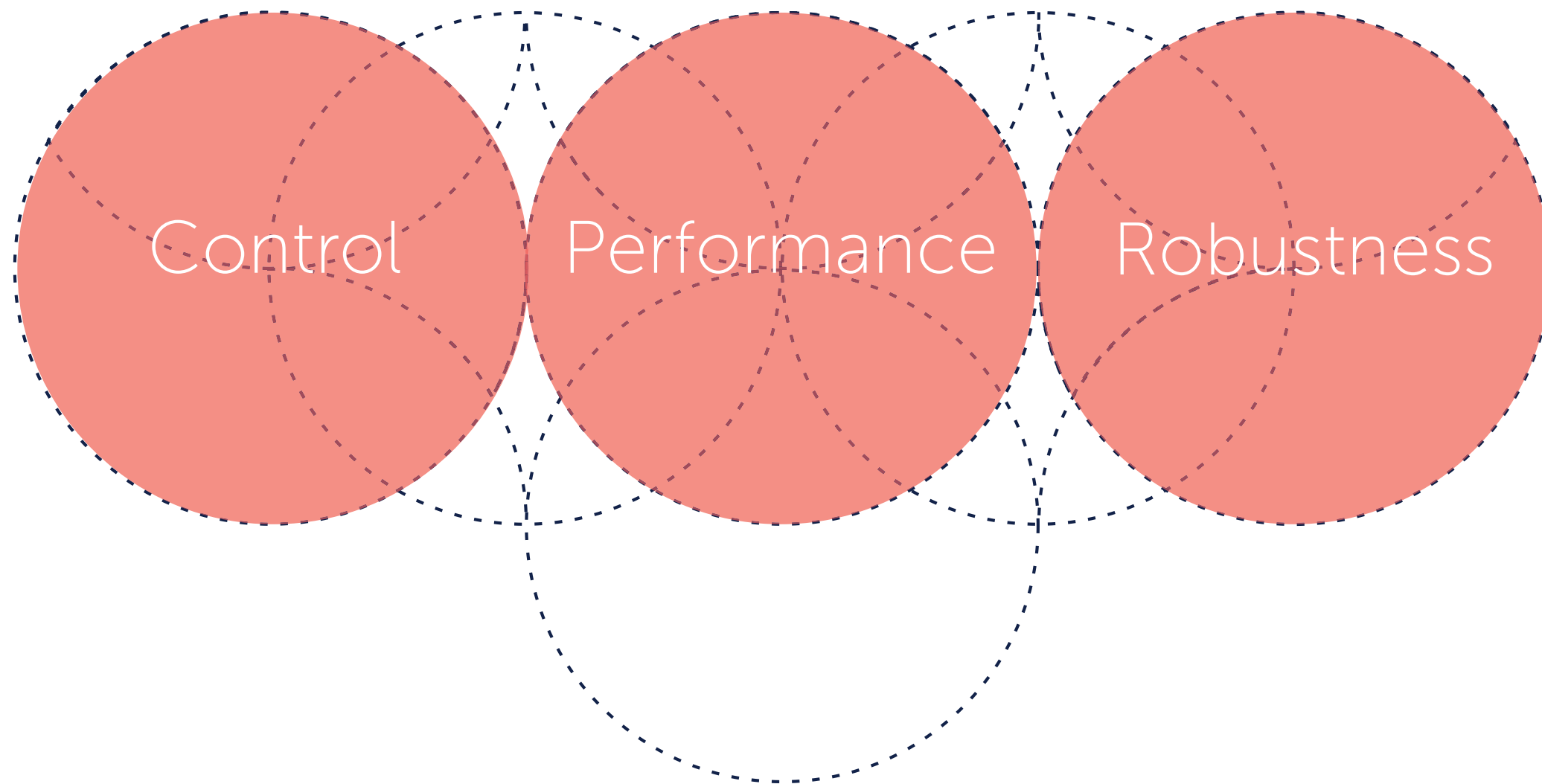
integrate with central bulding managment system

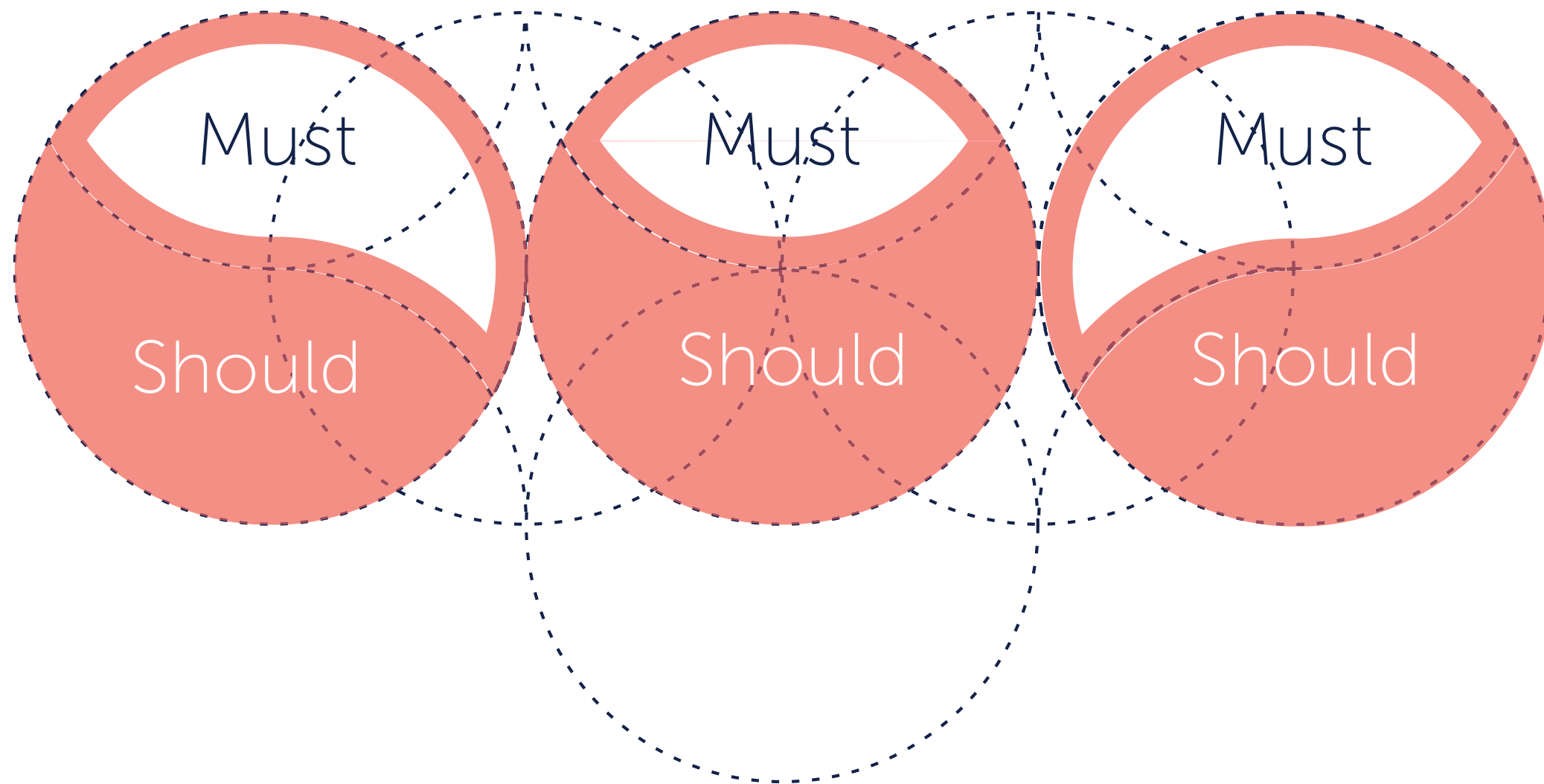
Design means for achieving an airpower spectrum slope $\beta \approx 1.8$

Design means for achieving turbulence intensity between 40% - 60%

Select material with low thermal emmissivity

Select sustainable materials





MUST

SHOULD

Control

Performance

Robustness

Precize adjustable per body par

Visual & tangible feedback

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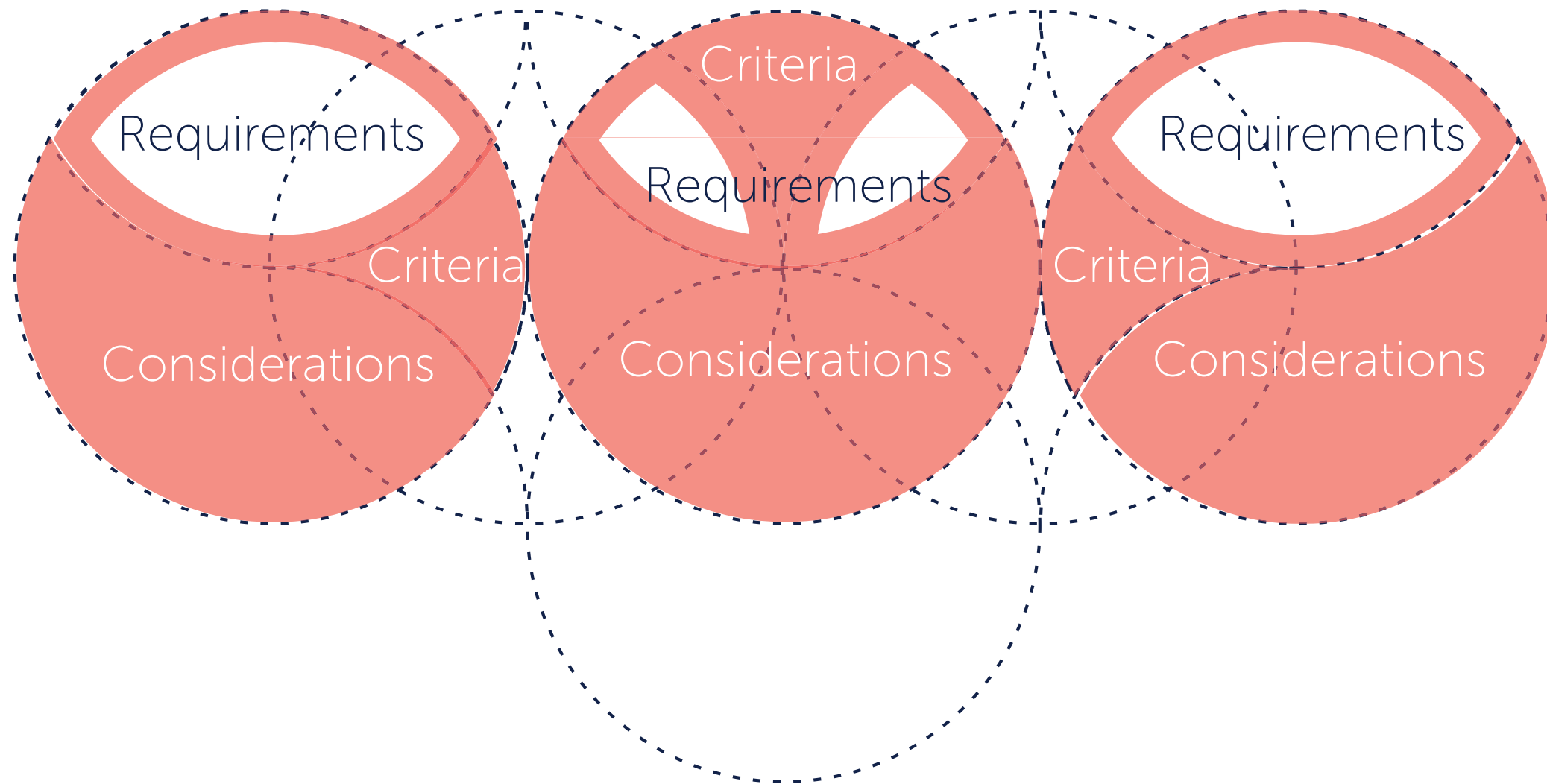
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Control

Performance

Robustness

DESIGN CRITERIA

Precize
adjustable per
body part

Visual
& tangible
feedback

Silent
operation

Avoid draft
felt by towards
occupants

Contextual
and aesthetic
integration

Flexibiltiy
towards the
office floorplans

Position
the contol
point in the
2nd or 3rd
ergonomic
zone

Communicate
by using:
1. Buttons,
2. Symbols,
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Numbers

Position
the device
in the 3rd
ergonomic zone
or beyond

Selecting
energy-
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to produce 1.5
m/s at user's
location

Keep each
layer easy to
separate

Design
for easy
maintenance
to be done by
non-experts

Design means
for finetuning
airspeed

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Design
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Provide
automatic
control of
airspeed

Design
the PEC as
a detachable
element from
the building

Provide
means
for adjusting
for personal
selection of
settings

DESIGN CONSIDERATION

Add presence
sensors

integrate with
central bulding
managment
system

Design
means for
achieving
an airpower
spectrum slope
 $\beta \approx 1.8$

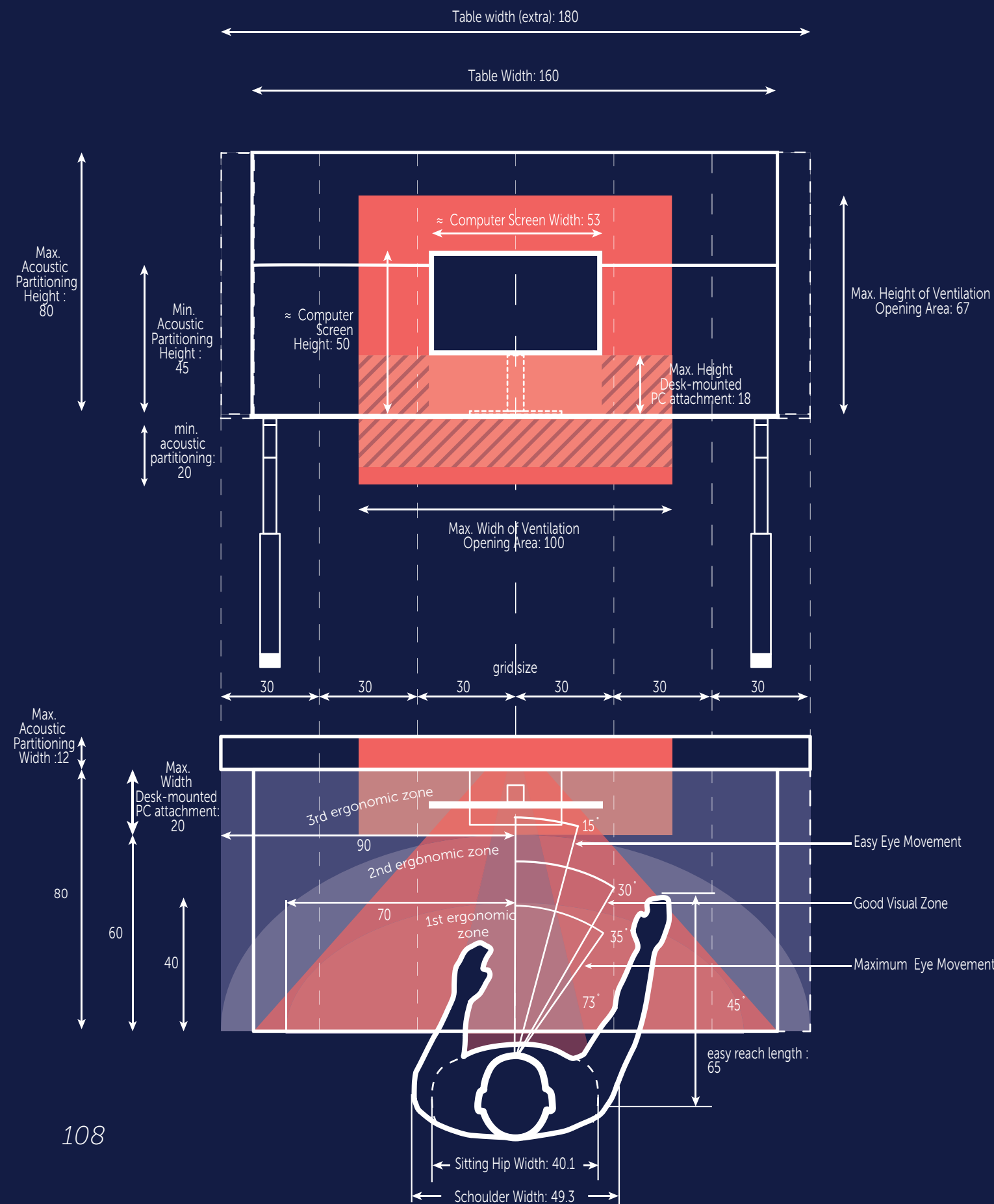
Design
means for
achieving
turbulence
intensity
between
40% - 60%



Select
material with
low thermal
emmissivity

Select
sustainable
materials

Ergonomic Manual

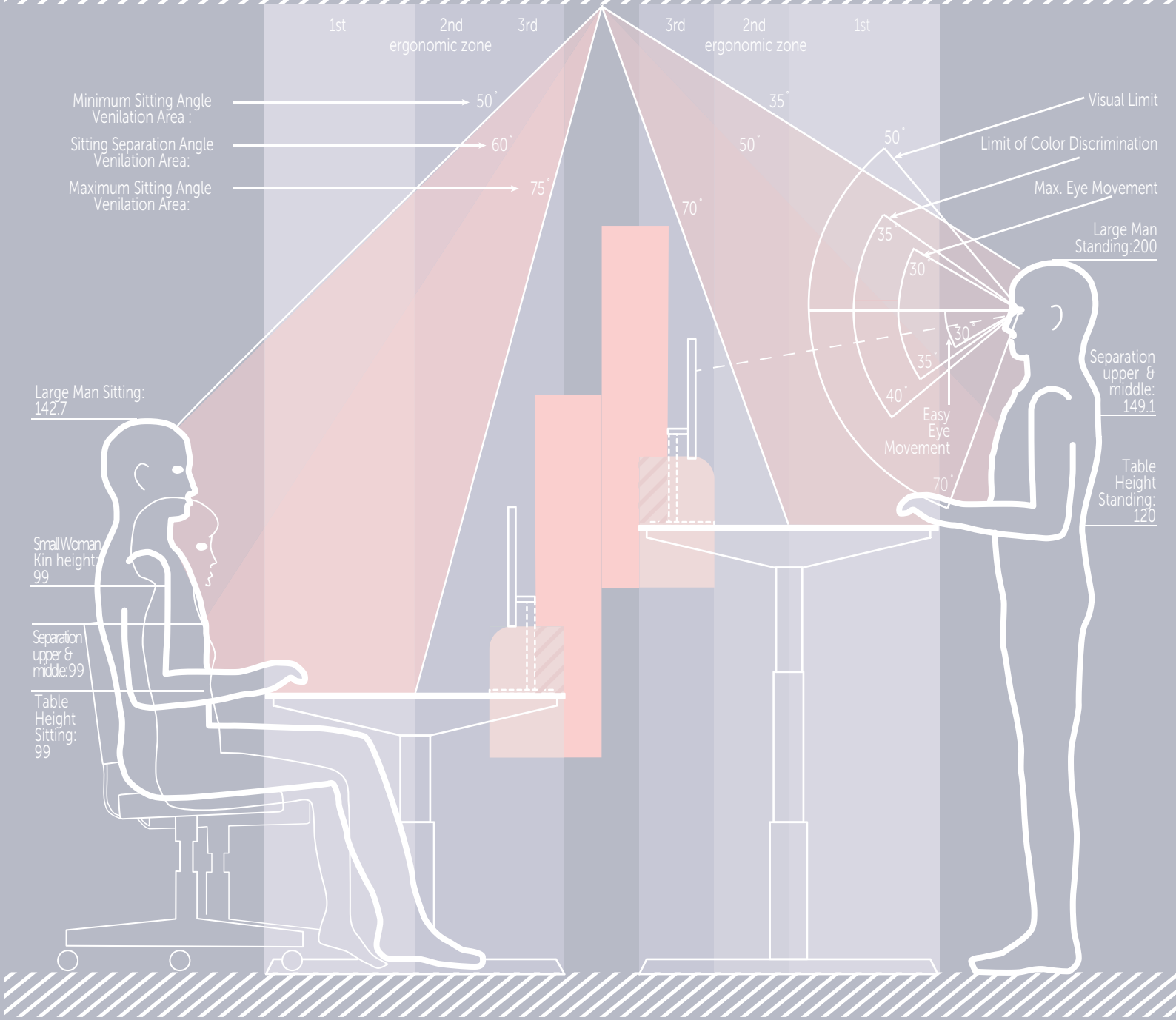
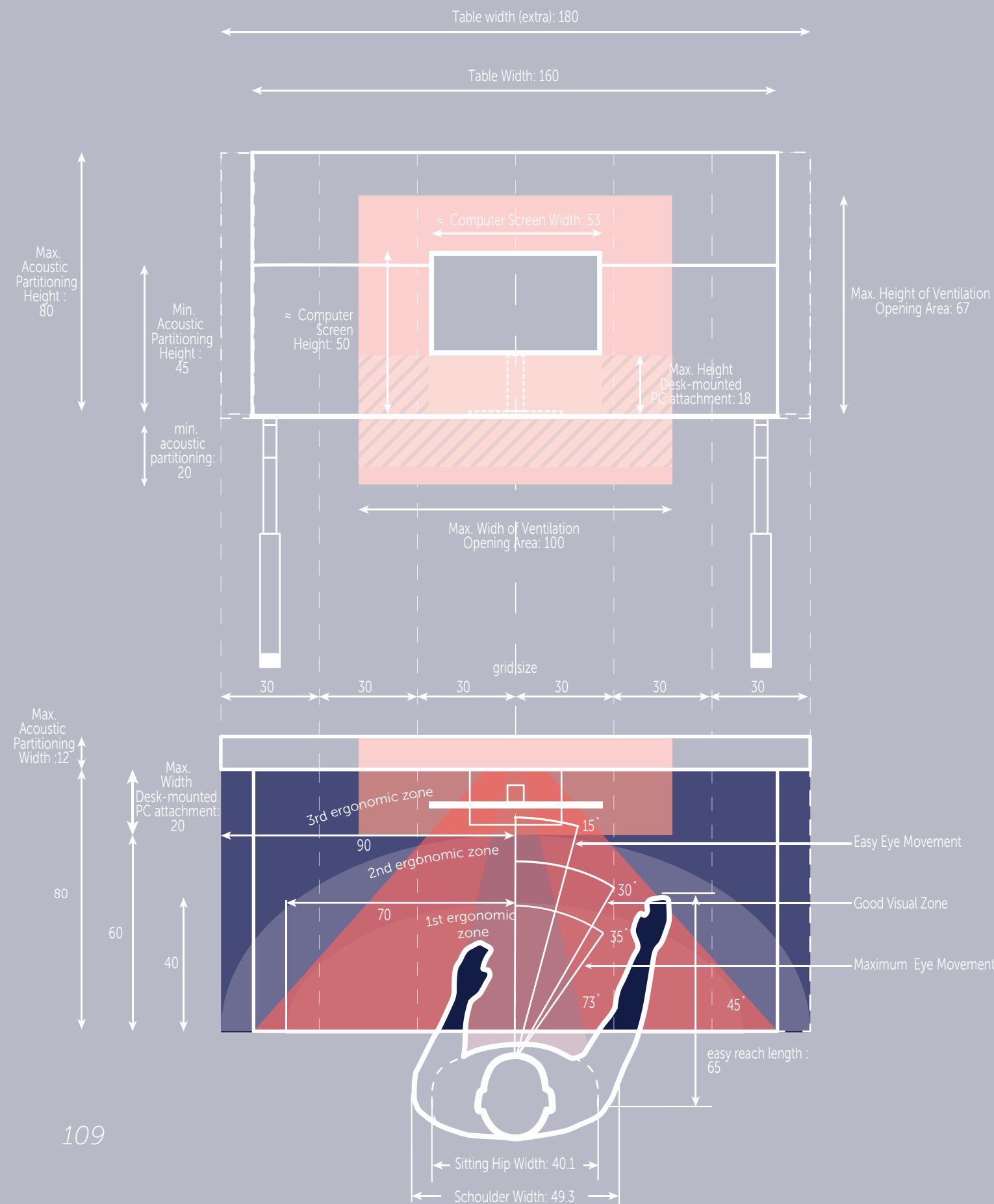
Measurements for a BreezeMaker Device based on the minimum & maximum dimensions of the human body in centimeters



Visual Display		Organization	
Letter Style :	Simple and Sans Serif (e.g., Futura, Helvetica, Venus or Gothic)	Minimum Font Height 3.3 Routine Marking	Panel Hierarchy : 1. Physical Button 2. Symbols 3. Letters
Location of Titles :	Above displays or controls (except when the control or display is above eye level)	Minimum Font Height 4.8 Critical Marking	Panel Organization : priority controls first, related controls together, max 8 controls
Character Orientation :	Prefer always vertical	Minimum Size of Indexes Low Illumination	Climate Communication: warm(er) or cold(er), temperature up or down
Work Orientation :	Prefer always horizontal	 Major Index : 7.1 x 1.1 Minor Index : 3.3 x .81 Intermediate : 5.1 x .91 Spacing : 2.3	On/Off: Up/Down, Right/Left, Fwd/Back, Pull/Push, Clockwise/Counnter C
Optimum Contrast :	10:1	Minimum Size of Indexes High Illumination	Increase/Decrease: Up/Down, Right/Left, Fwd/Back, Clockwise/Counnter C
Min. Contrast ratio:	3:1	 Major Index : 7.1 x .4 Minor Index : 2.8 x 0.4 Intermediate : 5.1 x .4 Spacing : 1.8	Raise/Lower: Up/Down, Back/Fwd
Spacing Optimum between controllers:	1.9		

Ergonomic Manual

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



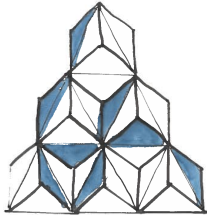



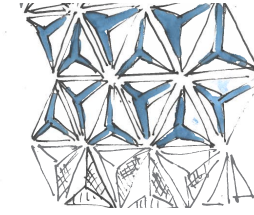
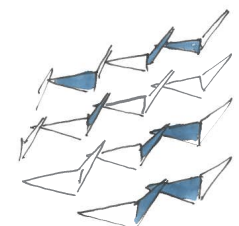
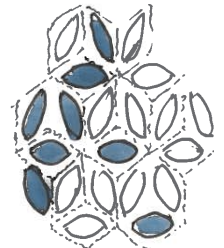



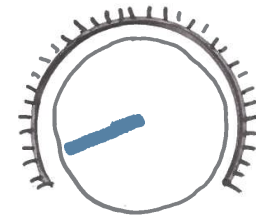
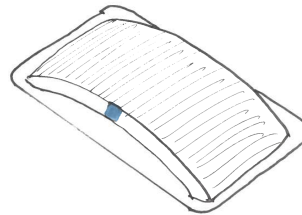
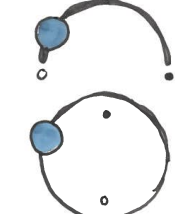
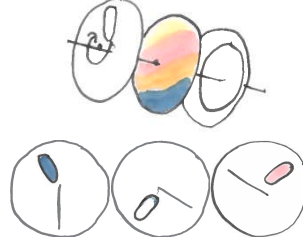


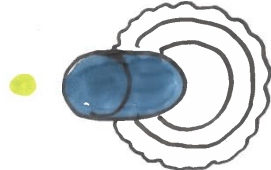


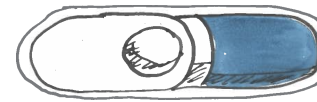
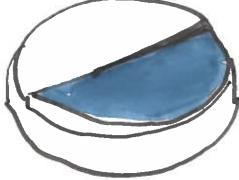
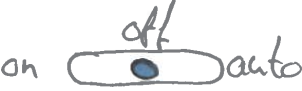


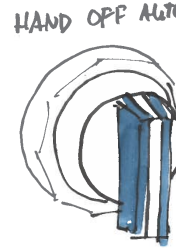

Visual Display		Organization	
Letter Style :	Simple and Sans Serif (e.g., Futura, Helvetica, Venus or Gothic)	Minimum Font Height 3.3	Routine Marking
Location of Titles :	Above displays or controls (except when the control or display is above eye level)	Minimum Font Height 4.8	Critical Marking
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Work Orientation :	Prefer always horizontal	Major Index : 7.1 x 1.1 Minor Index : 3.3 x .81	
Optimum Contrast :	10:1	Intermediate : 5.1 x .91 Spacing : 2.3	
Min. Contrast ratio:	3:1	Minimum Size of Indexes High Illumination	
Spacing Optimum between controllers:	1.9	Major Index : 7.1 x 4 Minor Index : 2.8 x 0.4	
		Intermediate : 5.1 x 4 Spacing : 1.8	
		Panel Hierarchy :	1. Physical Button 2. Symbols 3. Letters
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		Increase/Decrease:	Up/Down, Right/Left, Fwd/Back, Clockwise/Counnter C
		Raise/Lower:	Up/Down, Back/Fwd

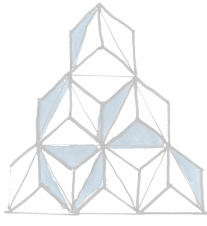

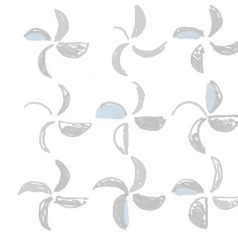

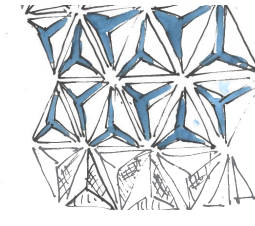
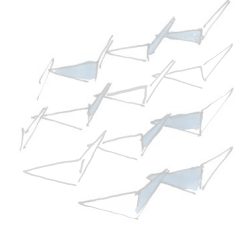
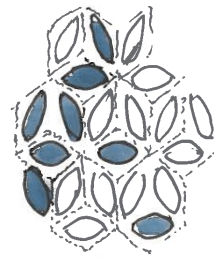



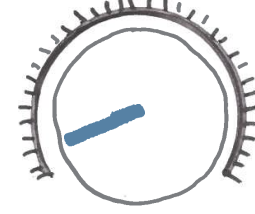
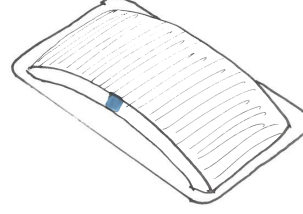

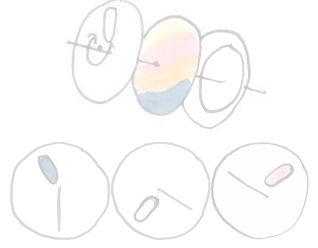


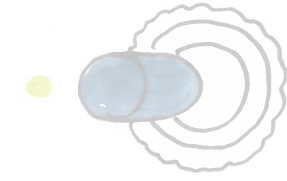


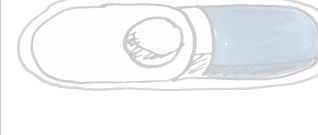
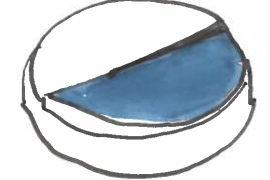


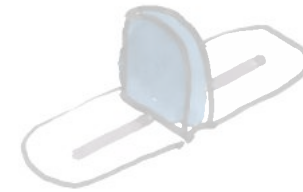
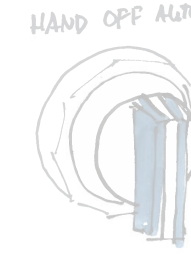

Application of the Framework

Morphological Chart Method

Morphological Chart Method

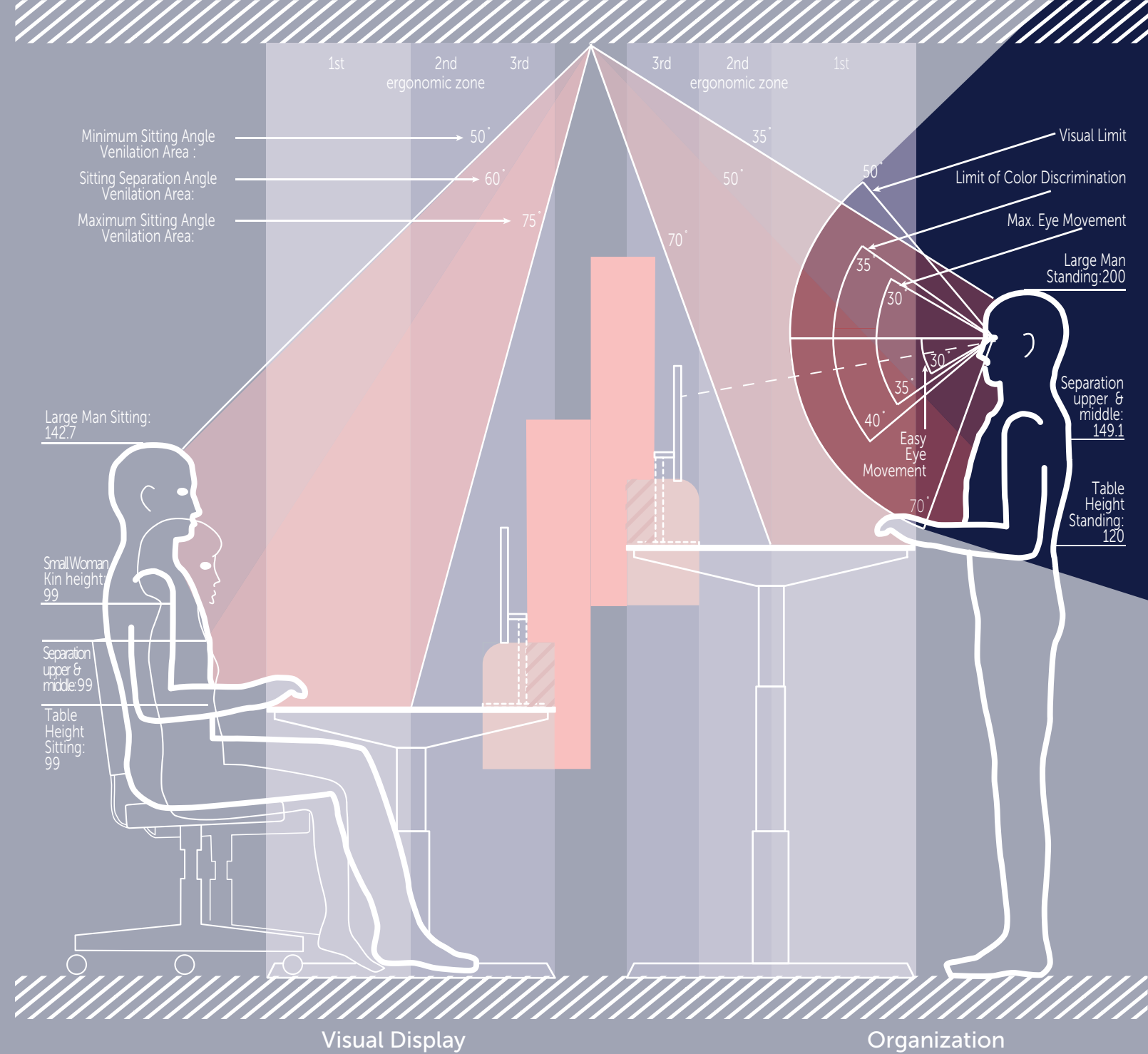
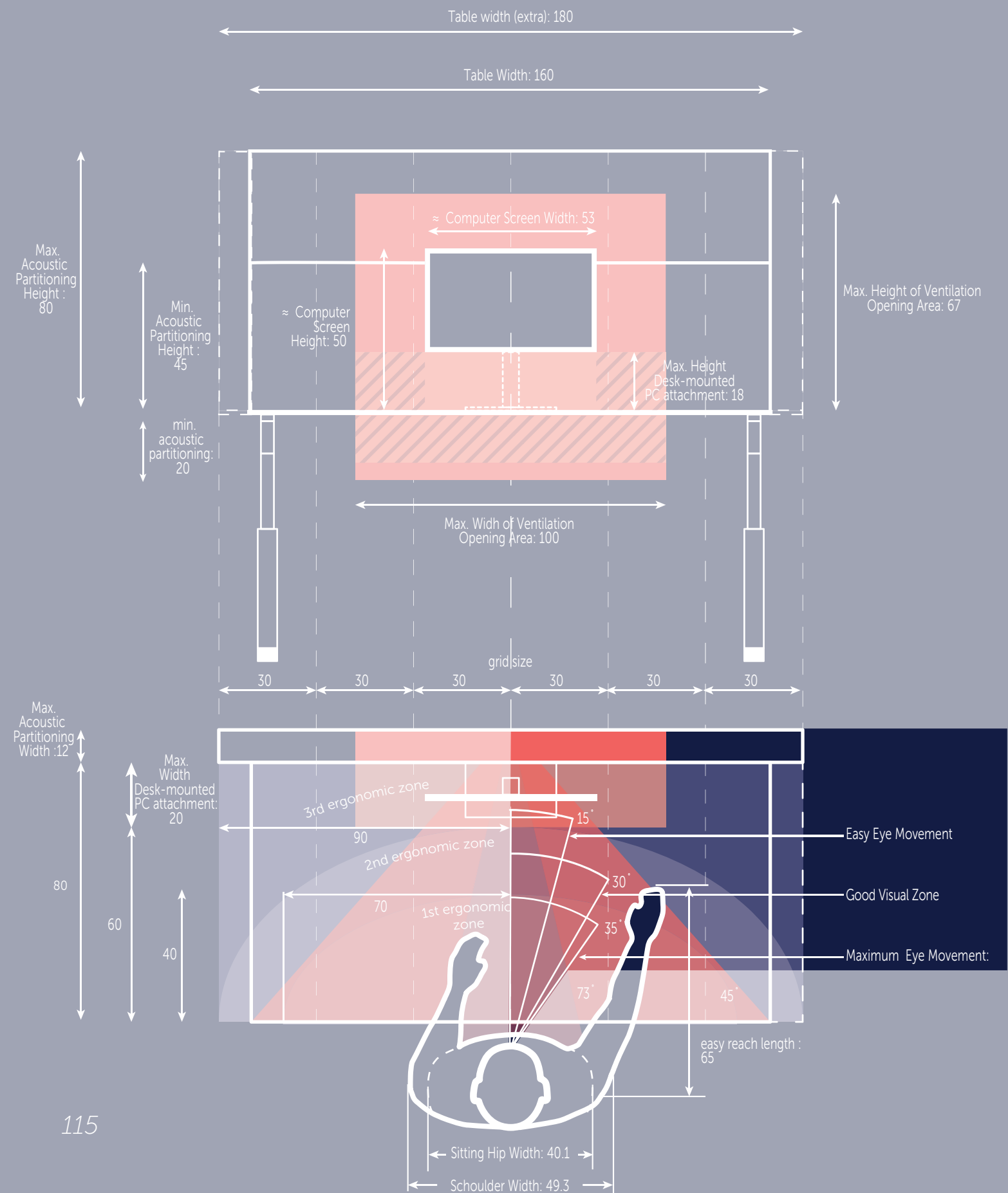
Design Requirement 1	Variation 1	Variation 2	Variation 3	etc			
Design Requirement 2	Variation 1	Variation 2	Variation 3				
Design Requirement 3	Variation 1	Variation 2	Variation 3	Variation 4	Variation 5	Variation 6	Variation 7



Physical Interface							
Finetuning							
On/Off							
Automatic preset funtion							

Physical Interface							
Finetuning							
On/Off							
Automatic preset function							

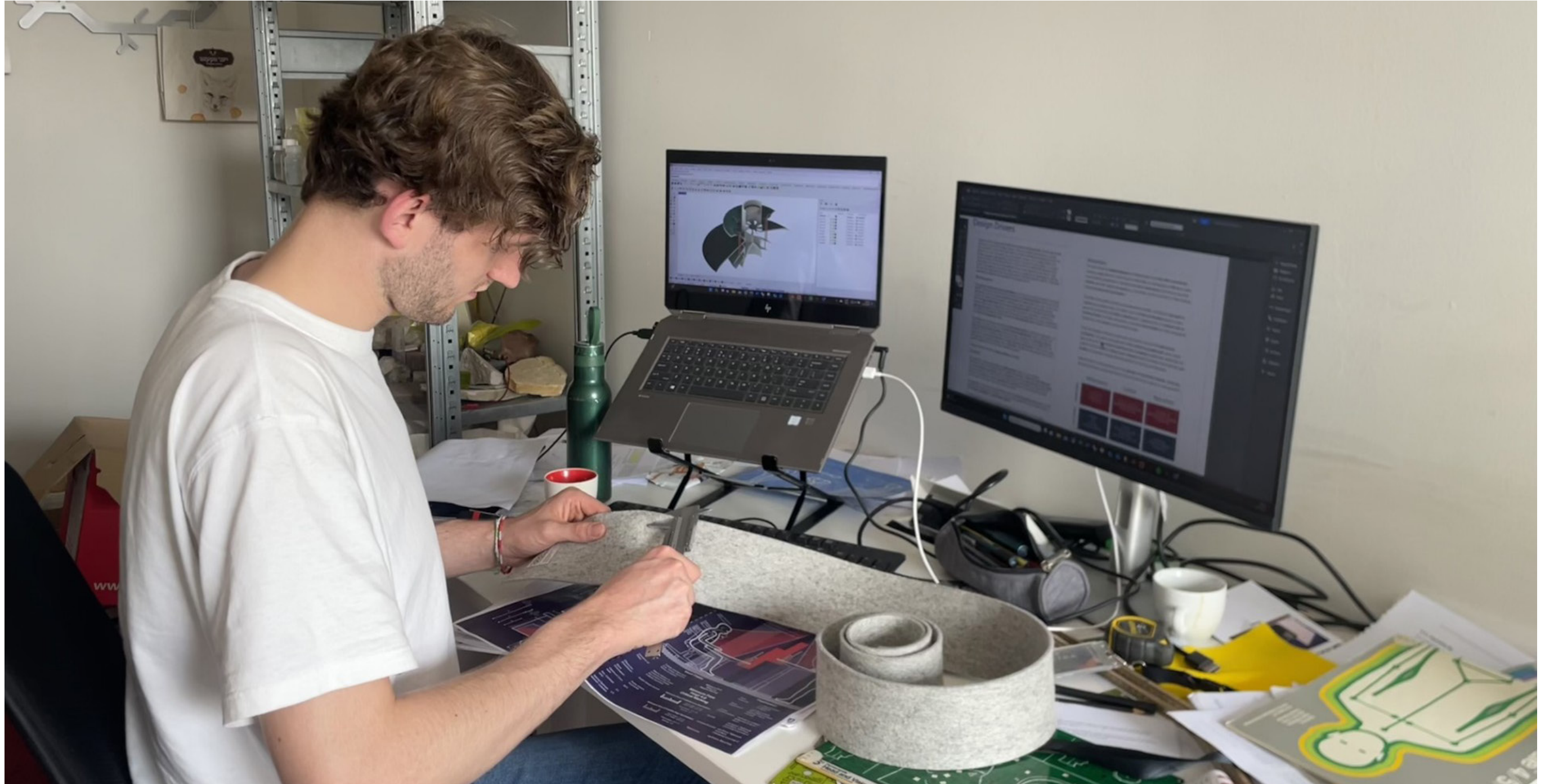
Ergonomic Manual

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Spacing Optimum between controllers:	1.9		




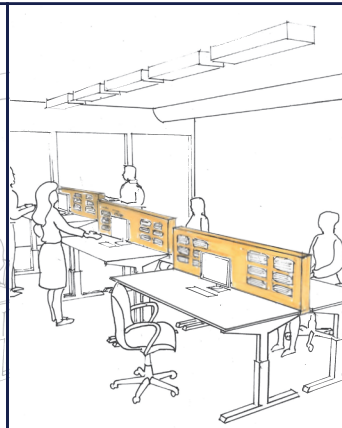
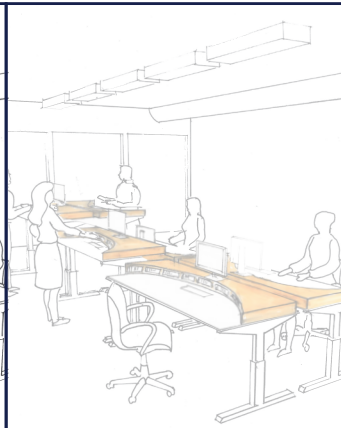
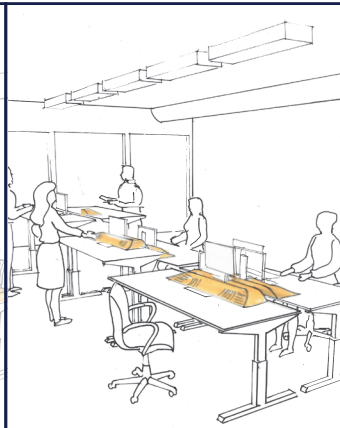
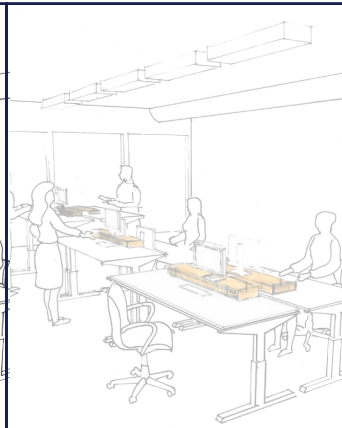
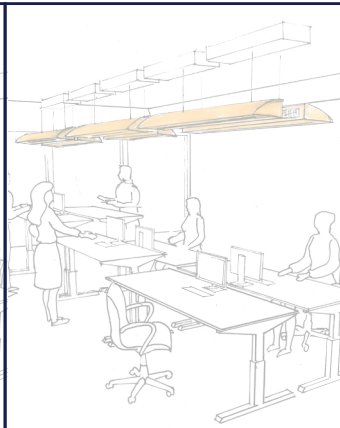
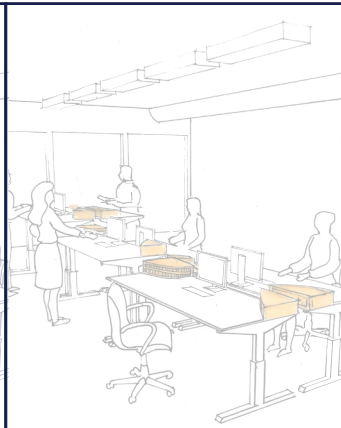


How do you determine which
variant is the best?

Harris profile

	-10	-5	+5	+10
<i>Design Criteria 1</i>				
<i>Design Criteria 2</i>				
<i>Design Criteria 3</i>				
<i>Design Criteria 4</i>				
<i>Design Criteria 5</i>				
<i>Design Criteria 6</i>				

	-10	-5	+5	+10
<i>Silent operation</i>				
<i>Avoid Draft felt by Others</i>				
<i>Precize Adjustable per Body Part</i>				
<i>Visual & Tangible Feedback</i>				
<i>Cont. and Aesthetic integration</i>				
<i>Flexibiltiy towards the office floorplans</i>				

Airflow on Arms																												
	under the desk (5)				partition(35)				full 3rd erg. zone (15)				flow under pc screen (35)				box under pc screen (15)				lamp idea (15)				side elements (20)			
	-10	-5	+5	+10	-10	-5	+5	+10	-10	-5	+5	+10	-10	-5	+5	+10	-10	-5	+5	+10	-10	-5	+5	+10	-10	-5	+5	+10
Noiseless																												
No Draft felt by Others																												
Precize Adjustable per Body Part																												
Visual & Tangible Feedback																												
Visually Integrated																												
Limitless office space Flexiblity																												



Deskmounted



Partition element



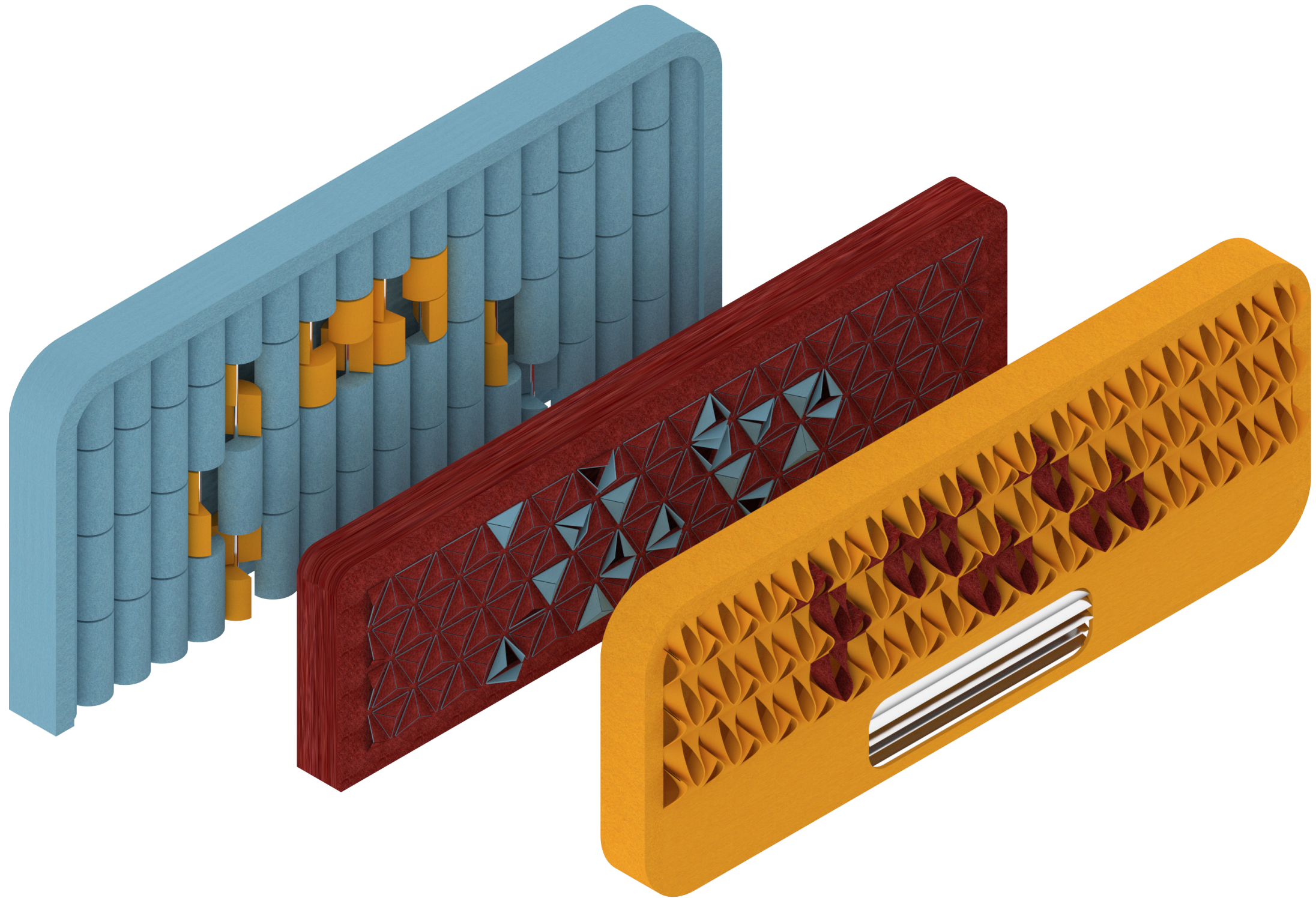
Ceiling mounted

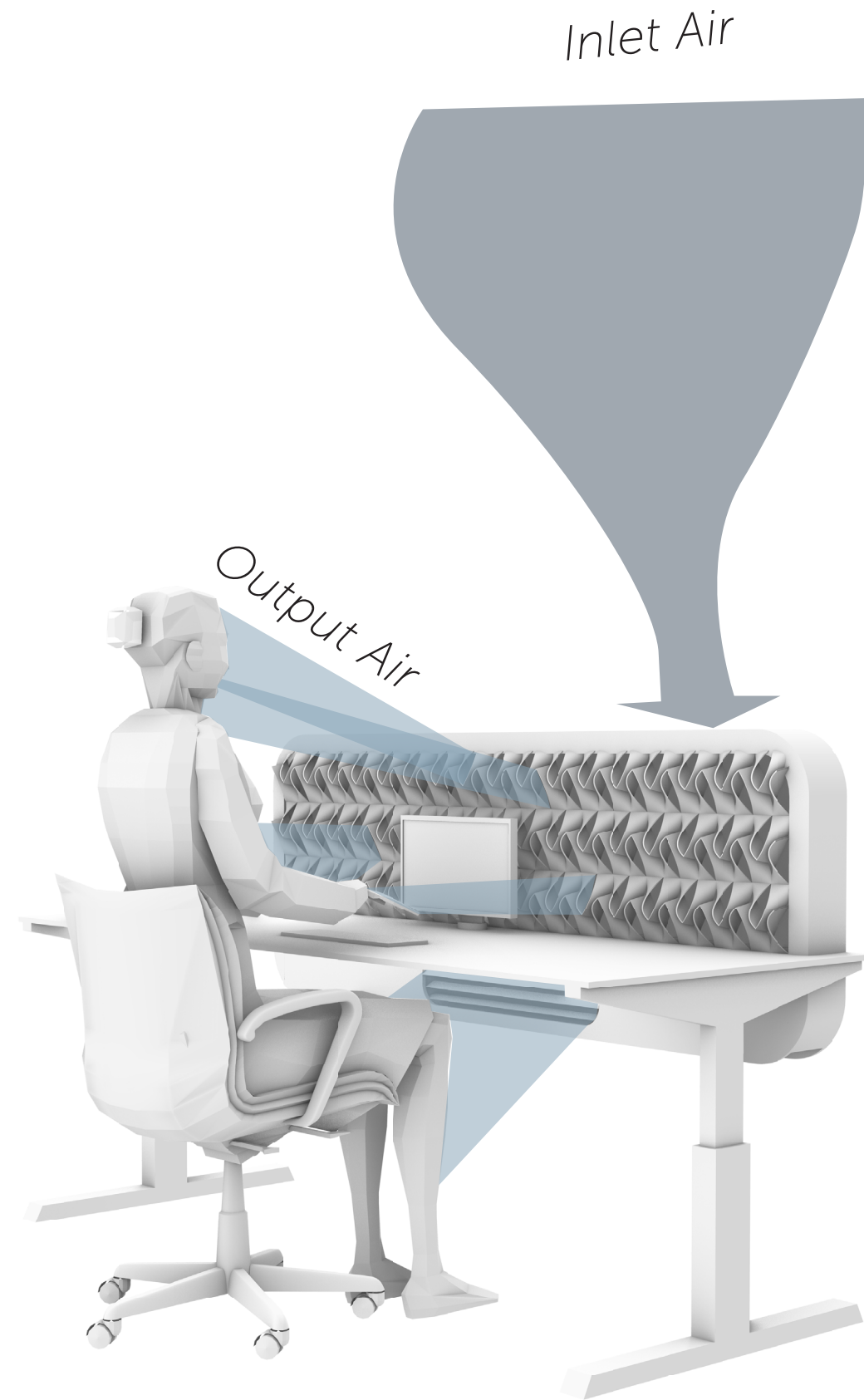
Deskmounted element



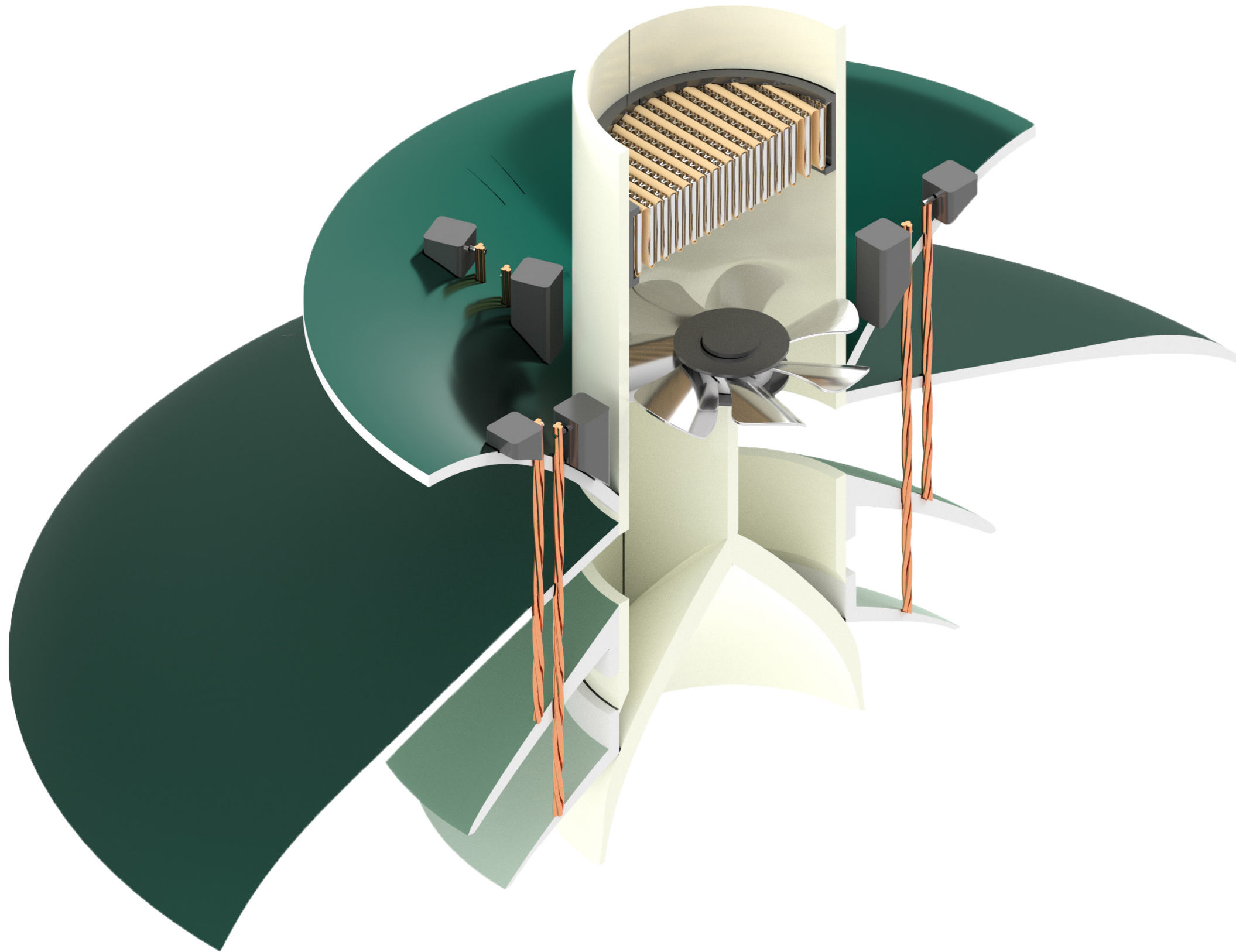


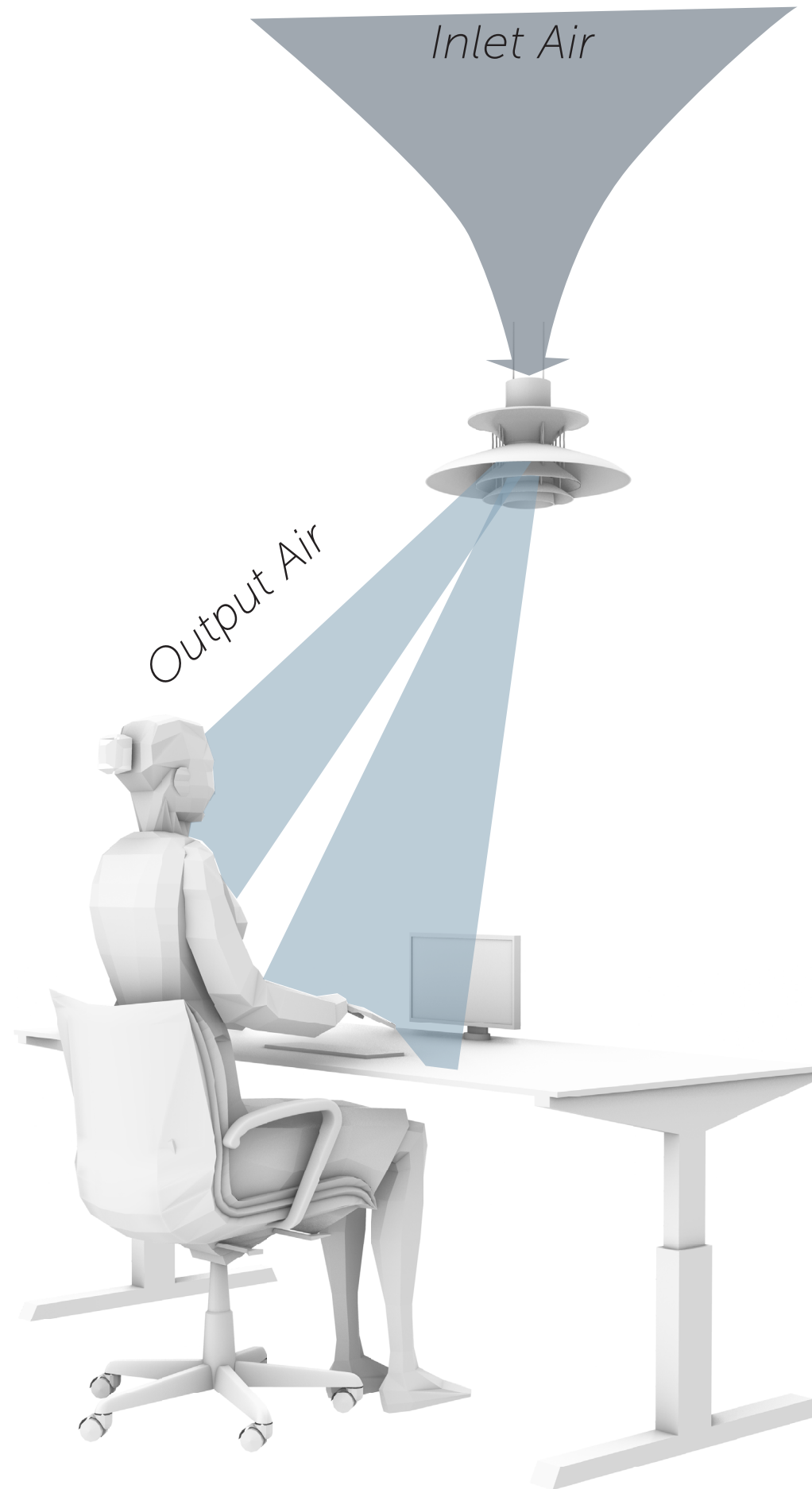
Partition element

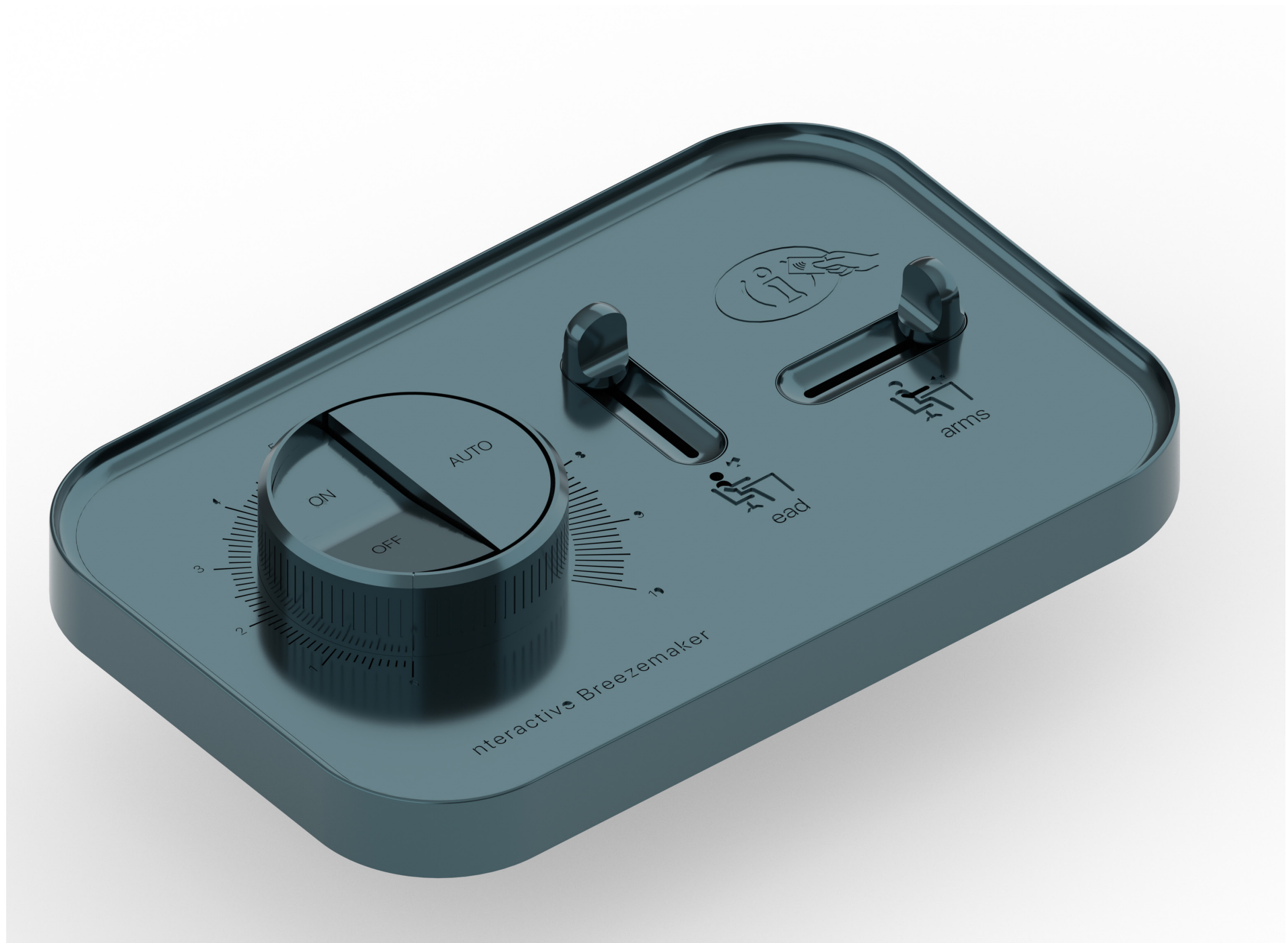




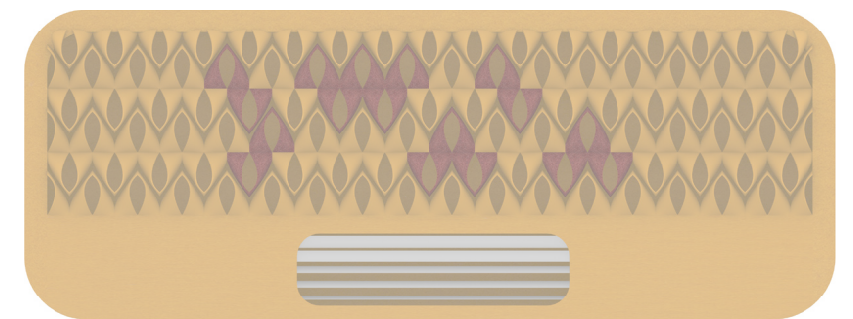
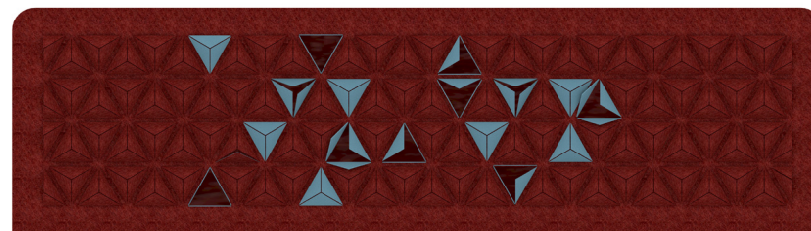
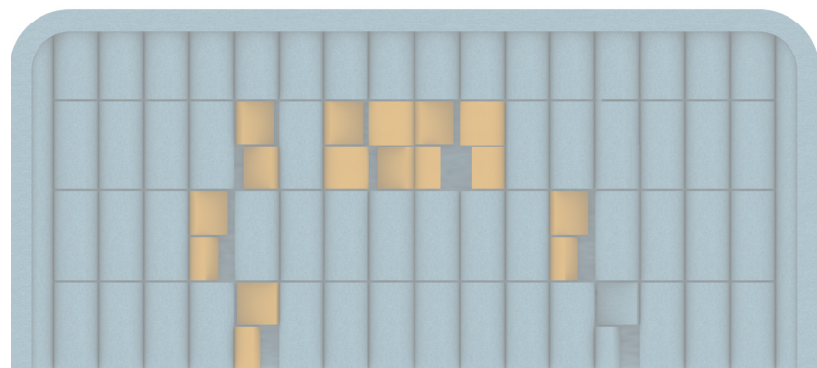
Ceiling mounted element







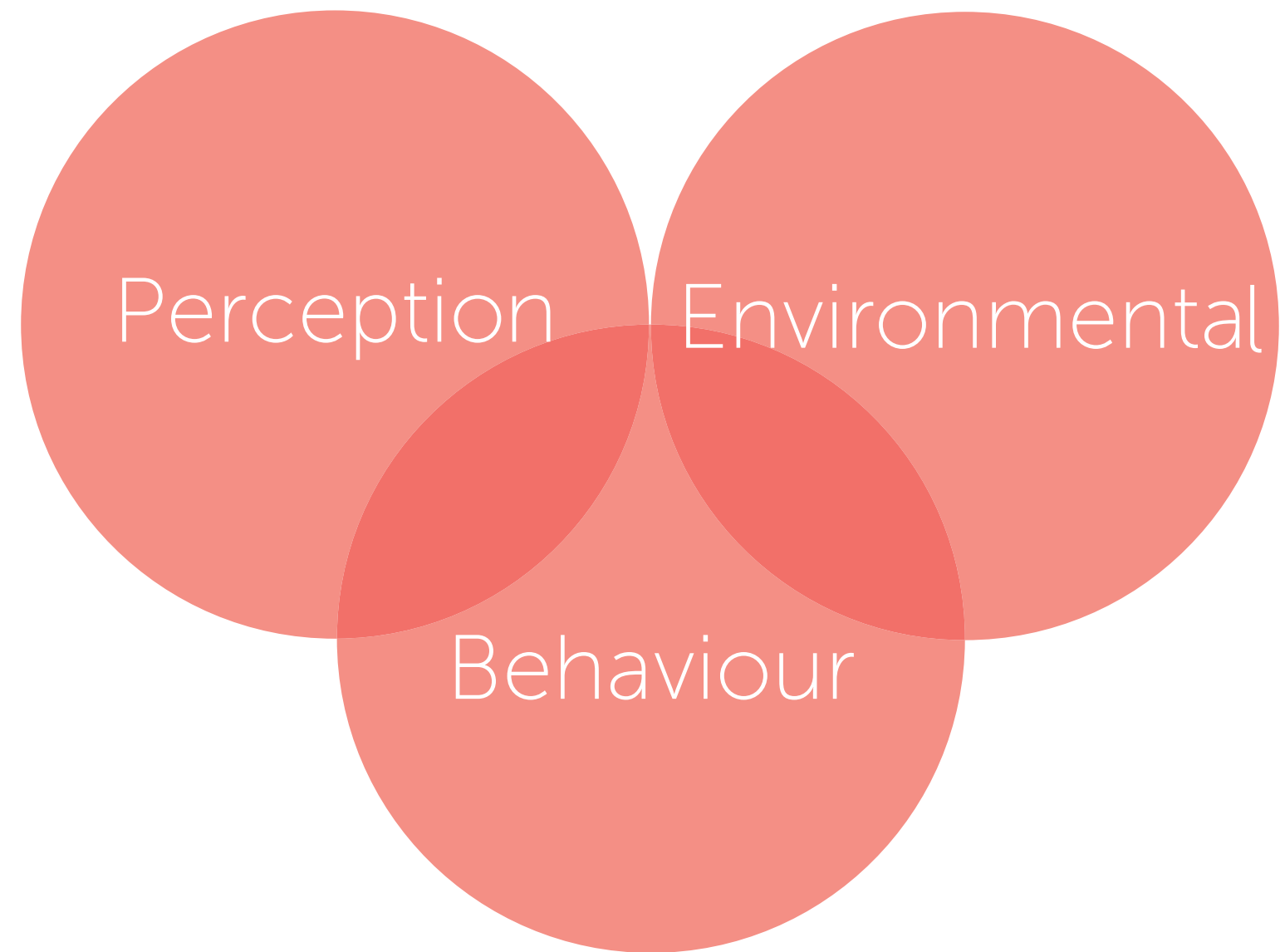
Final Design

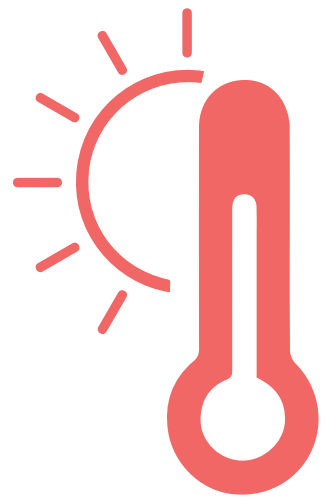


Conclusion & Final Design

Research question

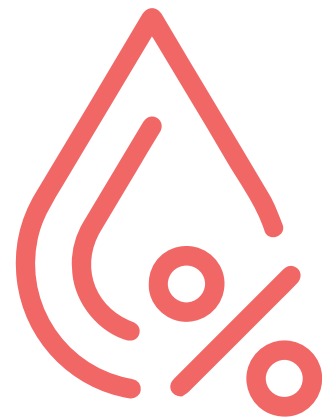
How can we develop an evidence-based framework to implement personalized air velocity for occupants in open-plan offices during summer and design an effective solution?





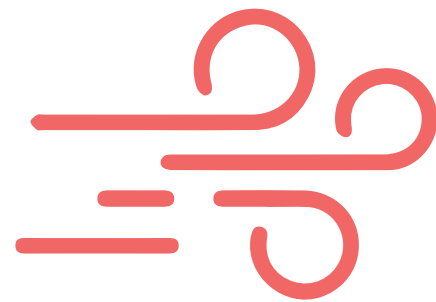
Operative
Temperature
(°C)

24-30 °C



Relative
Humidity
(%)

40 -60%



Airspeed
(m/s)

0.2 - 1.5 m/s



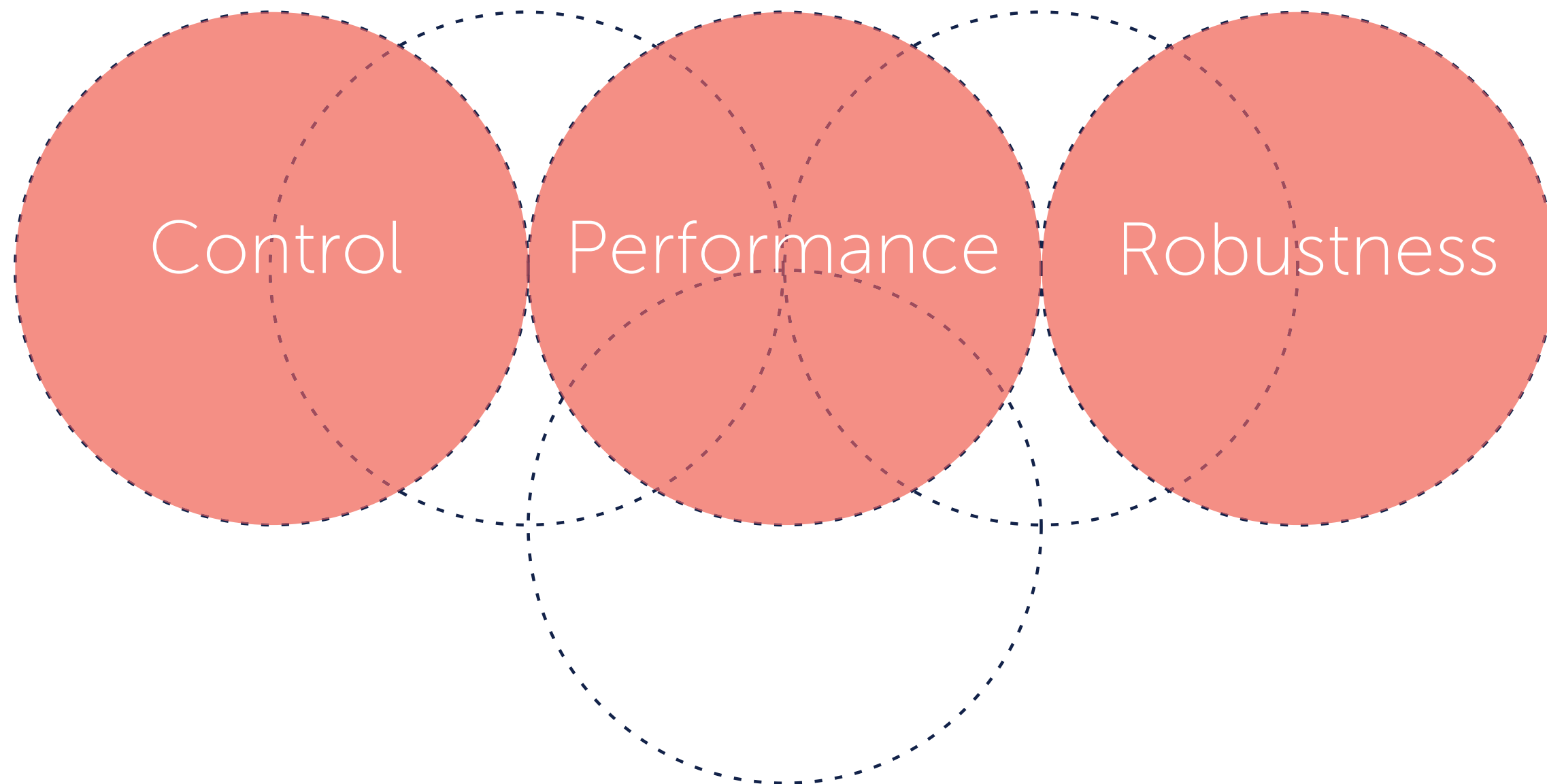
Clothing
Insulation
(clo)

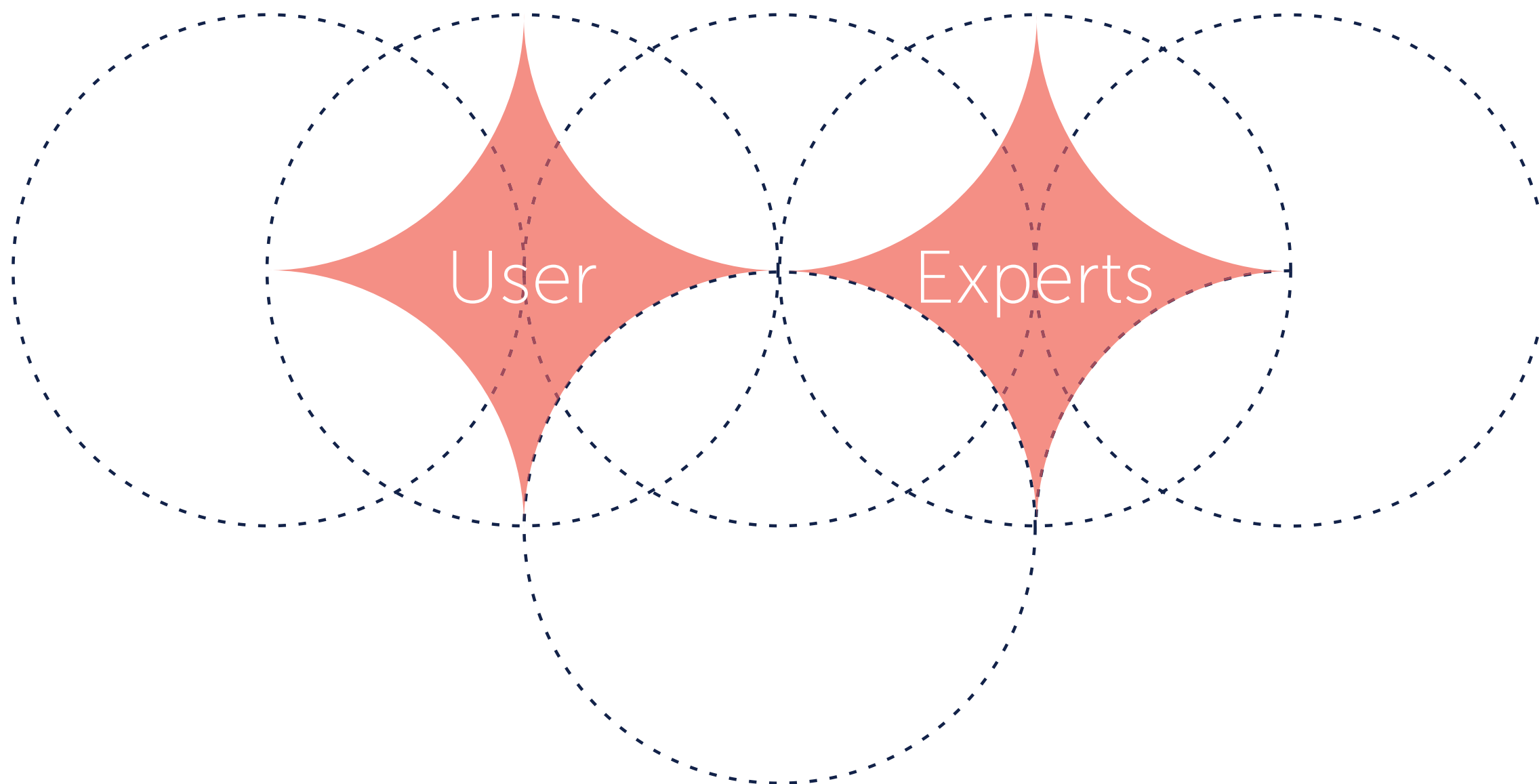
0.6 clo

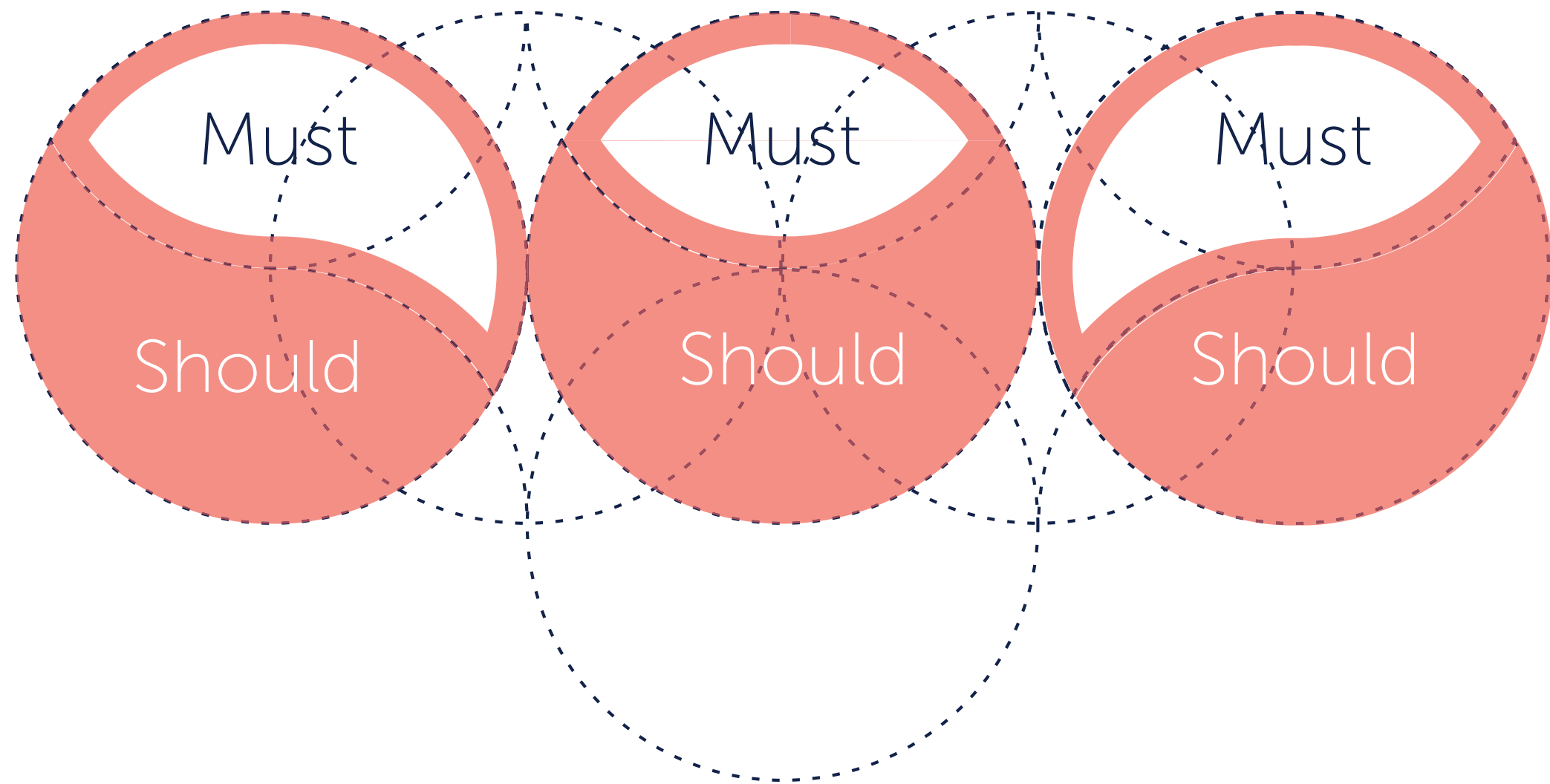


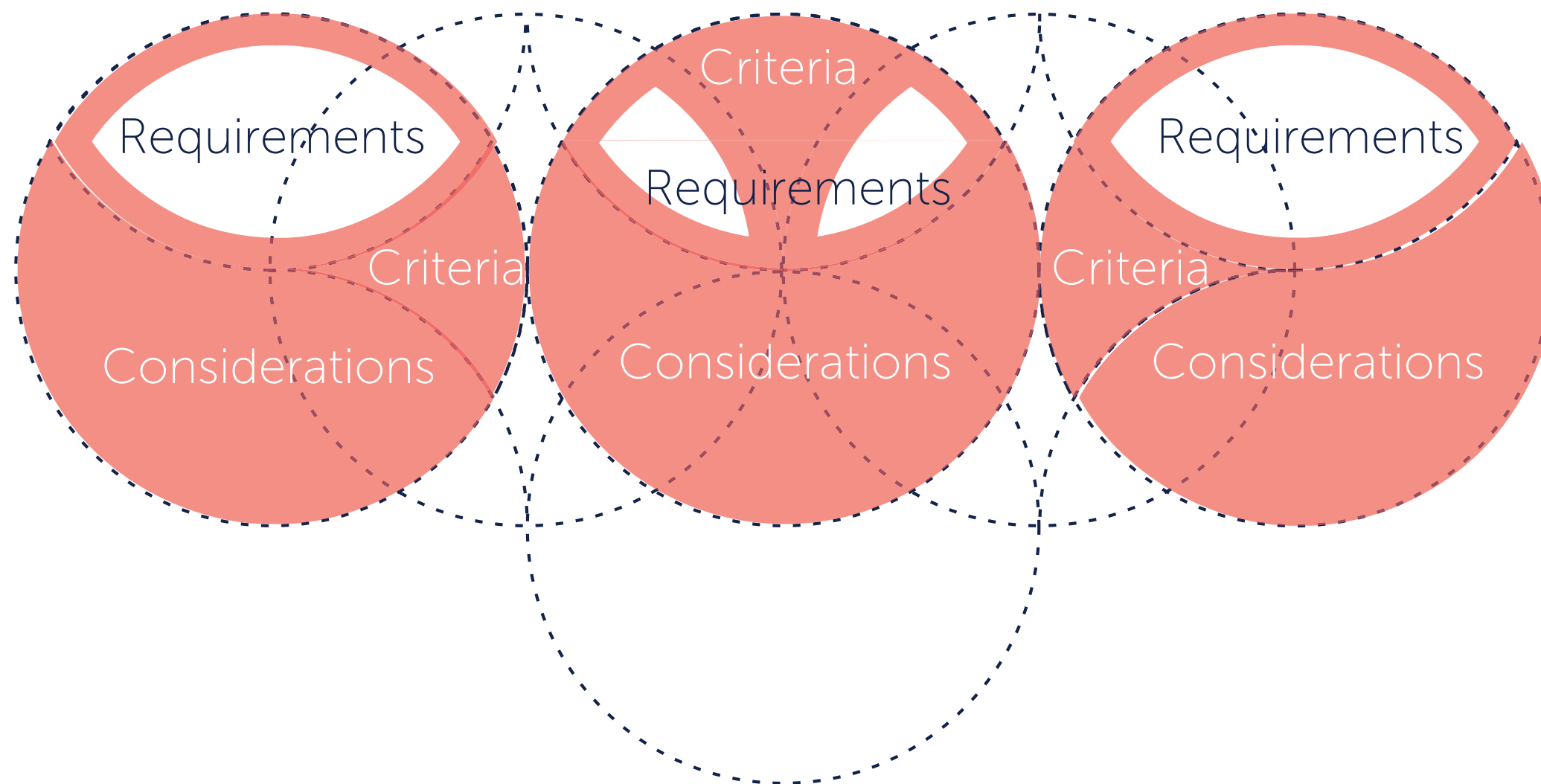
Metabolic
Rate
(met)

1 - 1.4 met









Control

Performance

Robustness

Precize
adjustable per
body part

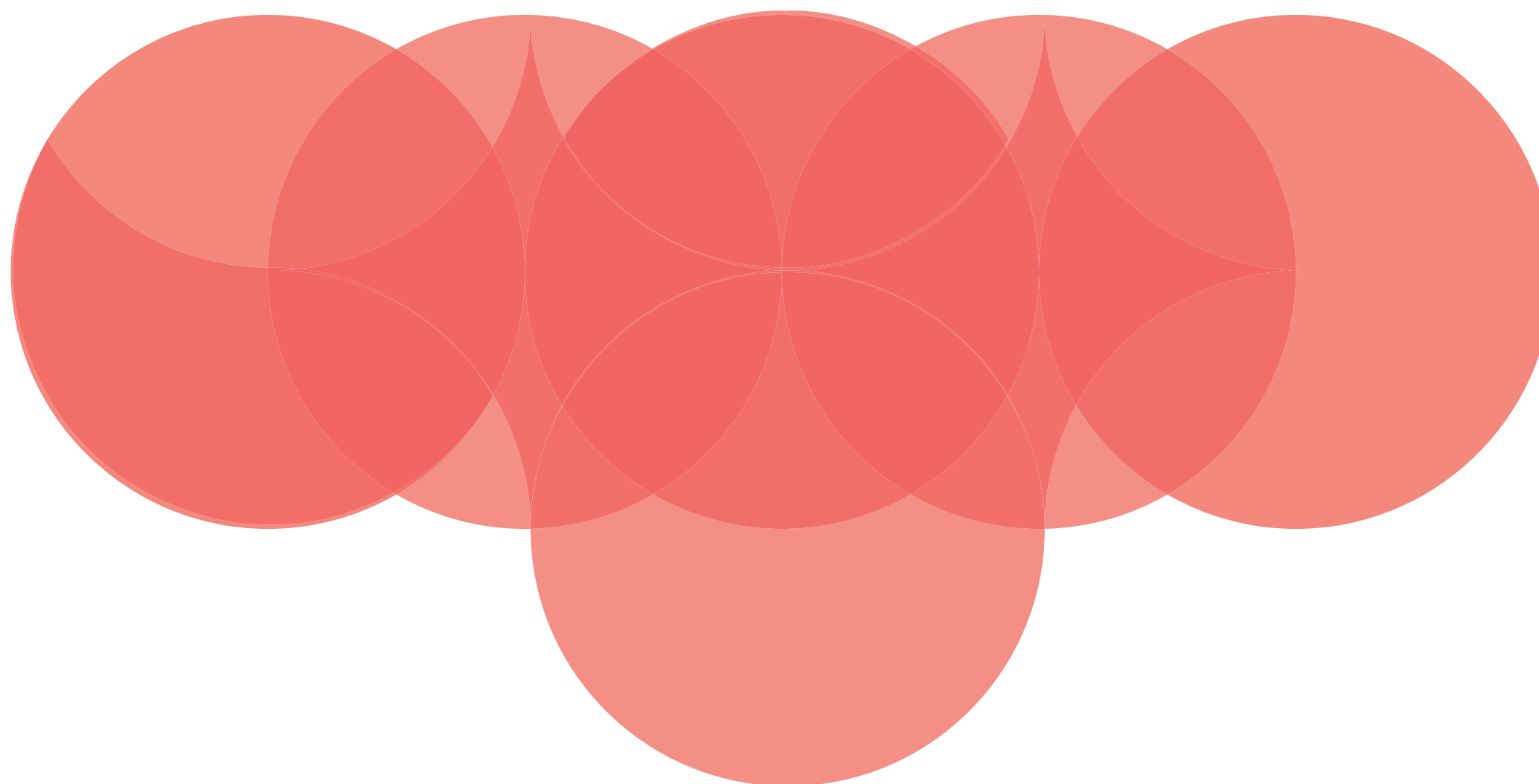
Visual
& tangible
feedback

Silent
operation

Avoid draft
felt by towards
occupants

Contextual
and aesthetic
integration

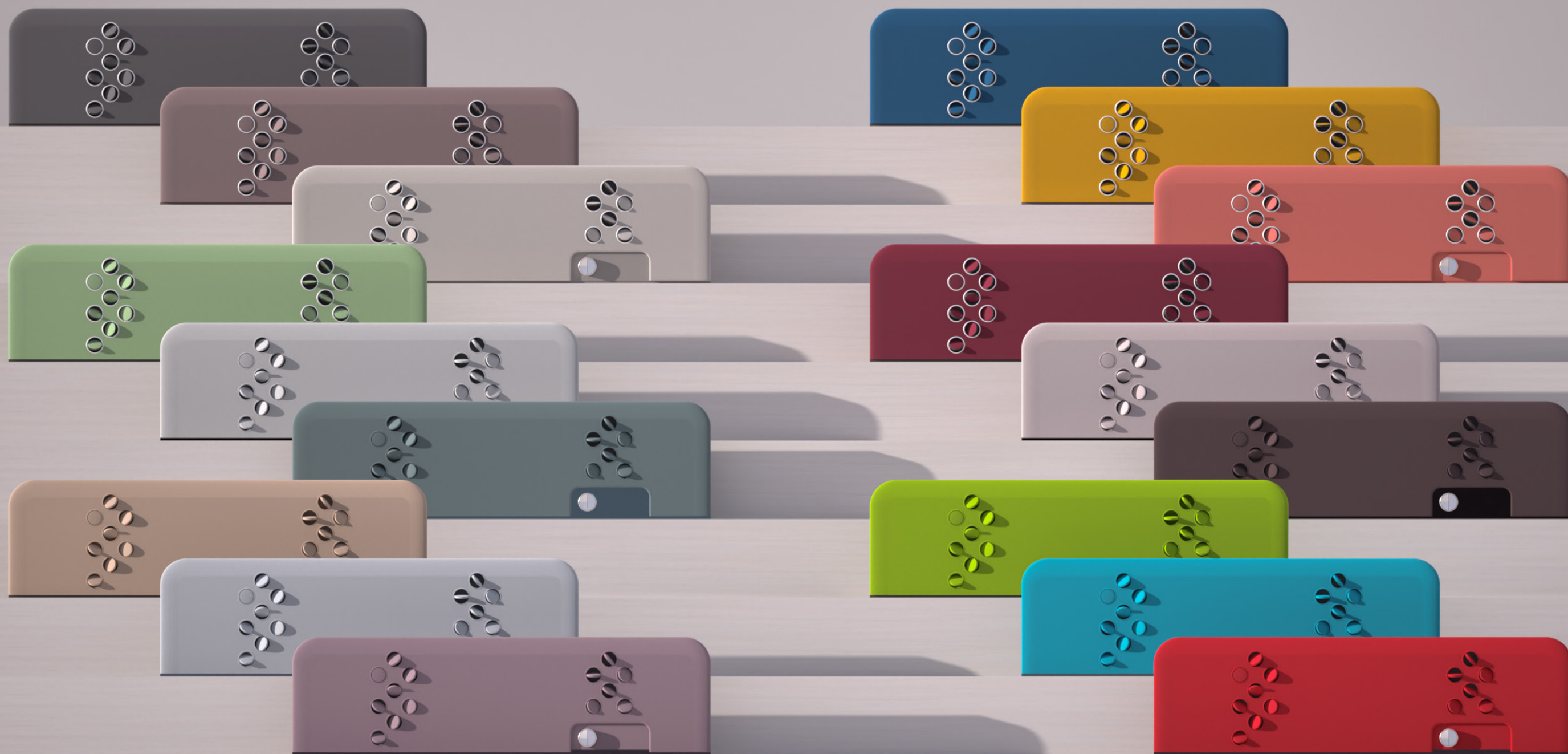
Flexibiltiy
towards the
office floorplans





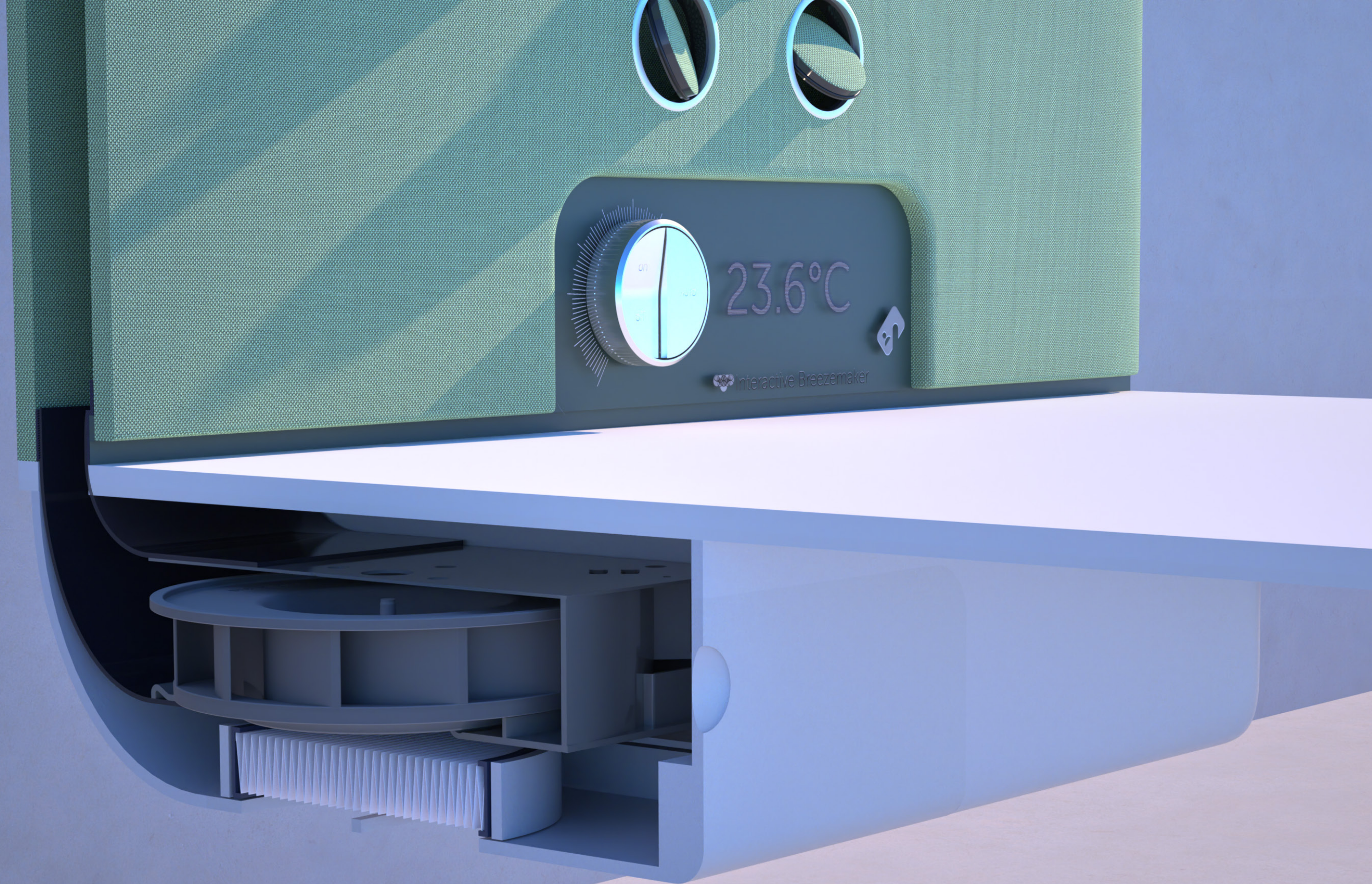


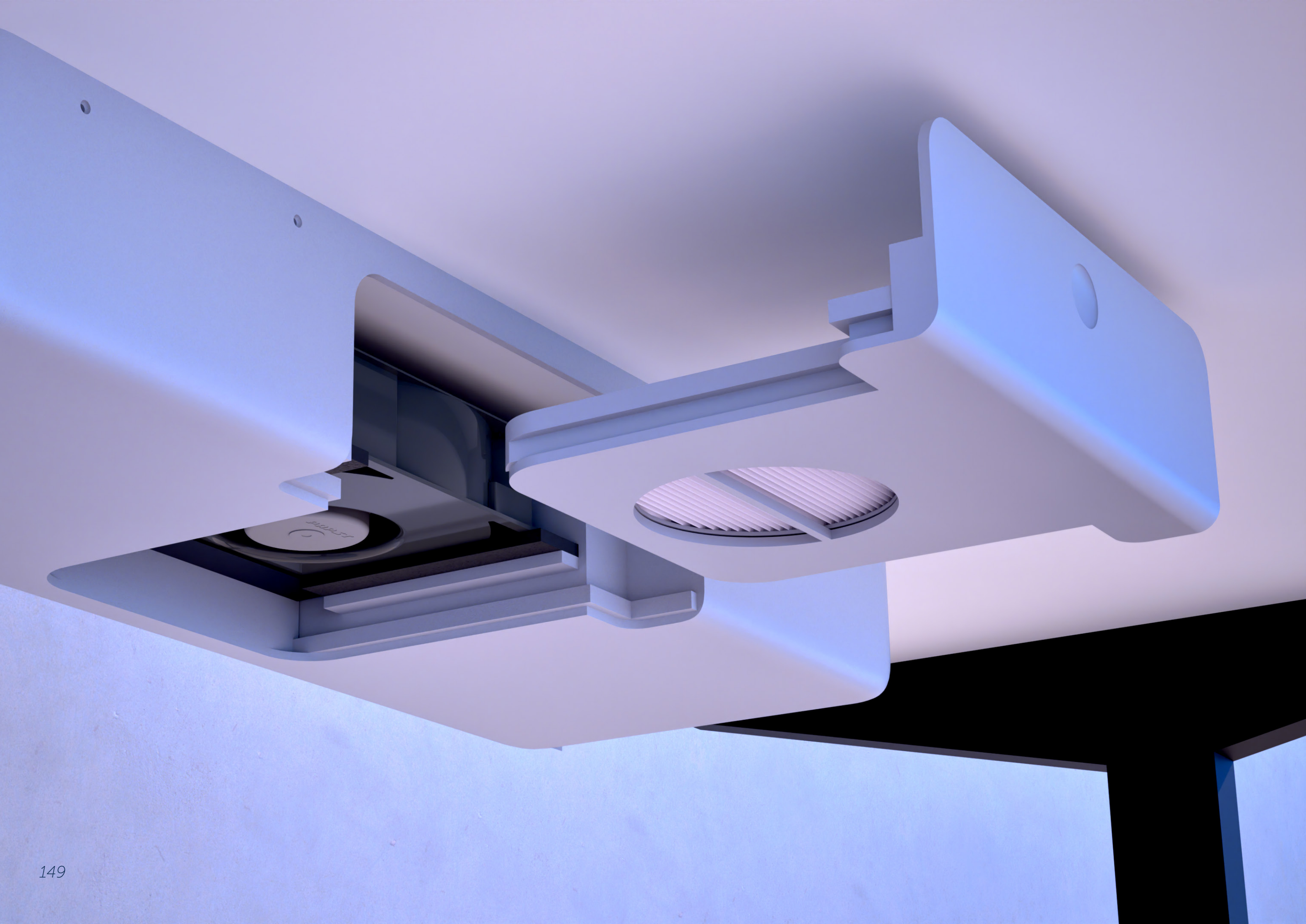


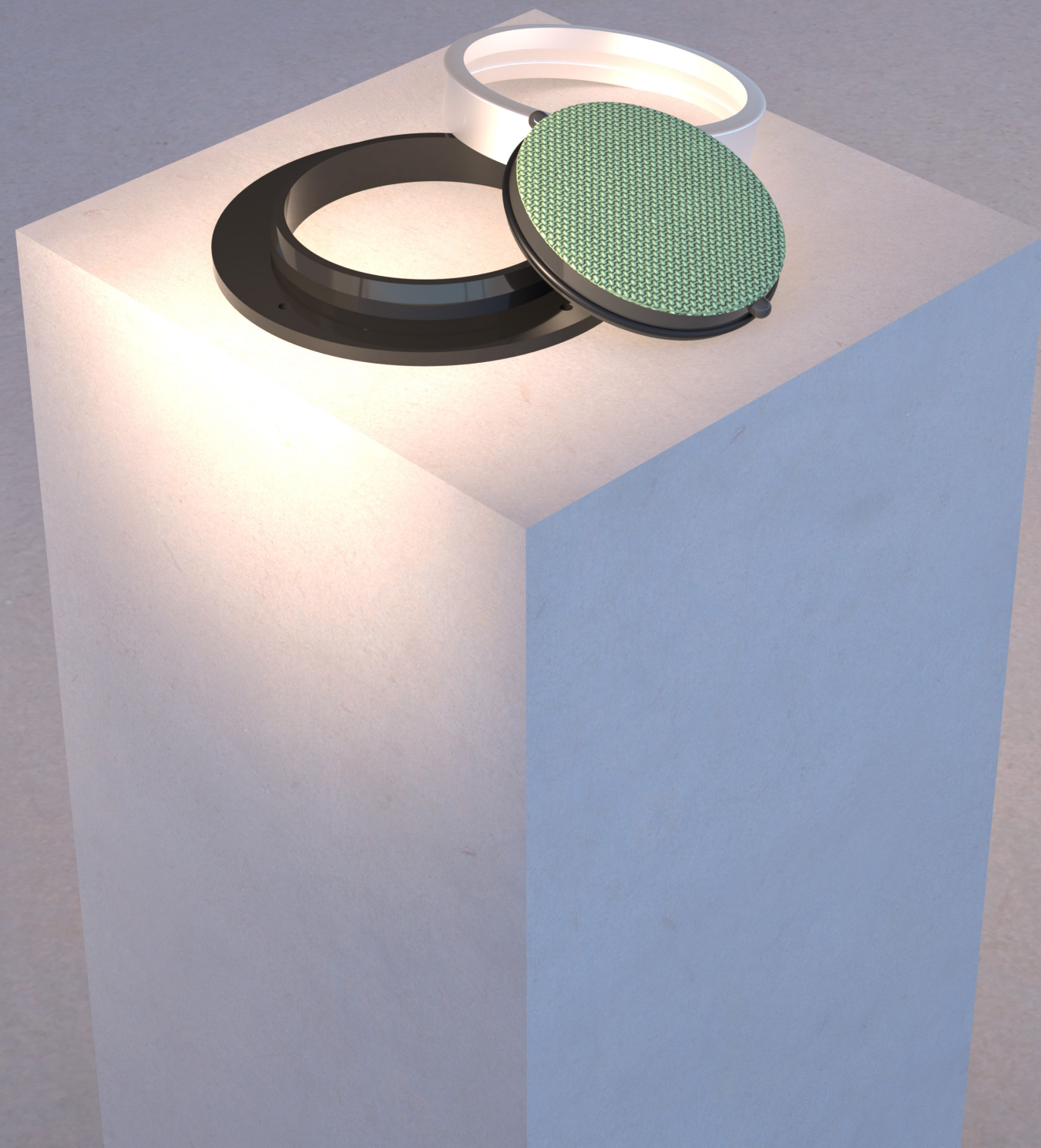


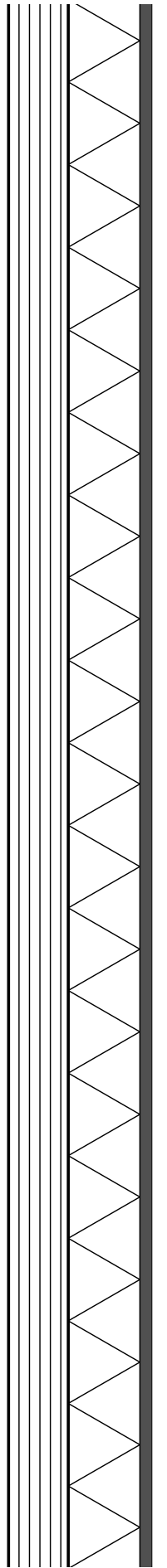
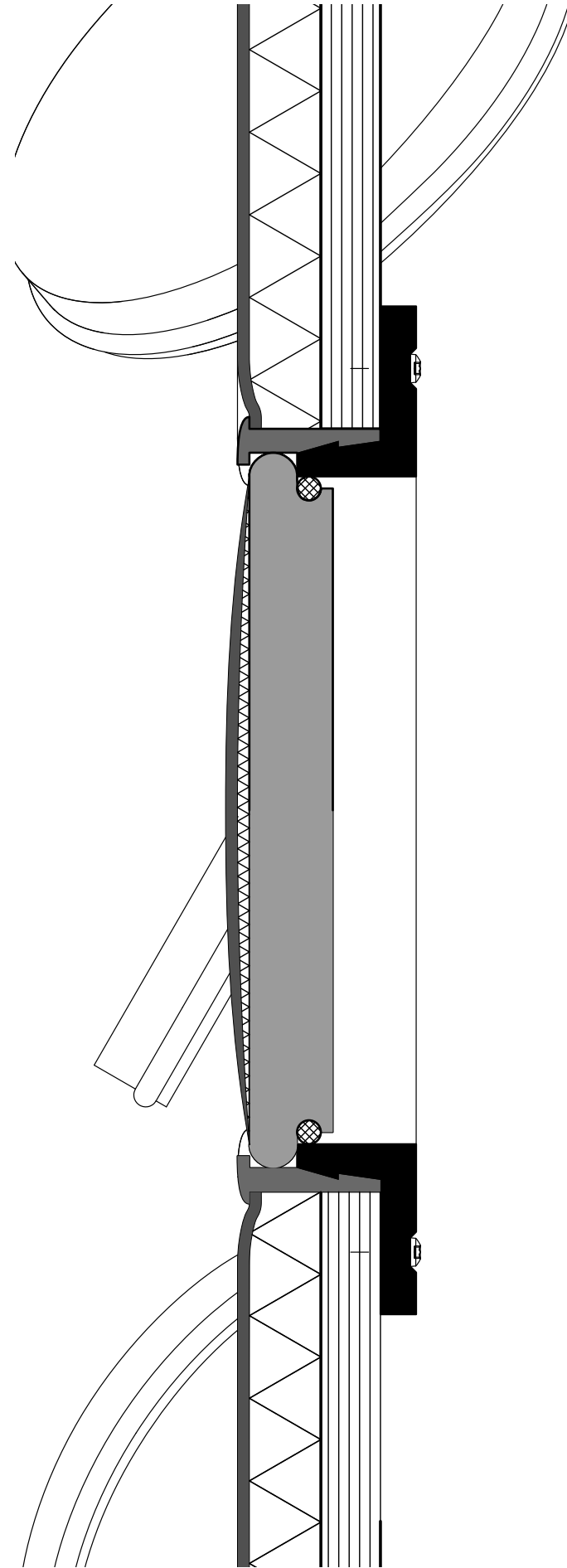
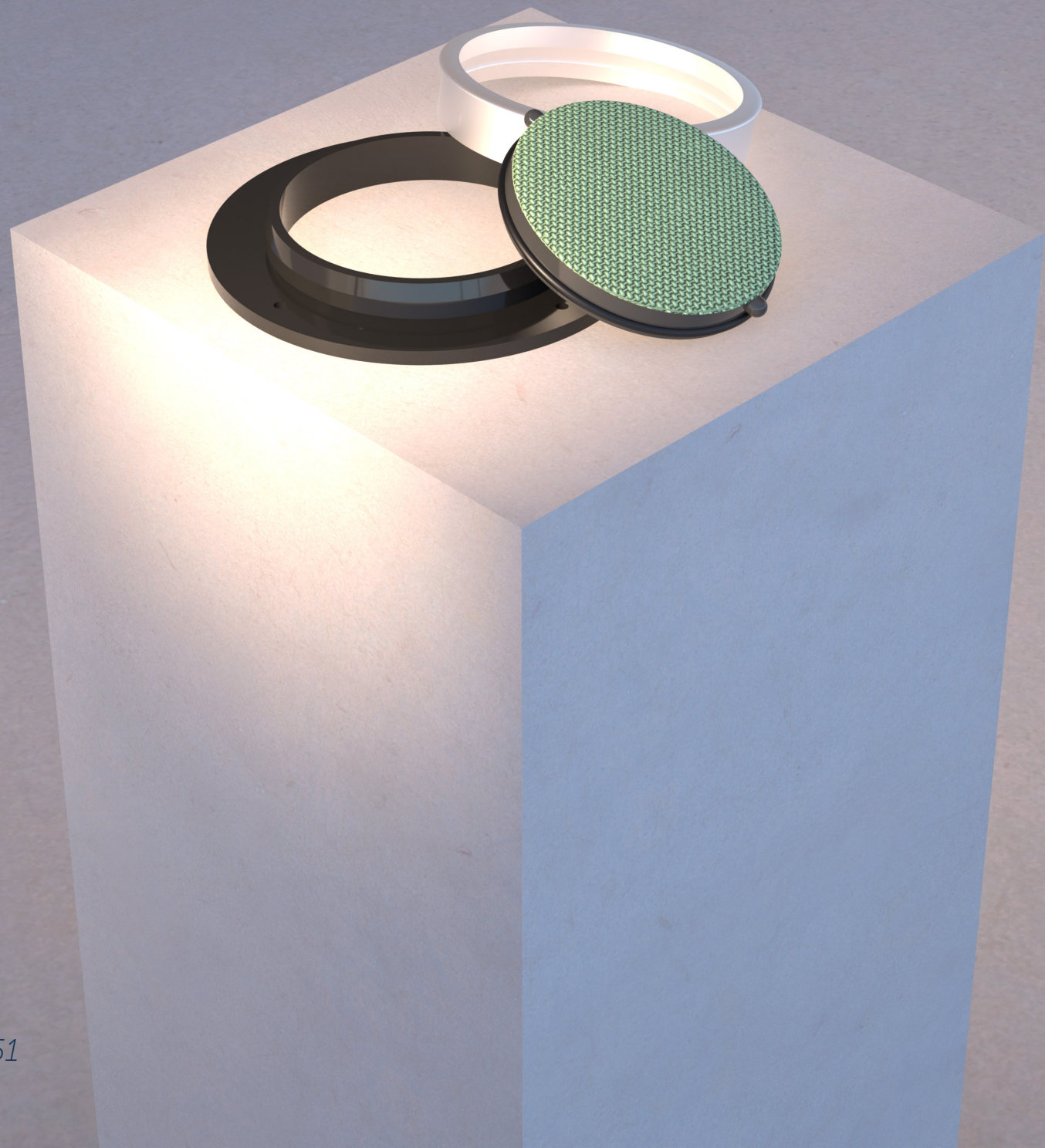


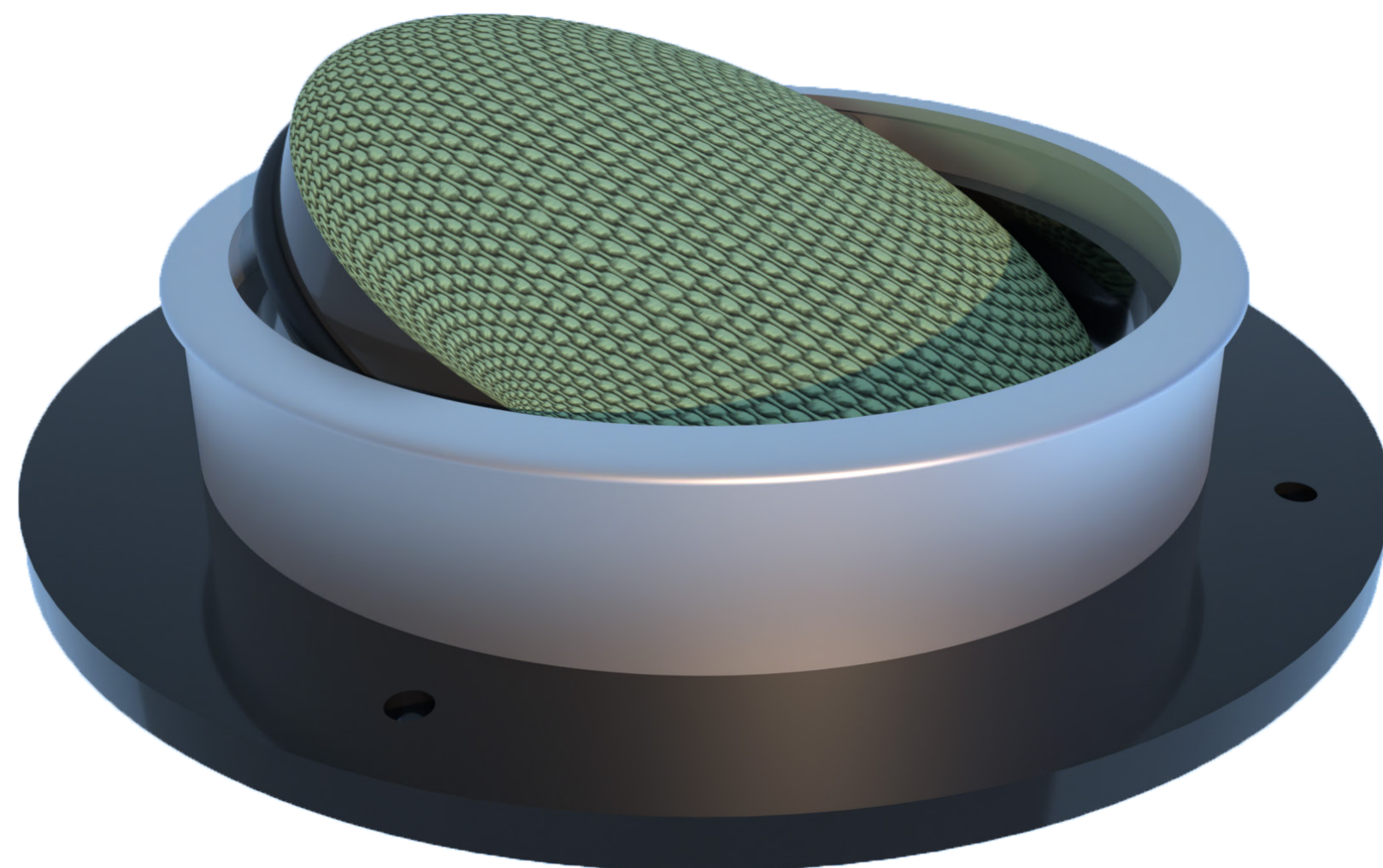


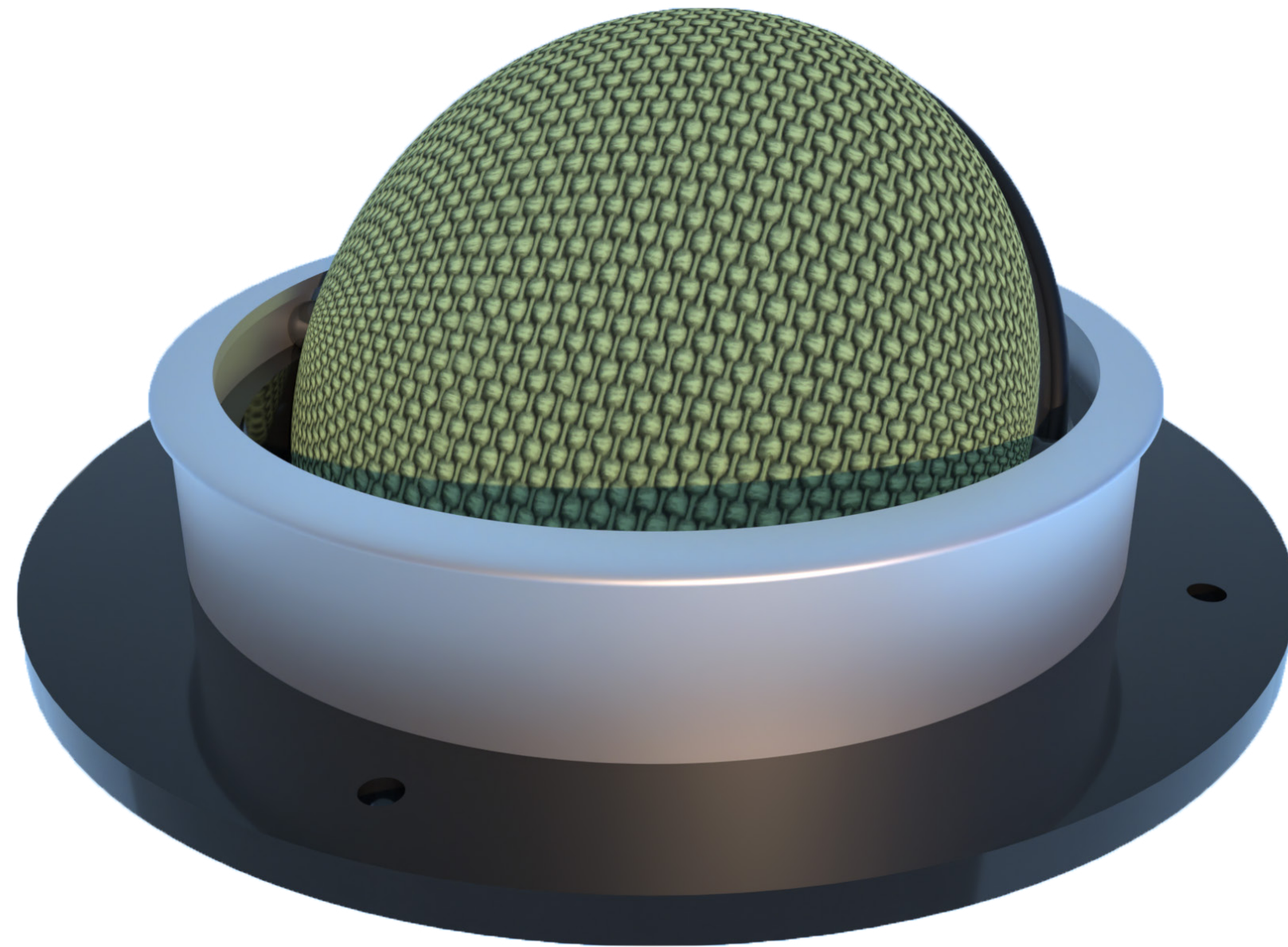


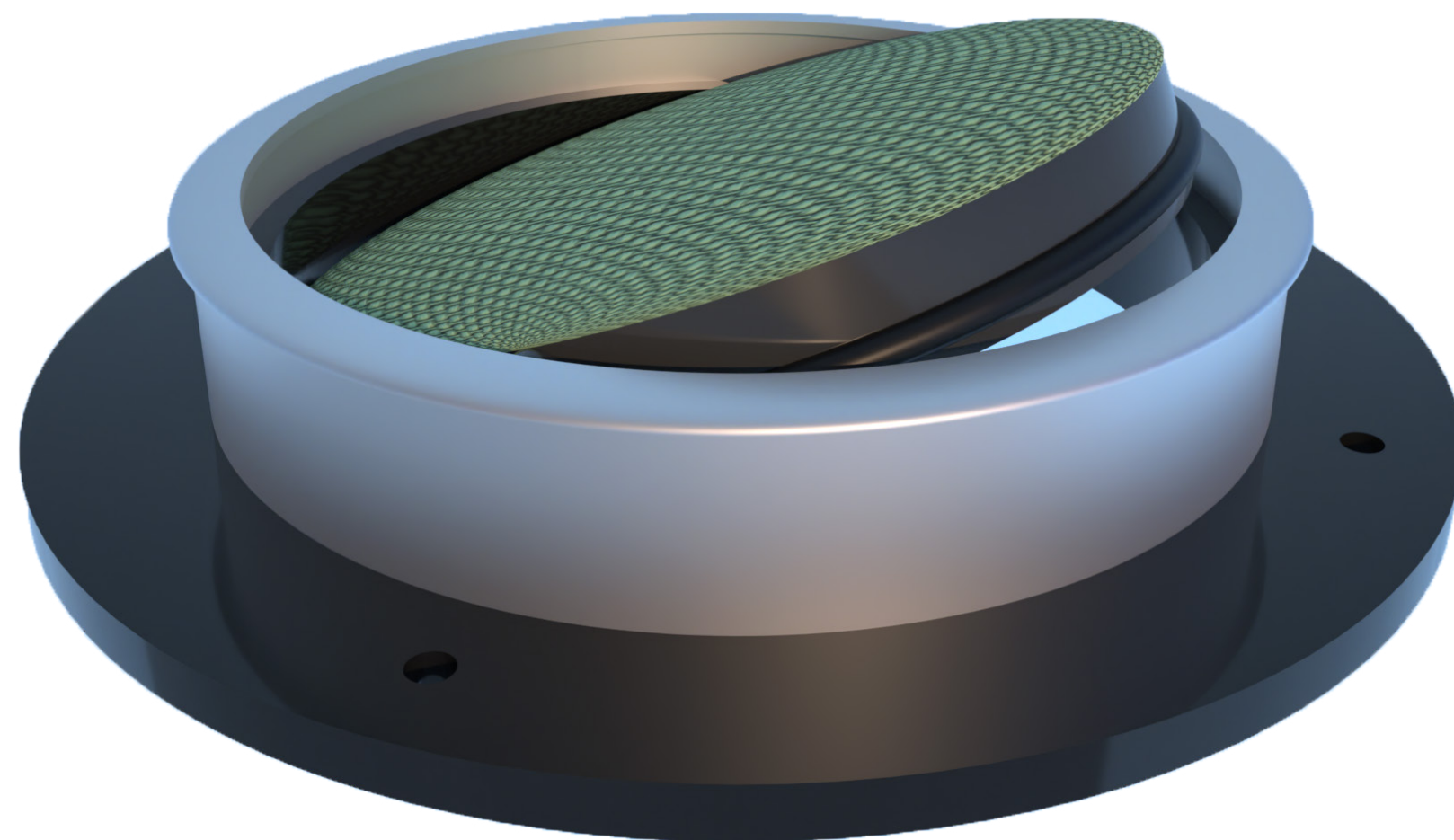




















ON
OFF

DEVICE OUT
OF ORDER

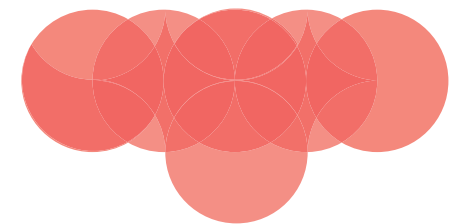
Interactive Breezemaker



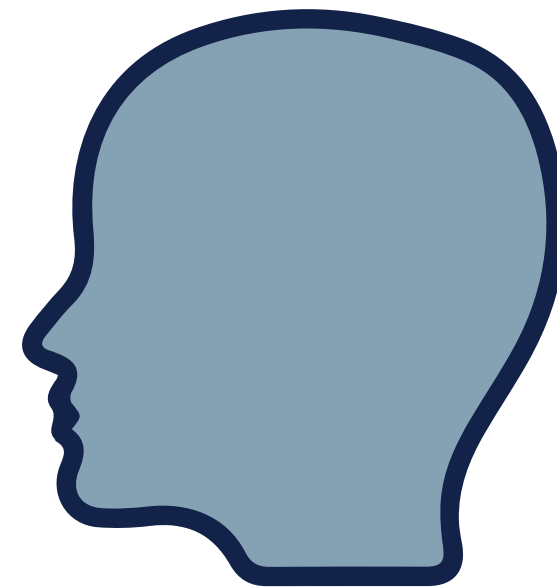




Interactive Breezemaker

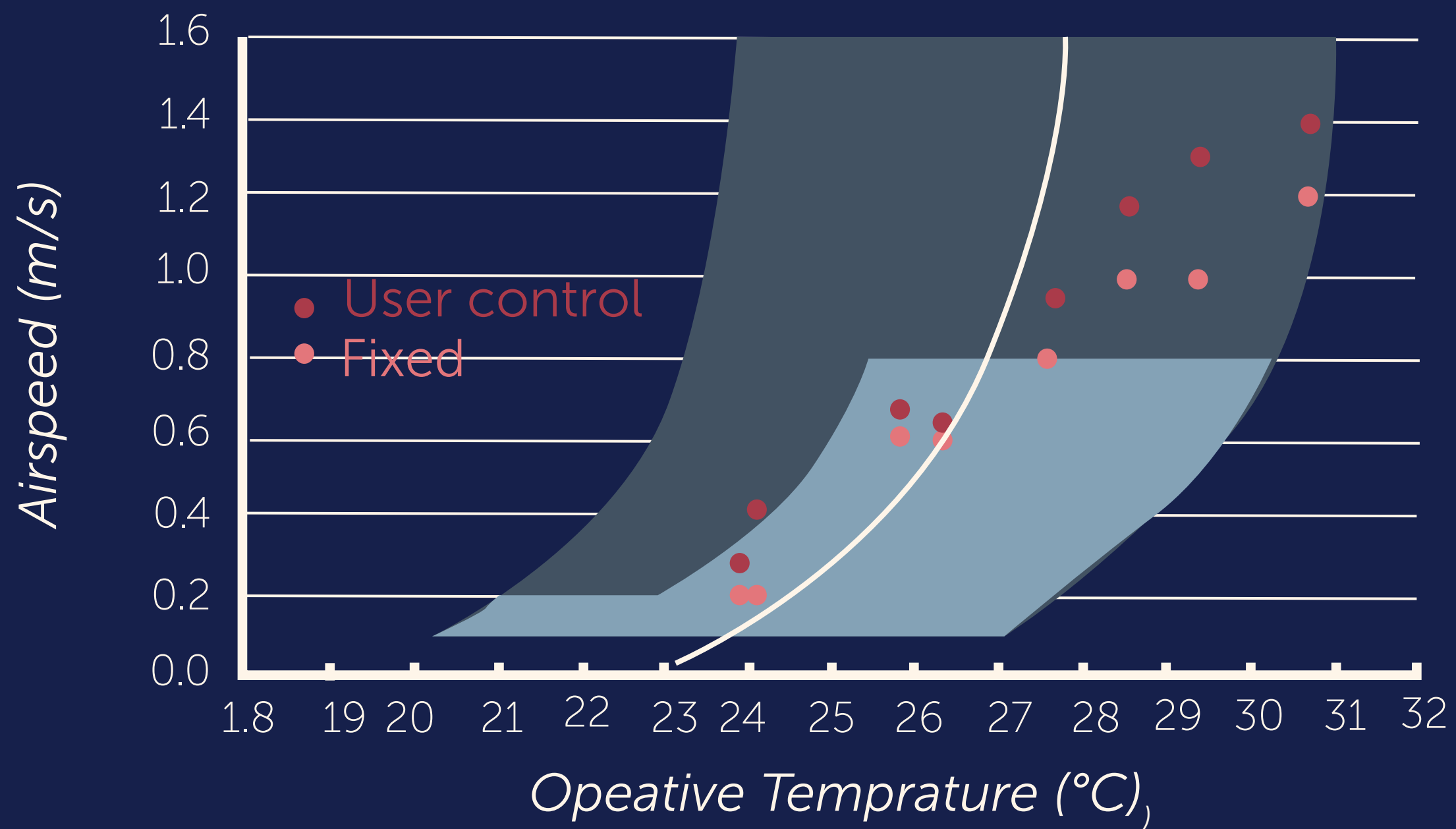


Targeting the wind

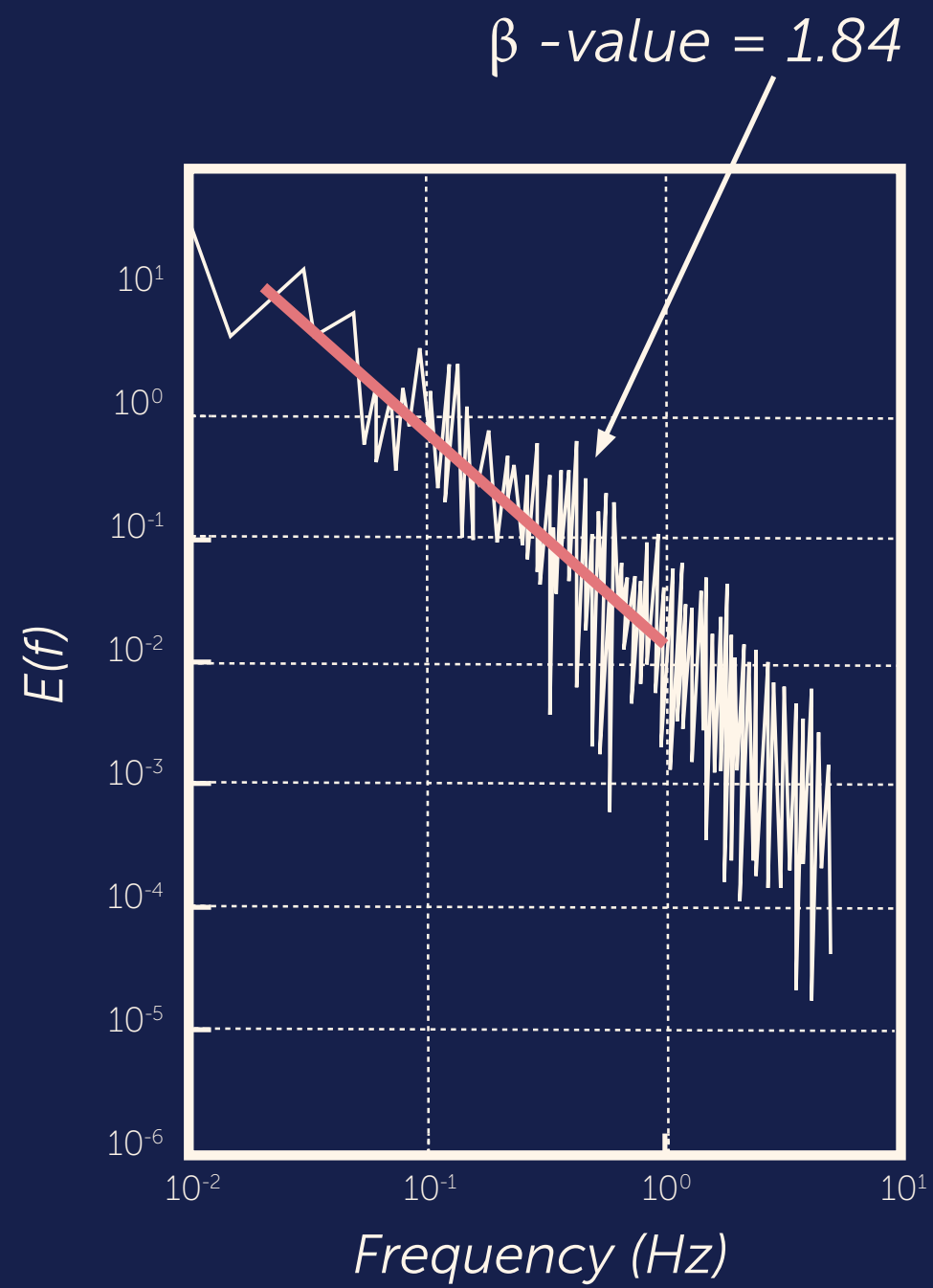


Targeting the wind

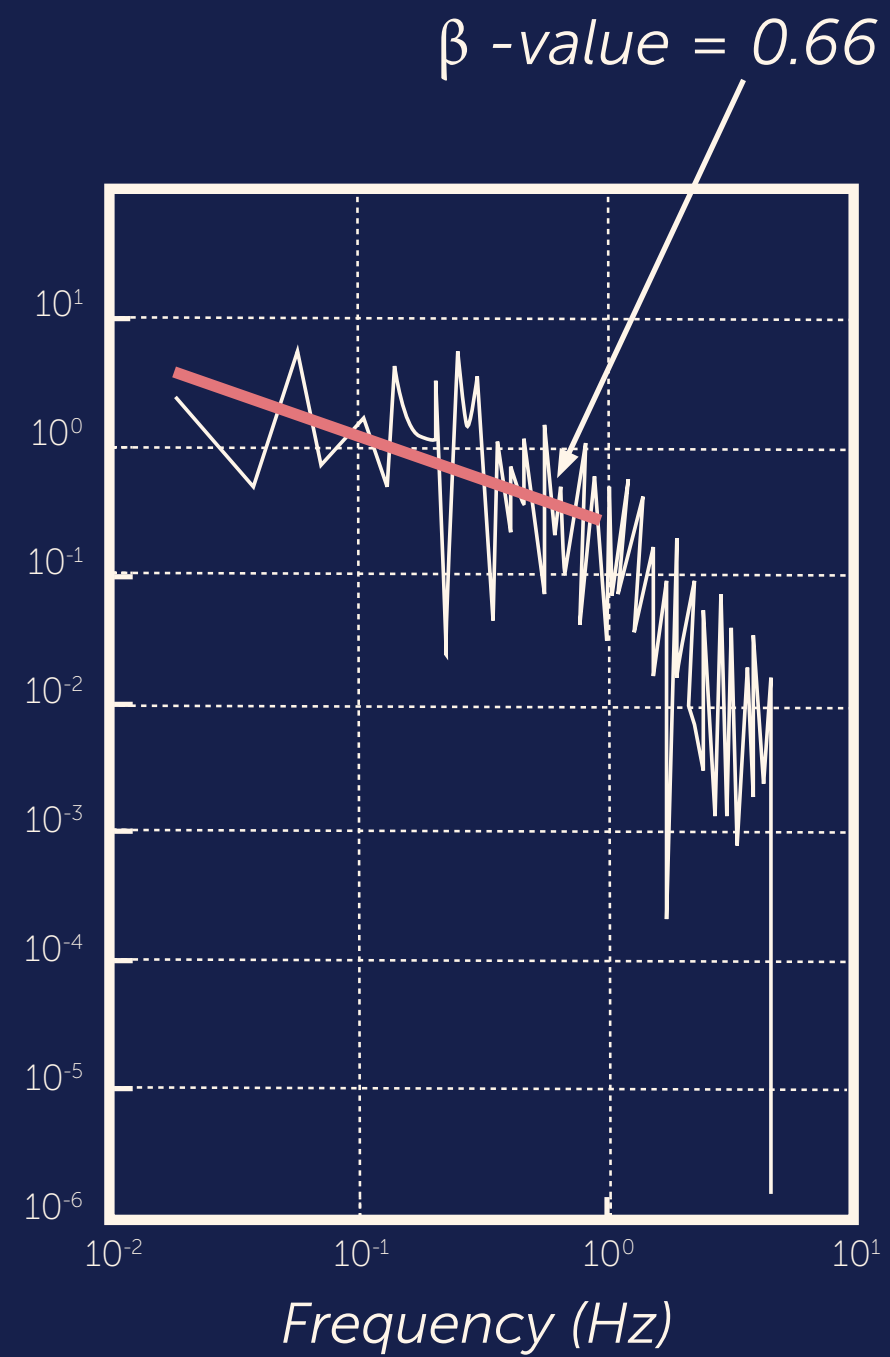




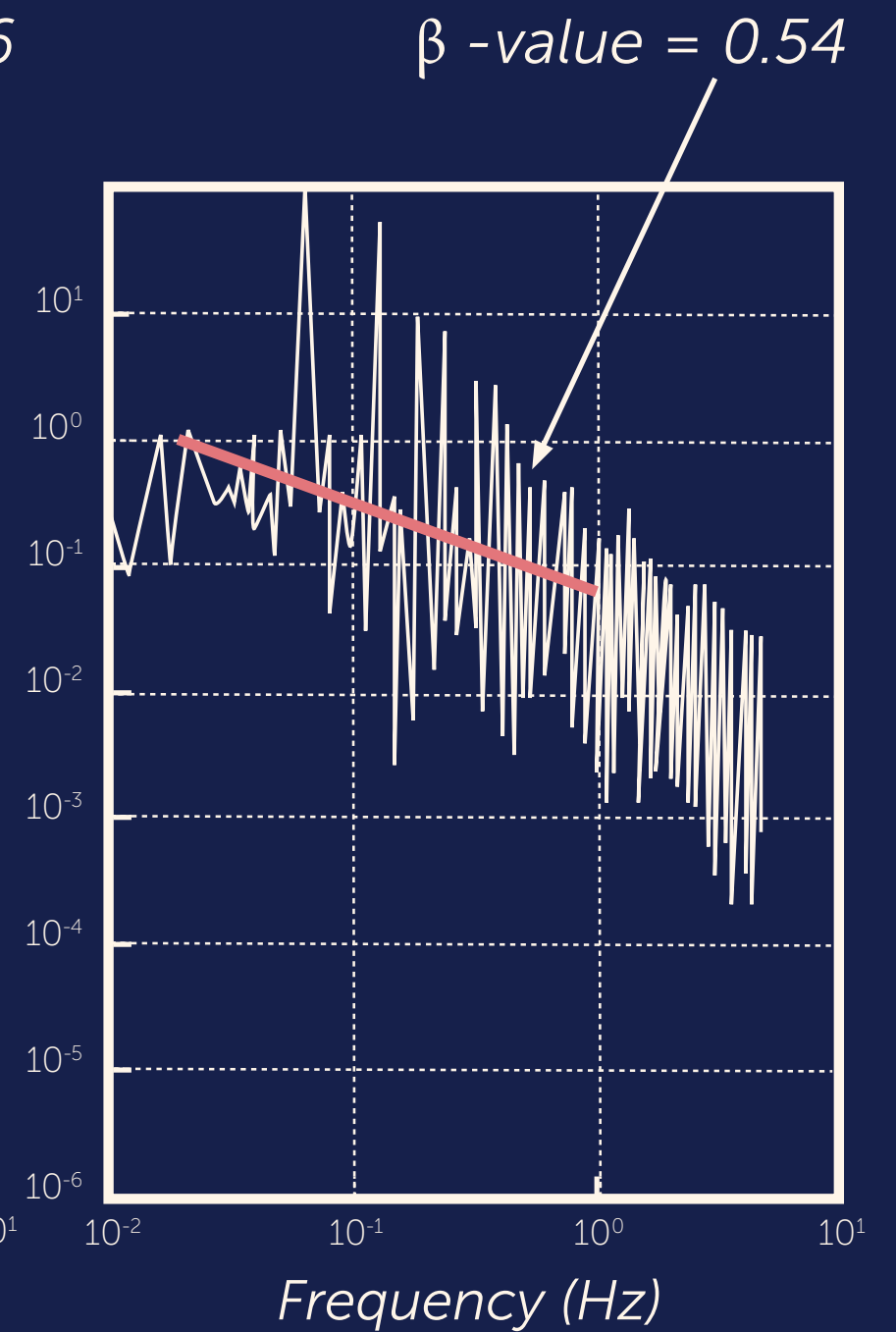
Test results projected onto the ASHRAE-55 standard (Zhai et al., 2017)



Comfortable natural
wind

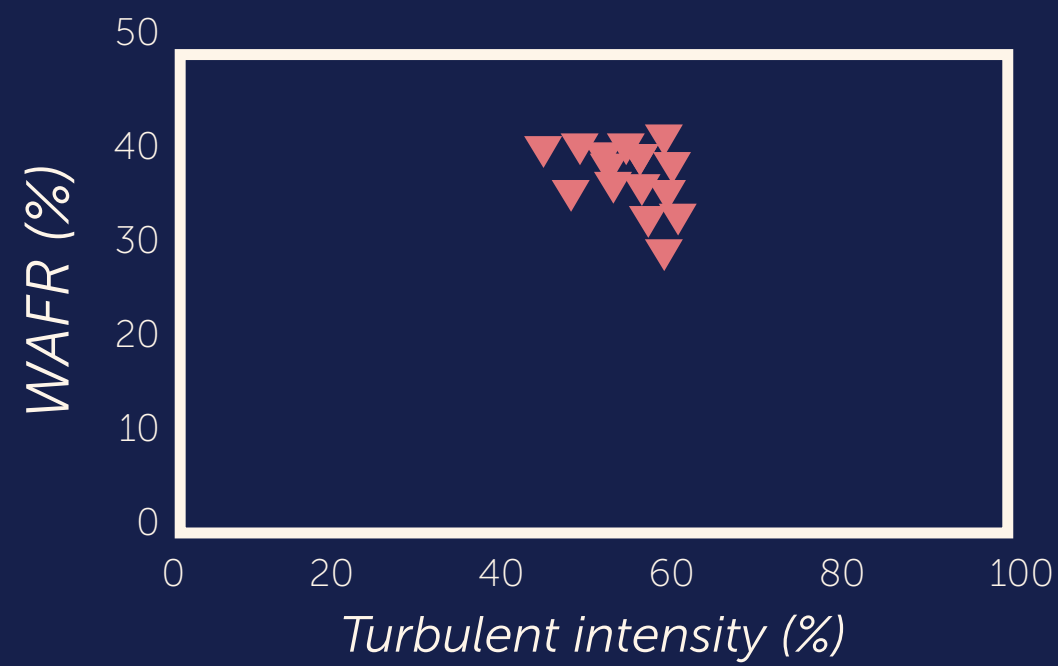


Uncomfortable natural
wind

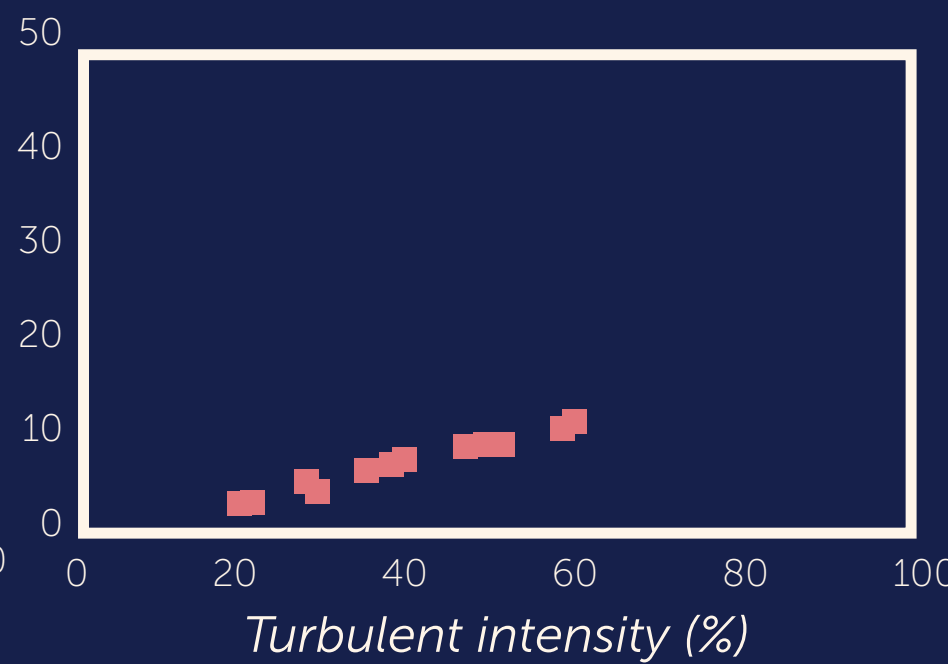


Mechanical wind

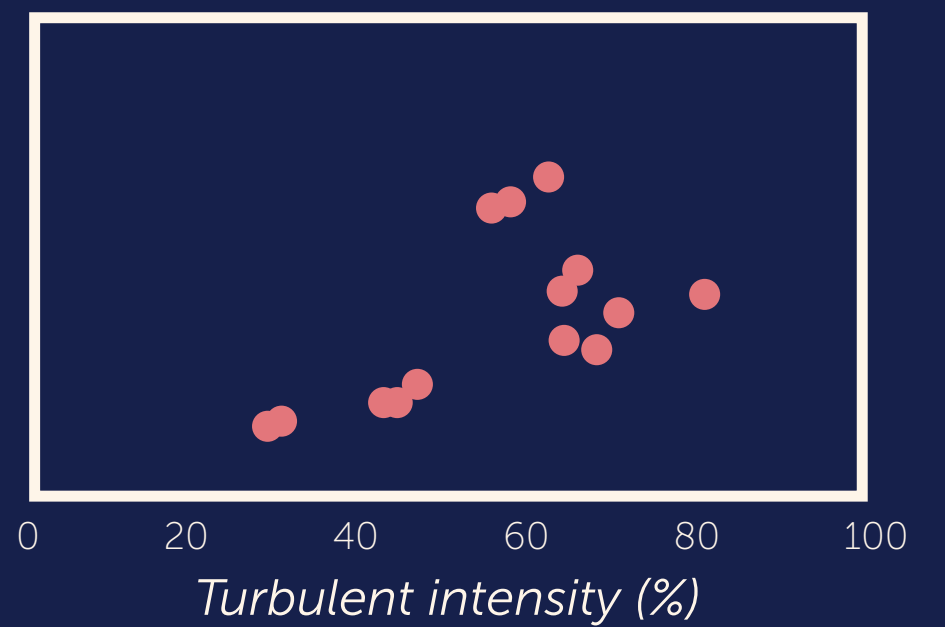
(Zeng et al., 2021)



Natural wind

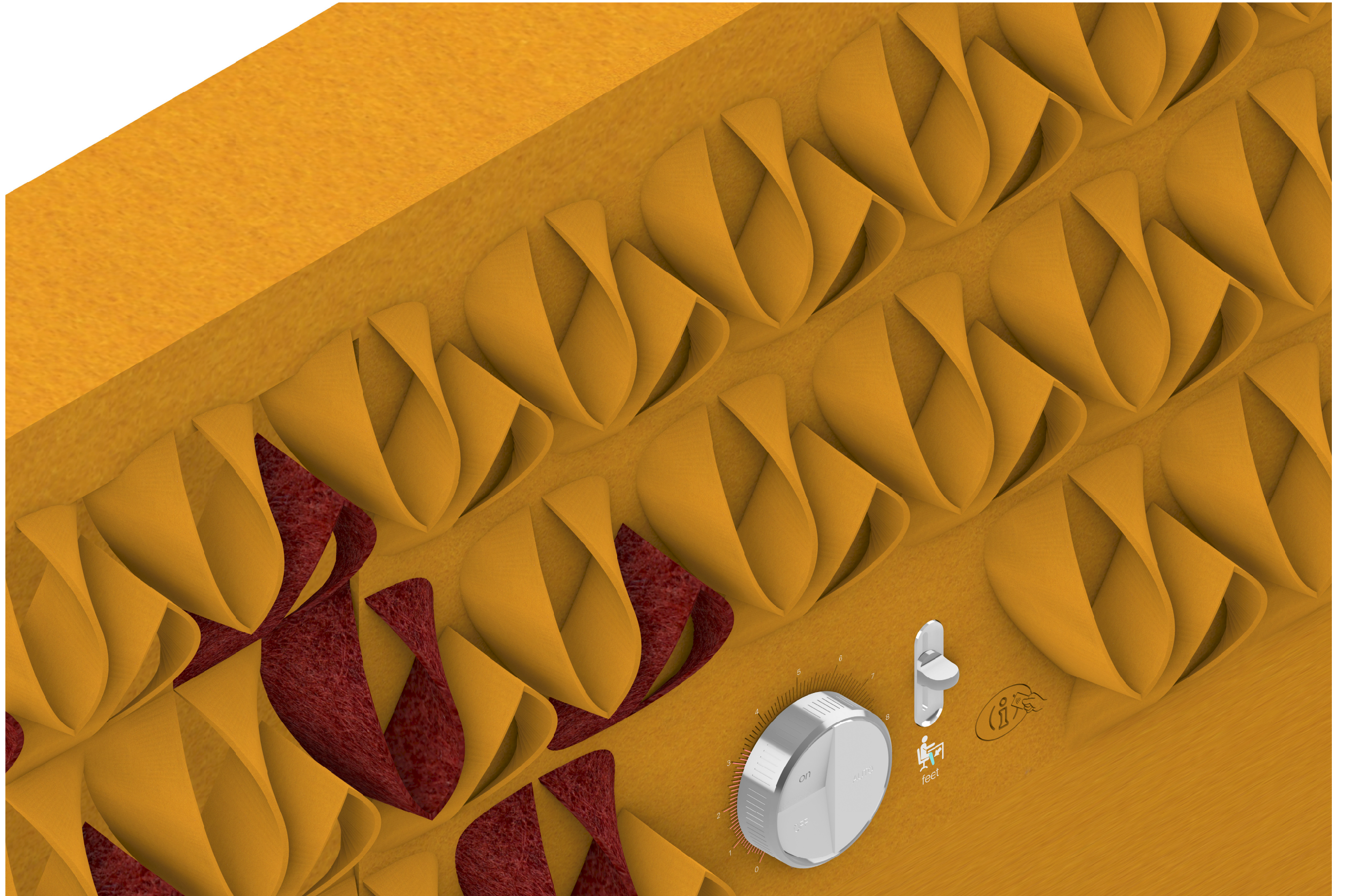


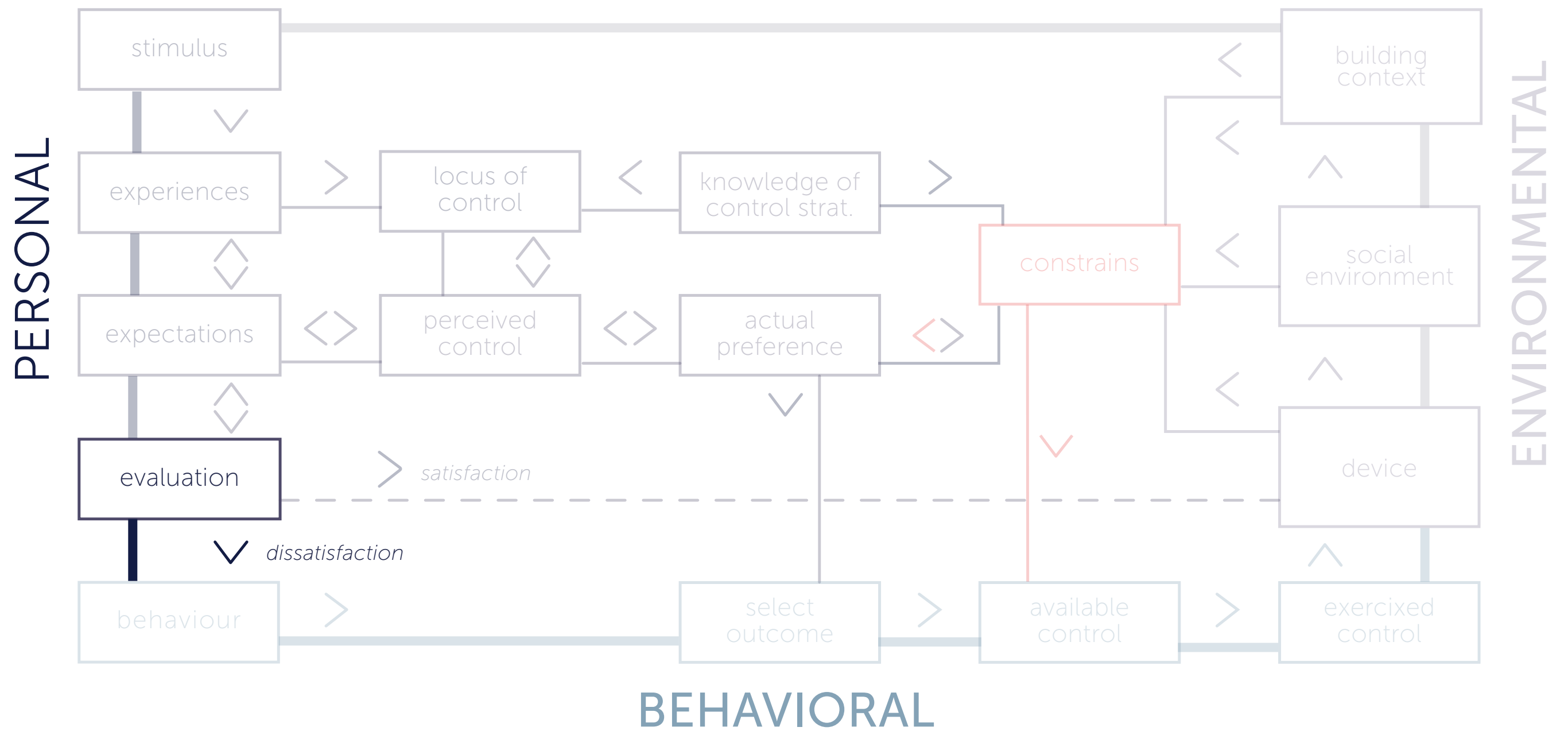
Axial fan



Wall airco

(Xie et al.,2023)



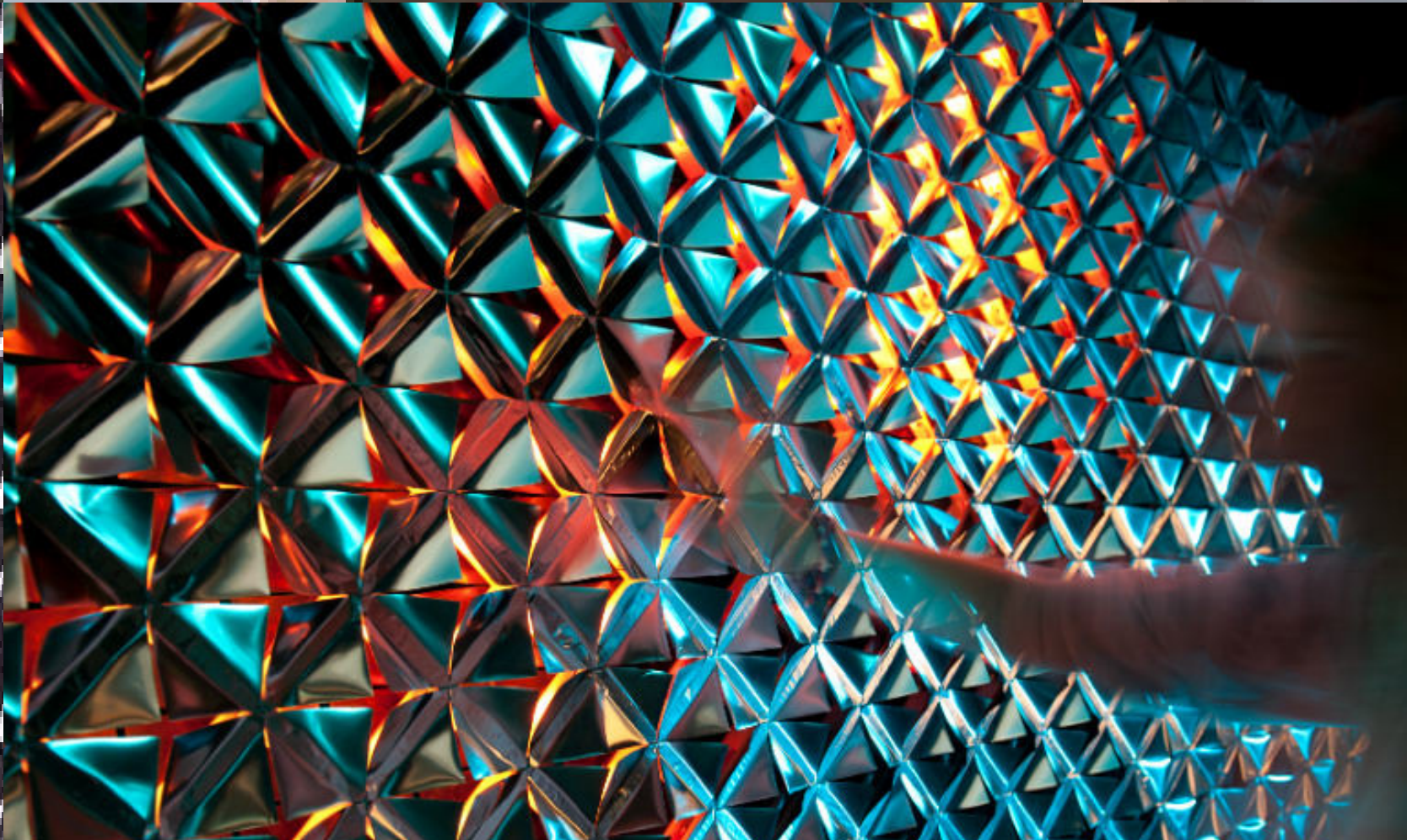
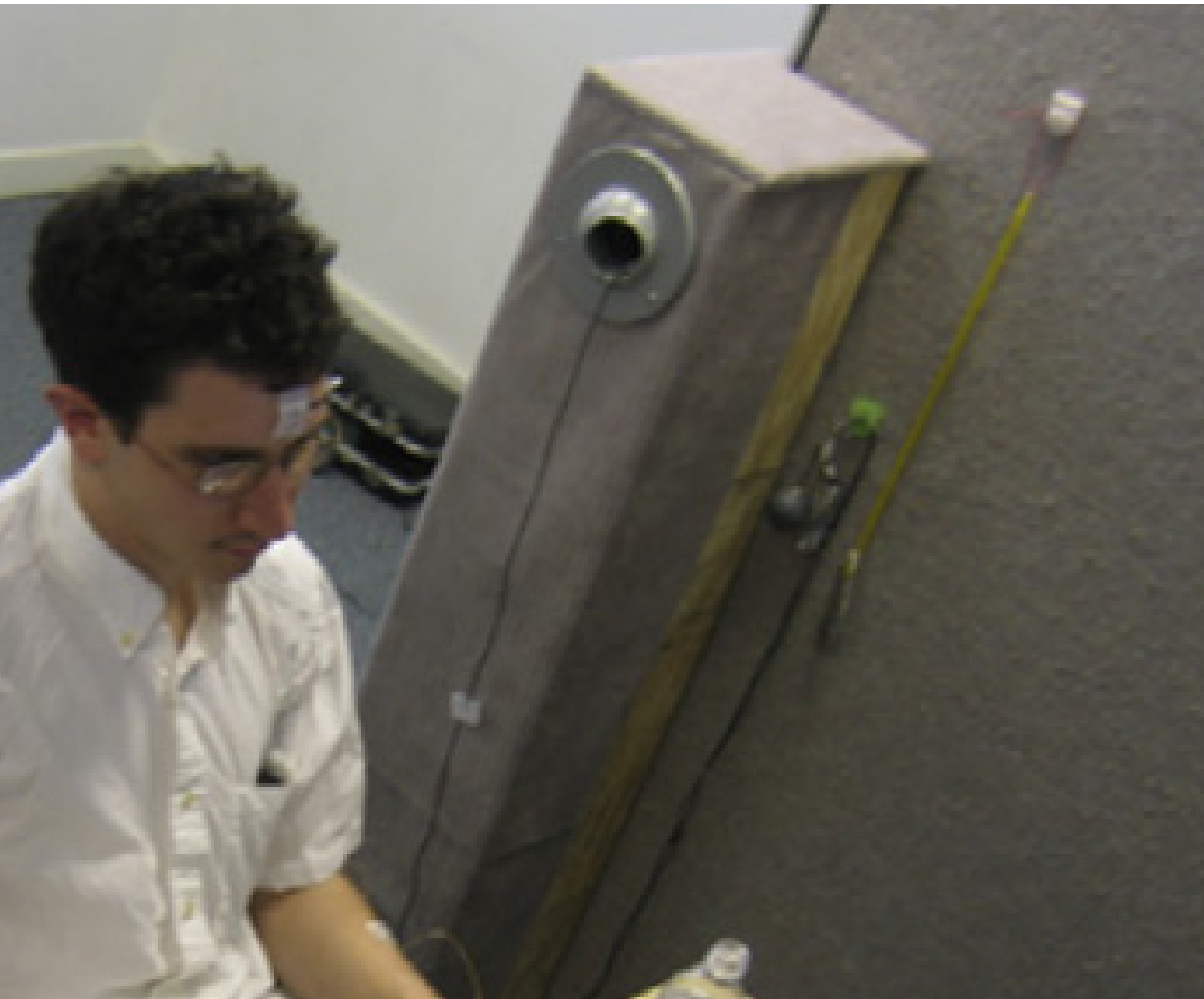






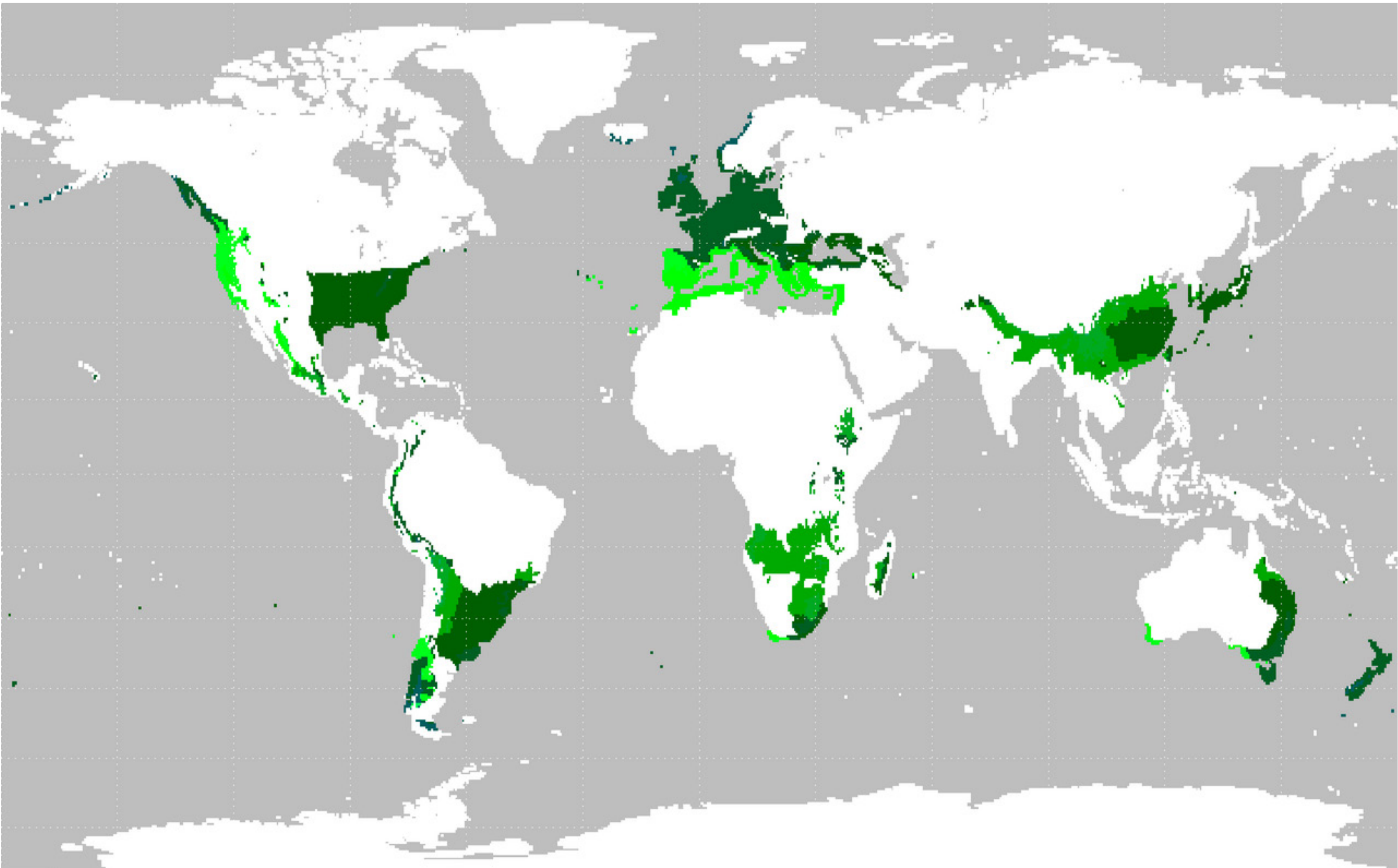








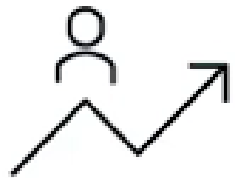




Aw	As	Af	Am	BSh	BSk	BWh	BWk	Cfa	Cfb	Cfc	Cwa	Cwb	Cwc	Csa	Csb	Csc	Dfa	Dfb	Dfc	Dfd	Dwa	Dwb	Dwc	Dwd	Dsa	Dsb	Dsc	Dsd	EF	ET
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The Workplace Reset

A new minimum viable office



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