Environmental Data Physicalization ENVI

Exploring Data Physicalization For Environmental Conditions In Offices

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ABSTRACT

Despite the massive impact on their mental and physical well-being, office workers are often unaware of the environmental conditions in the office. Currently, this data is not accessible enough, can an aethetical data physicalization artifact create the missing awareness through a combination of scientific guidelines and self-reflecing feedback? Contextual Inquiry and Provotype-induced Discussions were used to explore this case, and according to this process, it is extremely important to take individual preferences into account. With these insights, the artifact ENVI was created and tested in a simulated experience test to evaluate and get insights from office workers.

Keywords

Office workers; Data physicalizations; Environmental conditions; Temperature levels; Thermochromic ink; Self-reflecting; Office context;
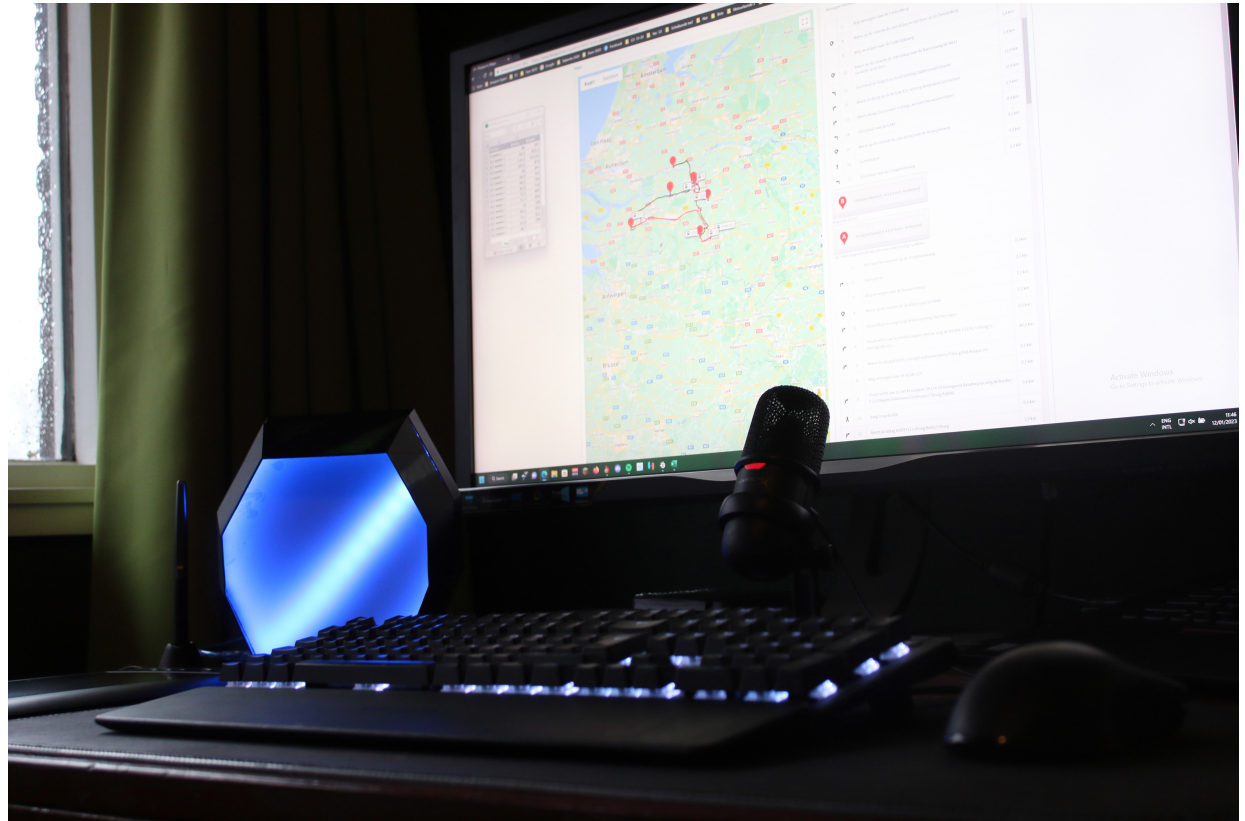
ENVI: Gaining insight into your personal environmental office conditions

INTRODUCTION

Environmental conditions, such as humidity, noise levels, and temperature, have a significant impact on the mental and physical well-being of people working in an office. Working in an office with inadequate environmental conditions unwittingly results in a feeling of discomfort, therefore directly influencing both productivity and physical condition[25]. Some conditions are really clear, extreme noise levels, for example, will be instantly perceived. Less perceptible conditions like temperature or air quality, however, are the silent killers of an office environment, because they often go unnoticed.

On average, people working in an office spend 8.3 hours per day behind their desks[20], and while the sedentary behavior is quite well addressed, environmental aspects are often overlooked or given insufficient attention. One of the main reasons causing this is that the effects of environmental conditions on health and performance are often not immediately obvious[20]. For example, the negative effects of a warm temperature may not be immediately apparent, but can accumulate unwittingly over time and lead to decreased productivity or even health problems. Studies have shown that cognitive task performance decreases as temperature deviates from the optimal range of around 22-24°C.[23]

Maintaining proper environmental conditions in an office environment does not only benefit the employees. Keeping personal happy and healthy is also an important aspect for the managing board, making sure to keep productivity optimal and absenteeism to a minimal. Trade unions also strive for the best possible working conditions for their members, supporting their interests.

From an initial set of contextual interviews[Appendix 3], performed to specify the design problem and challenge, 83.3% stated to be aware of the importance of having proper environmental conditions in the office. However, only 33.3% claimed to have good view on the current status of those conditions. These insights made the question arise; is it so hard to get that information?

Currently, the only indication office workers can use to get insight on the current environmental status, is the number displayed on the often already small thermostat hidden somewhere in the area. Not only goes the thermostat almost always unnoticed, it also does not take individual preferences into consideration.

Every person is unique, with different temperature preferences, and should therefore also have the possibility to receive feedback based on their own personal comfort range[9]. By adding a personal touch, it also adds communal possibilities, like sharing an office space with people that have similar environmental preferences.

Therefore, active awareness can be created by designing a more prominent data-physicalizing design, with both statistical and subjective feedback. With such design, office workers can confirm the current temperature status based on both their individual preferences and the scientifically determined optimal range, resulting in more environmental awareness among office workers, also allowing the consideration of subjective and scientific, which are not necessarily going to be the same.

RELATED WORK AND BENCHMARK

Office workers

Despite the fact that environmental conditions in the workplace can significantly affect the health and well-being of office workers, many are not adequately aware of the impact that these conditions can have [27]. For example, temperature extremes can lead to discomfort and decreased performance, with research indicating that both high and low temperatures can be detrimental [27]. Inadequate lighting can also cause a range of negative effects, including eye strain and headaches [16]. In addition to these environmental factors, office workers may not engage in sufficient physical activity or take adequate breaks, which can further contribute to negative health outcomes [17]. It is therefore crucial that office workers are educated about the importance of maintaining optimal environmental conditions in the workplace, and are proactive in taking steps to ensure their own health and well-being [16].

Environmental aspects in an office environment

There are numerous environmental factors that can influence the health and well-being of office workers. These can be physical, such as temperature and lighting, or psychological, such as noise and social support.

Temperature

Temperature is a physical environmental factor that can significantly affect the comfort and productivity of office workers. Studies have shown that both extreme heat and extreme cold can have negative impacts on cognitive function, with optimal temperatures ranging from 21-24°C (70-75°F) [1,7].

At high temperatures, the body must work harder to maintain a stable internal temperature, leading to increased physical strain and decreased mental performance. In fact, research[9] has shown that performance on cognitive tasks decreases as temperatures rise above comfortable levels. This is because the body's natural cooling mechanism, sweating, can be disrupted at high temperatures, leading to an increased heart rate and decreased blood flow to the brain(Figure 1).

On the other hand, low temperatures can also be detrimental to productivity. Cold temperatures can cause discomfort, leading to decreased motivation and increased absenteeism. In addition, cold temperatures can lead to an increase in the risk of respiratory infections, as the body's immune system is weaker in cold environments.

Condition of forehead	22°C	26°C	30°C
Matt	51 (96%)	38 (64%)	13 (24%)
Shiny	2 (4%)	21 (36%)	39 (71%)
Visible sweat drops	0	0	3 (5%)
No. of observations	53	59	55

Figure 1: Visual effects of warmer office environments[30]

Humidity

In addition to temperature, humidity can also play a role in comfort and productivity. Humidity, or the amount of water vapor present in the air, can also have an impact on office workers in an office environment. High humidity levels can lead to discomfort and decreased productivity, as it can make the air feel heavy and stagnant. On the other hand, low humidity levels can lead to dryness and irritation of the respiratory system, as well as static electricity and dry skin. In addition, low humidity levels can also contribute to the spread of respiratory infections, as viruses and bacteria can survive and spread more easily in dry air. Therefore, it is important to maintain an optimal humidity level in the office, typically between 40-60%, in order to ensure the comfort and well-being of office workers [1,7].

Lighting

Light has been found to have various effects on the behavior and performance of office workers.

According to a study, the intensity and spectral distribution of light can affect cognitive performance, mood, and sleep. High-intensity light has been shown to improve alertness and performance on tasks that require sustained attention[14]. On the other hand, low-intensity light has been associated with decreased performance on tasks that require vigilance and decision making [14].

The spectral distribution of light, or the colors of light, has also been found to have an impact on human behavior. A study [29] found that blue light was more effective at improving performance on tasks that required visual and cognitive skills, compared to white and green light. Similarly, another study [2] found that exposure to blue light increased subjective alertness and reduced sleepiness, compared to exposure to green light.

In addition to the intensity and spectral distribution of light, the timing and duration of light exposure can also affect the performance and well-being of office workers.

Noise

Noise has been shown to have a significant impact on the productivity and well-being of office workers. According to a study conducted by the University of Sydney [1], high levels of background noise can decrease the ability of workers to perform tasks that require concentration, such as reading or writing. In contrast, moderate levels of ambient noise can actually enhance performance on creative tasks [19].

In addition to its effect on task performance, noise can also have negative impacts on the health and well-being of office workers. Noise has been linked to increased stress and anxiety levels [1], as well as increased risk of cardiovascular disease [21].

To mitigate the negative impacts of noise in the office, it is important for organizations to establish and enforce policies to minimize unnecessary noise. This may include the use of noise-cancelling headphones or the implementation of quiet zones within the office. It is also important for organizations to consider the layout of the office space, as well as the materials used in the construction and furnishings, as these can all contribute to the overall noise level in the environment.

Figure 2: Selection of Data physicalization, Environmental influences in Office environments & Existing intervention benchmark

Data Physicalization

Data physicalizations refer to the representation of data through physical objects or forms, rather than through traditional visual displays such as graphs or charts. These physicalizations can take various forms, including tangible objects, interactive installations, or even physical spaces.

One advantage of data physicalizations is that they can make complex or abstract data more accessible and understandable for a wider audience. By providing a concrete and tangible representation of the data, people are able to more easily grasp the meaning and significance of the information. For example, in a study on the use of physical objects to represent data, it was found that participants were able to more accurately interpret and recall data when it was presented through physical objects, compared to traditional visual displays[11].

Additionally, data physicalizations can facilitate more engaging and interactive forms of data exploration. Desjardins [6] explored the use of "Listening Cups" as a data physicalization to represent sound data in an urban environment. The cups were placed in various locations and connected to a central hub, allowing users to physically move between the cups to explore and compare different sound environments. This interactive approach to data exploration can facilitate a deeper understanding and appreciation of the data.

Overall, data physicalizations offer a powerful and effective way to represent and explore data, enabling more accessible and interactive forms of information communication.

Design

Designing data physicalizations is the practice of making information more concrete and relatable through the use of physical objects or technology. One example of this is the use of microrobots in the design artifact Zooids[15]. The microrobots are employed to give a physical form to data, thereby supporting the decision-making process.
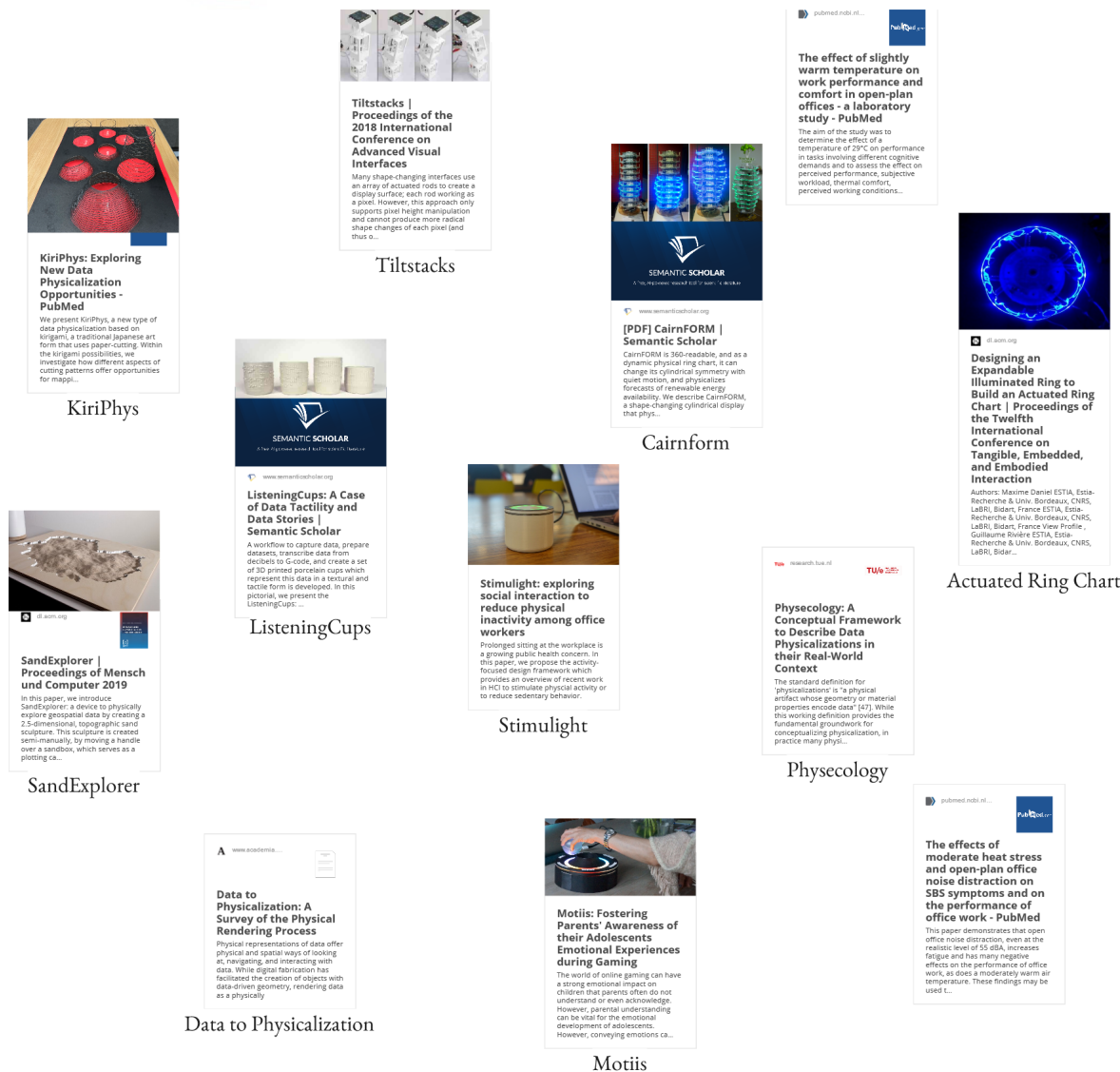
Another instance of data physicalization is seen in the design artifact Motiis [22], which converts children's emotions experienced during gaming sessions into a tangible form, allowing parents to perceive these emotions through touch.

Data physicalization allows for a more interactive and accurate exploration of data, as compared to traditional visualization methods. The tangible nature of data physicalization can also provide added value by utilizing multiple sensory channels, leading to a more meaningful perception of data [10]. The ListeningCup[6], which uses the senses of sight and touch to physicalize everyday ambient sound, is a good example.
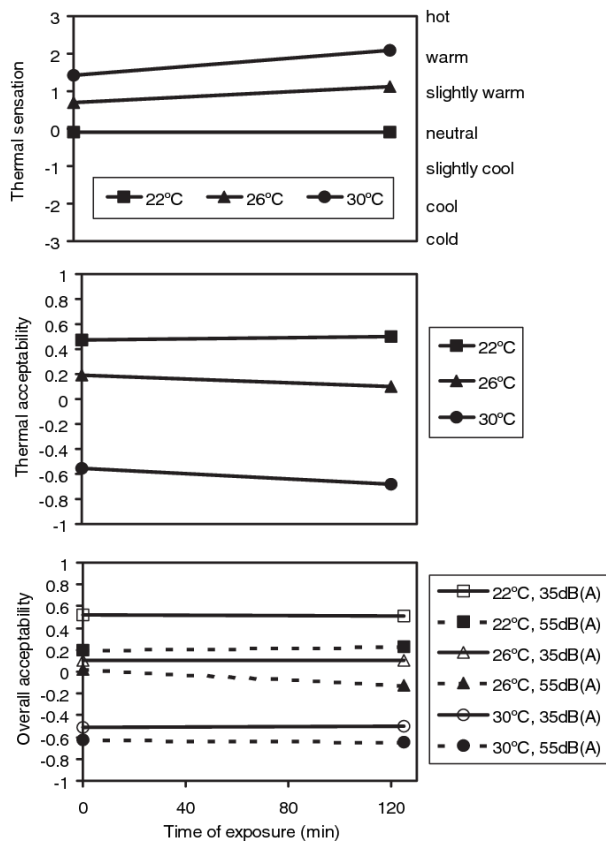

Figure 3: Acceptability rates for temperature levels[30]

Regulations and Guidelines

In the Netherlands, the regulations and guidelines for environmental conditions in offices are primarily set by the Dutch Working Conditions Act (Arbowet) and the Dutch Building Decree (Bouwbesluit).

The Dutch Working Conditions Act (Arbowet) lays out the legal requirements for a safe and healthy workplace, which includes provisions for indoor air quality, lighting, and temperature. The Arbowet requires employers to assess and address any potential hazards in the workplace, including those related to indoor air quality. Employers are expected to control or eliminate sources of indoor air pollution, such as tobacco smoke, pesticides, and indoor combustion sources, and provide adequate ventilation to bring in fresh outdoor air.

The Dutch Building Decree (Bouwbesluit) also sets regulations for indoor air quality, lighting, and temperature in offices. According to Bouwbesluit, the building code requires that new buildings be designed to provide an adequate indoor climate, including appropriate ventilation and lighting. Additionally, the building code sets specific requirements for lighting levels in offices, including recommendations for both natural and artificial lighting.

The Dutch Organization for Applied Scientific Research (TNO) provides guidelines for indoor air quality in offices, including recommendations for ventilation rates and temperature ranges(Figure 3) to ensure that indoor air quality is at an acceptable level. According to TNO, the recommended temperature range for offices is between 20-22°C and a relative humidity of 40-60%.

Furthermore, The Netherlands Organization for Health Research and Development (ZonMw) recommends temperature range between 20-23°C and humidity between 30-60% with the intention of balancing comfort and energy efficiency, providing more comfortable and energy efficient workplaces.

It's important for employers in the Netherlands to be familiar with both the Arbowet and the Bouwbesluit, as well as the guidelines provided by TNO and ZonMw, in order to ensure compliance and provide a safe and healthy workplace for employees.

Design potential

A study by Thomas Witterseh(Figure 4) demonstrates that a moderately warm air temperature increases fatigue and has many negative effects on the performance of office work[23,30]. One of the main design potentials of ENVI is its ability to increase awareness of the environmental conditions in an office. By providing visual feedback on the current temperature and how it compares to the scientific standard for optimal working conditions, ENVI allows office workers to become more conscious of their own personal preferences and the impact that the environment has on their comfort and productivity. This increased awareness can lead to a number of positive outcomes, such as improved focus and productivity, as well as a sense of personal control over one's work environment.

Additionally, the use of thermochromic ink in the design of ENVI adds a unique and individualistic aspect, allowing office workers to visually express their preferred temperature range and potentially sparking conversations and social interactions based on this visual. Overall, the design of ENVI has the potential to create a more comfortable and collaborative office environment, ultimately leading to enhanced well-being and job satisfaction for office workers.

Furthermore, the design of ENVI has the potential to be aesthetically pleasing and to enhance the overall appearance of the office space. Its visually appealing and unique design can contribute to a more positive and inviting atmosphere, which can further improve the working experience for office workers.

	22°C, 35dBA	26°C, 35dBA	30°C, 35dBA	22°C, 55dBA	26°C, 55dBA	30°C, 55dBA
Air temp., pre-exp. (°C)	21.9	22.0	21.9	21.8	21.8	22.0
Air temperature (°C)	22.2	25.9	29.9	22.3	25.8	29.7
Operative temperature (°C)	22.4	26.0	29.7	22.5	26.0	29.7
Relative humidity (%)	50	43	34	50	41	37
Absolute humidity (kg/kg)	0.0082	0.0090	0.0090	0.0082	0.0086	0.0098
$L_{eq,A}$ (dB)	35	35	35	55	55	55
Air velocity (m/s)	< 0.15	< 0.15	< 0.15	< 0.15	< 0.15	< 0.15
Outdoor air supply (L/s)	88	92	88	88	91	90
CO_2 (p.p.m.)	666	704	763	685	729	694
Average metabolic rate (met)	0.99	1.06	1.27	0.99	1.10	1.32
Ozone, outdoors (p.p.b.)	8	4	7	4	8	11
Ozone, indoors (p.p.b.)	3	1	2	1	2	6
Ozone, I/O-ratio	0.33	0.20	0.26	0.23	0.30	0.41
Lighting level, average (lux)	895	660	635	770	770	925
Average finger temp. (°C)	30.1	33.5	34.9	30.6	33.6	34.9

Figure 4: Overview of study demonstrating temperature and noise influence on work performance[30]

Perception	Time	22°C, 35dBA	26°C, 35dBA	30°C, 35dBA	22°C, 55dBA	26°C, 55dBA	30°C, 55dBA	Main effect	Interaction effect
Dizziness	0 min	7	5	12	4	9	12		
	125 min	12	11	17	8	13	17		
scale coding: 0 = "not dizzy"; 100 = "dizzy"									
Fatigue	0 min	26	29	24	25	18	25		
	125 min	27	40	37	32	45	40		
scale coding: 0 = "rested"; 100 = "tired"									
Ability to concentrate	0 min	22	24	32	30	40	36		
	125 min	26	35	49	37	48	52	N: $P < 0.05$ T: $P < 0.01$	
scale coding: 0 = "easy"; 100 = "difficult"									
Sleepiness	0 min	24	24	26	25	22	30	N: $P < 0.05$ T: $P < 0.05$	
	125 min	31	36	38	35	43	33		
scale coding: 0 = "alert"; 100 = "sleepy"									
Self-estimated performance	0 min	86	84	79	83	83	76	T: $P < 0.05$	
	125 min	81	75	65	76	71	64	T: $P < 0.001$	
scale coding: 0 = "0%"; 100 = "100%"									

Perception	Time	22°C, 35dBA	26°C, 35dBA	30°C, 35dBA	22°C, 55dBA	26°C, 55dBA	30°C, 55dBA	Main effect	Interaction effect
Air quality acceptability	0 min	0.54	0.02	−0.38	0.51	0.16	−0.45	T: $P < 0.001$	
	125 min	0.63	0.15	−0.38	0.56	0.06	−0.47	T: $P < 0.001$	
	re-enter	0.39	0.11	−0.41	0.43	−0.05	−0.59	T: $P < 0.001$	
scale coding: +1 = "clearly acceptable"; −1 = "clearly unacceptable"									
Odor intensity	0 min	0.65	1.06	1.22	0.74	1.01	1.38	T: $P < 0.05$	
	125 min	0.38	0.65	1.17	0.53	0.76	1.17		
	re-enter	1.02	1.03	1.16	0.80	1.11	1.68	T: $P < 0.05$	
scale coding: 0 = "no odour"; 1 = "slight odour"; 2 = "moderate odour"; 3 = "strong odour"; 4 = "very strong odour"; 5 = "overwhelming odour									
Eye irritation	0 min	0.24	0.43	0.54	0.35	0.29	0.65		
	125 min	0.50	0.69	0.80	0.53	0.84	1.08	T: $P < 0.05$*	
	re-enter	0.43	0.55	0.59	0.17	0.78	0.96	T: $P < 0.05$*	
scale coding: 0 = "no irritation"; 1 = "slight irritation"; 2 = "moderate irritation"; 3 = "strong irritation"; 4 = "very strong irritation"; 5 = "overwhelming irritation									
Nose irritation	0 min	0.27	0.73	0.67	0.36	0.40	0.96	T: $P < 0.05$*	
	125 min	0.34	0.59	0.88	0.34	0.49	0.83	T: $P < 0.05$*	
	re-enter	0.56	0.60	0.83	0.36	0.62	1.03	T: $P < 0.05$*	
scale coding: 0 = "no irritation"; 1 = "slight irritation"; 2 = "moderate irritation"; 3 = "strong irritation"; 4 = "very strong irritation"; 5 = "overwhelming irritation									
Throat irritation	0 min	0.22	0.39	0.46	0.23	0.43	0.65	T: $P < 0.05$*	
	125 min	0.40	0.39	0.89	0.28	0.59	0.95	T: $P < 0.05$*	
	re-enter	0.42	0.43	0.60	0.17	0.58	0.88	T: $P < 0.05$*	
scale coding: 0 = "no irritation"; 1 = "slight irritation"; 2 = "moderate irritation"; 3 = "strong irritation"; 4 = "very strong irritation"; 5 = "overwhelming irritation									
Thermal sensation	0 min	−0.11	0.61	1.53	−0.07	0.75	1.31	T: $P < 0.001$	
	125 min	−0.13	−0.13	1.99	−0.03	1.14	2.19	T: $P < 0.001$	
scale coding: −3 = "cold"; −2 = "cool"; −1 = "slightly cool"; 0 = "neutral"; +1 = "slightly warm"; +2 = "warm"; +3 = "hot"									
Thermal acceptability	0 min	0.53	0.19	−0.56	0.42	0.19	−0.55	T: $P < 0.001$	
	125 min	0.54	0.10	−0.64	0.45	0.10	−0.72	T: $P < 0.001$	
scale coding: +1 = "clearly acceptable"; −1 = "clearly unacceptable"									
Noise acceptability	0 min	0.54	0.60	0.52	−0.19	−0.18	−0.19	N: $P < 0.01$	
	125 min	0.64	0.63	0.58	−0.10	−0.19	−0.21	N: $P < 0.01$	
scale coding: +1 = "clearly acceptable"; −1 = "clearly unacceptable"									
Indoor env. acceptability	0 min	0.52	0.10	−0.51	0.20	0.02	−0.62	N: $P < 0.05$ T: $P < 0.001$	
	125 min	0.51	0.11	−0.50	0.23	−0.12	−0.65	N: $P < 0.05$ T: $P < 0.001$	
scale coding: +1 = "clearly acceptable"; −1 = "clearly unacceptable"									
Air dryness	0 min	48	42	38	44	43	42		
	125 min	43	39	37	41	37	43		
scale coding: 0 = "air dry"; 100 = "air humid"									
Air stuffiness	0 min	24	73	82	41	71	82	T: $P < 0.001$	
	125 min	39	74	87	45	75	88	T: $P < 0.001$	
scale coding: 0 = "air fresh"; 100 = "air stuffy"									
Illumination	0 min	49	49	49	48	49	48		
	125 min	47	49	49	47	49	45		
scale coding: 0 = "too dark"; 100 = "too bright"									
Acoustic environment	0 min	53	52	55	76	78	79		
	125 min	52	50	54	78	78	78		
scale coding: 0 = "too quiet"; 100 = "too noisy"									
Nose dryness	0 min	33	32	33	34	36	25		
	125 min	33	28	25	41	33	26		
scale coding: 0 = "dry"; 100 = "runny"									
Throat dryness	0 min	46	49	48	44	54	45		
	125 min	47	43	60	46	55	58		
scale coding: 0 = "not dry"; 100 = "dry"									
Eye dryness	0 min	36	37	35	32	58	43		
	125 min	47	48	45	60	49	59		
scale coding: 0 = "not dry"; 100 = "dry"									
Intensity of headache	0 min	12	12	11	6	13	17	T: $P < 0.05$	
	125 min	15	23	25	12	26	35		
scale coding: 0 = "no headache"; 100 = "severe headache"									
Ability to think clearly	0 min	20	25	31	26	36	35	N: $P < 0.01$	
	125 min	24	34	46	31	41	49	N: $P < 0.01$	
scale coding: 0 = "easy"; 100 = "difficult"									

Figure 5: representation of the design process

DESIGN PROCESS

Design Case Research

The first aspect to establish was to decide on a suitable target group, for which office workers turned out to be a viable option with good potential for design interventions to make an actual impact. Office workers are an ideal group to study for a design case related to the Work, Sense, Action theme because they are a representative population of workers who spend a significant portion of their time in a controlled indoor environment. Office environments are designed to support the work that takes place within them, and as such, the conditions within the office can have a significant impact on the productivity, comfort, and well-being of office workers. Temperature is one of the key environmental factors that can affect the comfort and productivity of office workers, and as such, it is an important area to focus on when designing to improve the work environment.

Additionally, office workers are an easily accessible group to study and monitor, which makes it easier to conduct research and collect data to support the design, especially since I can get easy and broad access to offices because of my lease-car delivery job. Moreover, they are a diverse group that can be found in various sectors, making also the results and the solution more generalizable.

Furthermore, office work is one of the most common and prevalent forms of work in today's society, and by addressing issues related to thermal comfort in office environments, we can have a significant impact on the productivity and well-being of a large portion of the workforce.

Design Challenge

With a general design case in mind, the next step was focussed on specifying, turning a design case into an actual project. A visually-based brainstorming session was held, resulting in a large sum of potential concepts to proceed with. All these concepts were generated by the inspiration of a target group of office workers and a challenge focussing on environmental conditions. The 50 different concepts were visually developed(Figure 6), and after thematic analysis and selection, the conclusion could be drawn that this design challenge would go towards an explorative data-physicalization design project, to look into ways to facilitate environmental data to office workers.

Figure 6: Explorative concept sketches

Contextual Inquiry Interviews

To empathize with office workers, the target group, I visited 12 office workers to perform a contextual inquiry.

A contextual inquiry is a field study that involves in-depth observation and interviews to understand the in-depth thought processes of users and the underlying structure of their activities.

A contextual inquiry interview technique was used to collect insights into the environmental awareness of office workers. These 12 office workers all had been contacted through work visits and signed consent forms. Relevant outcomes can be found in Appendix 3.

During the 5-10 minute sessions, the participant would be asked about:

- Their personal experiences with environmental conditions in the office

- Their awareness concerning the influences of environmental conditions

- Their knowledge of current conditions in the office

> + When answered positively, they were asked to show where they gained that information and what they thought it represented

The main conclusions were that most of the office workers (83.3%) stated to be aware of the importance of having proper environmental conditions in the office, yet not in specific guidelines. Also only few (33.3%) stated to be well-informed about the current environmental condition status in their office, and were also able to back that up when asked to show how and where. Office workers know about the importance of proper environmental conditions, yet they do not have the knowledge or means to review the actual current conditions in their offices. This was exactly the design challenge I was looking for;

"Data physicalization to create awareness about current environmental conditions in an office environment."

Provotyping

With a concept direction from the sketching challenge and the insights from the Contextual Inquiry Interviews, a first iteration concept was created(Figure 7). This first concept was solely focused on creating a data physicalization design that would allow office workers to get easy and accessible information concerning the current environmental status of the office. Through a brightly colored LED animation, real-time feedback was shown about whether the current environmental temperature was in line with the scientific guidelines or too hot or too cold. The device was built from wood and plexi, and functioning on an LED strip and digital temperature and humidity sensor, to allow the potential implementation of humidity as a next step.
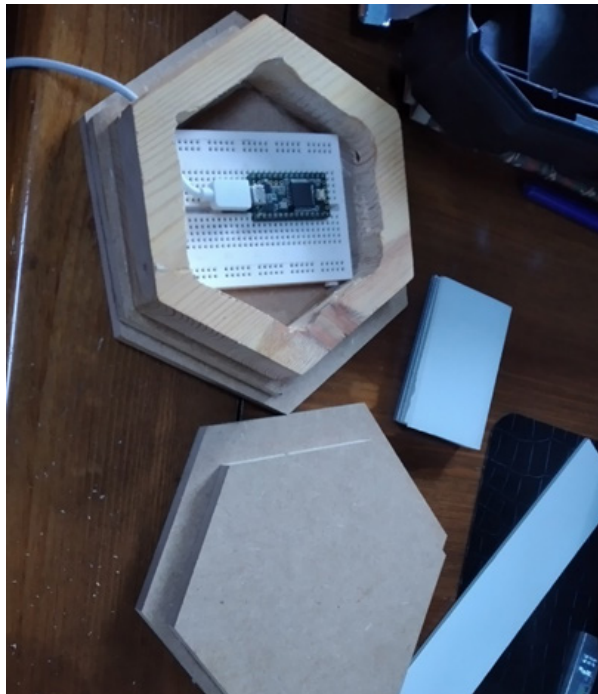
Figure 7: First iteration concept of ENVI

Provotype-induced Discussion

This concept(Figure 7) was evaluated through the presentation of a series of contextual demonstrations for both office workers and design students. This included contextual explanation and live demonstration of the prototype, followed by short discussion sessions. Relevant outcomes can be found in Appendix 3.

The main discussion point that came up during these sessions was regarding the issue of individual human preferences. It was acknowledged that there are differences in preferences for men and women, for young and old, skinny or muscular, etc. These differences are due to various factors such as gender, age, body shape, physiology, culture, and many more. It was recognized that each person has unique physiological and psychological characteristics that affect how they perceive and respond to environmental conditions. Therefore, each person prefers different environmental conditions to work in.

It was discussed that these individual preferences should be taken into consideration when designing solutions to improve the work environment. For example, some people may prefer a cooler temperature while others may prefer a warmer temperature. Some may prefer more natural light while others may prefer less. These individual preferences can impact the comfort and productivity of office workers, and as such, it is important to consider them when designing to improve the work environment.

This meant I needed a way to implement individualistic preferences into the concept. At that point there were two possibilities, either to implement a self-learning feedback option, or to find some way to still show the scientific data as on the first concept, yet this time with an added function of self-reflecting. After doing some more research, I decided to focus on the self-learning option, creating a bit more unique artifact instead of just another smart thermostat.

For my final design concept ENVI, I wanted to create an aesthetical data physicalization artifact that still had the LED feedback to provide insight into the scientific guidelines regarding temperature levels, yet also provide some way of allowing office workers to get information from the artifact and draw their own conclusions based on that information.

Thermochromic Inks

After some explorative research, the concept of thermochromic ink came up[26]. This was very interesting as I was looking for something non-electronic, making chemistry a really good option. Based on additional desktop research, it turned out that chemically reacting ink was a perfect match with the concept. Not only were there plenty of temperature ranges available, also all types of inks that would react to different environmental conditions such as for example light types or humidity levels.

To actually get a hand on these inks turned out to be quite the challenges as they were quite rare and delivery times were long. When they finally came in, a big exploration test was performed with all these types of ink, of which an overview can be seen in Figure 8.

Top row: Thermochromic inks reacting at:

27 °C; 41 °C; 15 °C; 31 °C; 25 °C;

Bottom row: Other conditions reacting at:

Humidity; Light levels; UV light; 20-25 °C gradient foil;

For all inks were testing samples created, like the blocks in Figure 9. This gave really good insights into the efficiency of all the different types of ink, and also allowed for an extra round of Provotype Testing.

This experiment was meant to determine which of the 'triggers' office workers would understand. The in-field experiment was simple and consisted of only 1 goal. The assignment was to take the 4 blocks along during one day of working in the office and figuring out what each individual block represents. For temperature the sample block of 15 °C because the experiment was conducted during autumn, the other blocks were Humidity, Light level and Day/Artificial light.

The experiment was performed under 10 office workers in different offices, and most considered it a challenge to figure it out. A bit unexpectedly, the main conclusion could not be determined from the quantitative data, but was mentioned during the feedback moment by almost all participants. It came down to the fact that however they liked the challenge of figuring the triggers out, focussing on only one environmental condition would work better because all the different conditions only brought confusion.

From the qualitative data(Figure 10) can be concluded that temperature is widely understood, way more than the other conditions. Therefore the decision was made to focus ENVI on temperature, to allow clear feedback on that aspect without confusion on the type of condi-

Figure 8: Overview of reacting inks
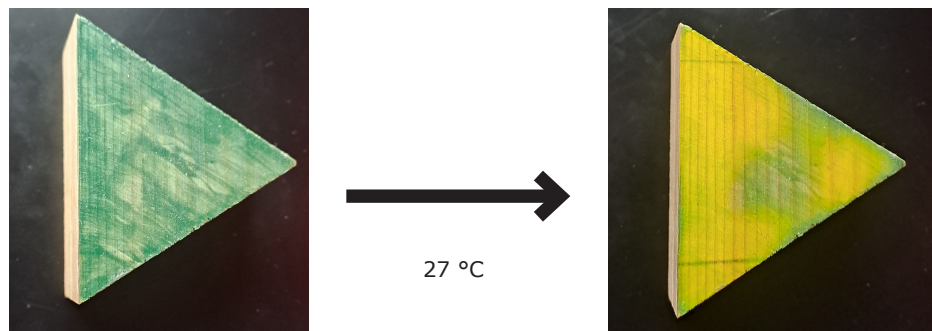
Figure 9: Experiment sample block reacting at

27 °C
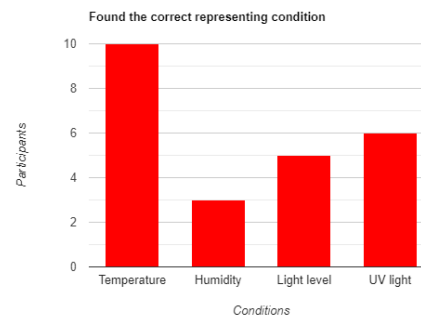
Figure 10: Succesrate determining the correct conditions

Shape Exploration

To make ENVI an actual aesthetically pleasing artifact for the office, it needs a good design. The shape should allow both types of feedback to be easily accessible, but also be pleasant for the eye and noticeable. Inspiration was gained from 2 sources. the first being a private design experiment that was recently done for personal use, the second through artificial intelligence.

My main inspiration to use the light inside the design instead of outside like on the first iteration came from a small rock-crystal project(Figure 11). Using a special drill, the crystal was hollowed out, to allow a candle or light to be placed inside. This gives the almost magical glow effect as the light shines through the crystal.

Figure 11: Rock-crystal design experiment

With this initial thought, I went into a special digital image rendering artificial intelligence. After a couple of attempts to learn the AI, some really interesting images(Figure 12) came out, and those formed the basic model to get working with.

Figure 12: Shape exploration through digital image generation

3D Modelling, Rendering & Printing

To realize the design, I started working in Fusion 360 to create a 3D model suitable for 3D printing. By using the generated images(Figure 12) as inspiration and applying 2mm thickness on the design, I was able to 3D-print the casing, as well as exporting to Blender to create some renders(Figure 13). Initially, it was planned to make the design about 30cm in height, yet due to printing time, the decision was made to convert the model to 22.5cm in height. With the printed casing ready, it was only a matter of putting in the electronics (Figure 16) and a plate of plexi. After that was all working, the thermochromic ink was applied to allow the self-reflecting feedback.

Simulated In-field Experience

With a now fully functional prototype in place, a simulated in-field user test was done. This user test consisted of 6 participants, all office workers from different offices. During the user test, the participants would be shown 3 different simulated scenarios to get their initial thoughts on the concept.

- Current temperature in the office

- Simulated 'Too hot' in the office

- Simulated 'Too cold' in the office

After all three scenarios, participants were asked to give an answer to three agree-disagree scales and three open questions.

Agree - disagree;

This device would help me be more aware about the temperature status in the office

This device would be a trigger to adjust the temperature to a level suitable for me

This device would allow me to socialize based on the information provided

Open-ended questions;

- What information does the device tell you about the current temperature?

- How could this design influence the social situation in an office?

- How could this design influence well-being for office workers in an office?

The insights from the simulated test were surprisingly insightful. Most participants naturally understood the concept really well. The aspect of receiving both scientific data and self-reflecting feedback was considered extremely interesting, and participants were already curious how their personal standard would held-up against the scientific range.

With an average outcome of 4, the participants considered it a great tool to create more awareness. The outcome regarding the social aspect, on the other hand, ended up quite low at 2.5, this was the result of 2 participants scoring it minimum. One of those participants also quoted:

"I share an office space with three other people, yet the first thing I do when I enter in the morning, is turn up the AC to match my preference. I think this device has the potential to add positive social value, yet even more negative, for example by creating friction between different preferences"

This quote really emphasizes the importance of correct usage and understanding, since it can also potentially cause a negative impact on the social flow.
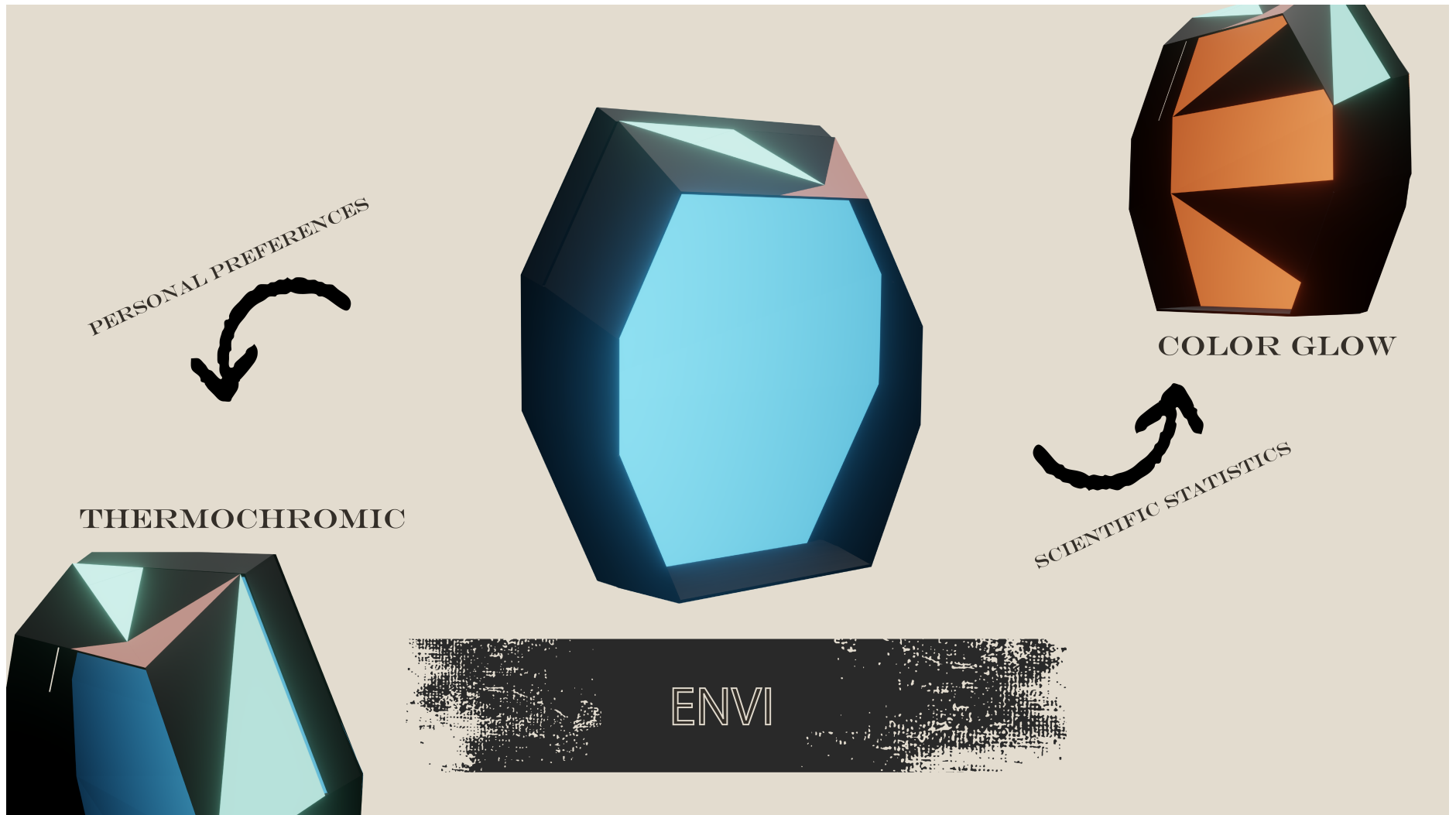
Figure 13: Concept visual made from renders made in Blender

ENVI

Design of ENVI

ENVI is a data visualization device designed to inform and create awareness among office workers about the current temperature in the office, using both self-reflecting and statistical feedback.

One of the main features of ENVI is its ability to provide real-time feedback on the temperature in the office. This is done through the use of an LED light animation, which indicates how the current temperature compares to the scientific standard for optimal working conditions. In addition to providing scientific temperature feedback, ENVI also utilizes a thermochromic ink visual to add an individualistic aspect to the device. The thermochromic ink visual consist of sections from different inks with different chemical reactions that change color based on the current temperature, allowing each ENVI device to have a unique appearance based on the local temperature around that specific office area. This individualistic aspect of ENVI can encourage office workers to reflect on their own comfort levels and make adjustments as needed. By displaying this information visually, ENVI can help office workers to quickly and easily assess the information concerning temperature in the office and make any necessary adjustments.

Furthermore, the unique appearances of each ENVI device can serve as a conversation starter or a way for office workers to bond over their shared work environment. This can lead to increased socialization and a sense of community within the office, which can have a positive impact on morale and overall job satisfaction. Overall, the ideal effect of ENVI would be to increase awareness about the temperature in the office and thereby contribute to an improvement in the office experience by creating a more comfortable and productive work environment for office workers.

Overall, the main goal of ENVI is to increase awareness among office workers about the temperature in the office. By creating this awareness and promoting self-reflection, ENVI has the potential to improve the comfort and productivity of office workers.

Underlying Design principles

When looking at the overarching principles that guided the design of ENVI, five principles were defined. The ideal design intervention should follow the principles:

- Aesthetical
- Informative
- Personal
- Contrast
- Unity

The aesthetical appearance of ENVI is of high importance for the accessibility of feedback while working in an office. The main aspect that matters is noticeability, it is important that users can easily access the information supplied by ENVI. Therefore, ENVI was designed to be an aesthetical artifact, to be more than just a functional device.

To create a design that actually provides more value than a basic thermostat, ENVI uses more than just aesthetics. Where normal thermostats only use scientific statistics to guide temperature, ENVI also supplies feedback in a way that allows for subjective self-reflecting. This aspect is crucial because everybody is unique and therefore has different personal preferences, meaning that the sole use of scientific averages will result in imperfect feedback.

On the other hand, allowing users to receive visual feedback on which they can self-reflect gives a personal meaning to the feedback, allowing them to interpret and act based on their personal preferences.
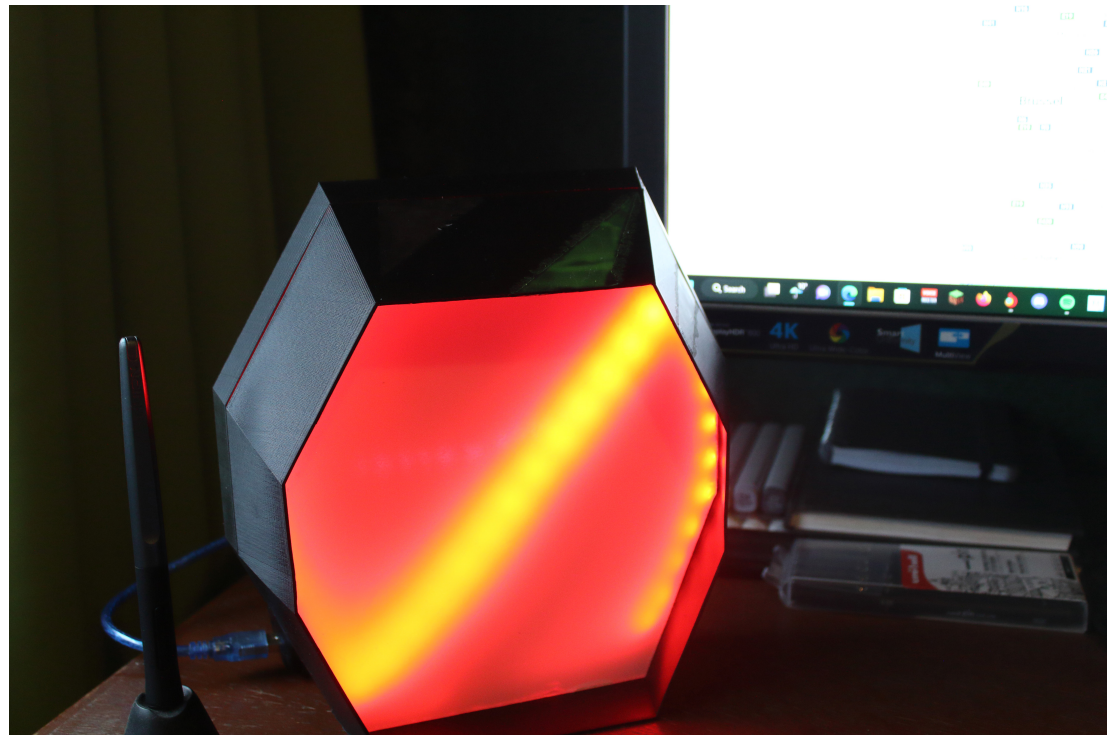
Figure 14: ENVI indicating hot temperature levels

Especially interesting is the contrast between the scientific standard and the subjective feedback. For example, ENVI may indicate that the temperature is statistically too cold, but an individual may personally prefer this temperature. By linking this subjective preference to the current visual display, the individual can now associate that visual with a good temperature for themselves.

By making the feedback personal, ENVI has the potential to unite. This is an aspect that can either work out really well or become a problem if not applied correctly. ENVI can create a better group feeling among a group of colleagues that prefer the same conditions, which is good, yet it must be avoided for people to be judged or left out based on their preferences. It is important to ensure that ENVI is used in a way that promotes inclusivity and respect for the preferences of all office workers.

Technology and realization

ENVI uses both digital and chemical measuring to read the current office temperature. Digital temperature readings are collected through an AM2301 Temperature sensor, then transferred to an Arduino UNO, from which the Arduino software sends the corresponding data to the SK6812 RGBW LED Strip to show the matching LED animations that represent the feedback matching with the measured temperature. The entire circuit(Figure 16) is powered through a GRIXX power bank, yet can, with minor adjustments, also be powered by a power plug.

The chemical aspect is achieved through thermochromic ink, showing a colored visual(Figure 15). Thermochromic ink is a type of ink that changes color as a result of a chemical reaction that occurs when the temperature changes. The ink contains a leuco dye, which is a colorless compound that when combined with a suitable color developer, will produce a visible color. The color change is caused by a change in the chemical equilibrium of the leuco dye, which is triggered by a change in temperature. At a higher temperature, the leuco dye is converted to its colored form, while at a lower temperature the leuco dye returns to its colorless form, which causes the ink to change its color[26].

In addition to thermochromic ink that changes between a single color and a colorless state, there are also thermochromic inks that can change between different colors. These inks use a different type of leuco dye called a thermochromic liquid crystal, which changes color in response to changes in temperature. These liquid crystals are composed of small molecules that are arranged in a specific pattern that reflects different wavelengths of light at different temperatures. As the temperature changes, the pattern of the liquid crystals changes, which causes the ink to change color. This type of ink can be used to create a wide range of visual effects, such as color-changing temperature-sensitive indicators in the case of ENVI[13].

Both types of data physicalization are connected by an aesthetical design. This design was created from a 3D-model made in Autodesk Fusion 360 (visual), from which it was exported to Blender to create renders. Also, an Ultimater S3 3d printer was used to 3D-print the model in black PLA. The design is about 25cm high and designed with a bit of a futuristic vibe attached to it, to really allow the aesthetical value to be recognized. The shape was also slightly inspired by a previous design experiment, in which a rock crystal was drilled out, turning it into a candle holder.
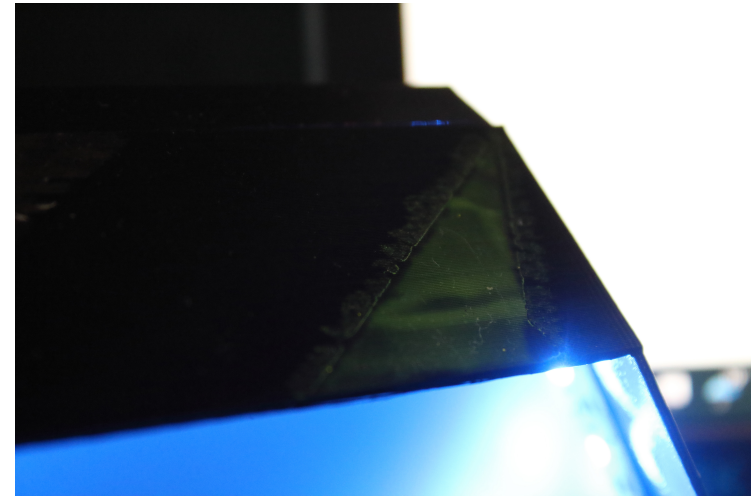

Figure 15: Thermochromic ink chemically changing color based on environmental temperature
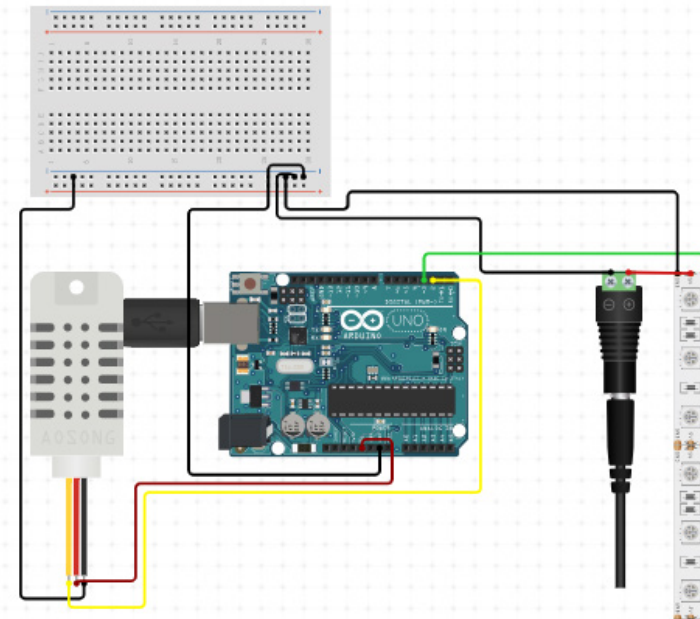

Figure 16: Electronics of ENVI

Figure 18: Self-made crystal design

Figure 17: Different types of chemically reacting inks used in the process

VALUE PROPOSITION

ENVI addresses a critical issue faced by businesses, organizations, and trade unions alike: maintaining optimal environmental conditions in the office. Studies have shown that thermal comfort is a vital factor in determining work performance and employee satisfaction, yet many offices do not have an effective way to display temperature. ENVI incorporates a real-time temperature monitoring system that creates awareness on the current temperature in the office.

Not only does maintaining proper environmental conditions benefit the employees, but it is also an important aspect for the managing board and trade unions. Happy and healthy employees lead to optimal productivity and minimal absenteeism, supporting the interests of both the business and trade unions. Additionally, ENVI is easy to install and integrates seamlessly into existing office infrastructure, making it a cost-effective solution for any office. By implementing ENVI, businesses, organizations, and trade unions can improve employee satisfaction and productivity

ETHICAL CONSIDERATIONS

Designer's Intention

Environmental conditions, such as temperature, play a significant role in the mental and physical well-being of people working in an office. Poor environmental conditions can lead to discomfort and a decrease in focus and work efficiency, which can negatively impact productivity and overall job satisfaction[23]. Unfortunately, the negative effects of inadequate environmental conditions are often overlooked and not properly addressed, leading to a persistent feeling of discomfort among office workers.

To address this issue, ENVI was designed as a data visualizing device that provides both statistical and subjective feedback on the temperature status in the office. When used appropriately, ENVI can create awareness about the temperature status in the office and help to create and maintain optimal cognitive performance and overall well-being.

Potential ethical implications

One potential issue with the use of ENVI in the office is the potential for social disruption. Different people have different preferences when it comes to temperature, and it is possible that groups of workers may form based on the information provided by ENVI. This could lead to social pressure or even exclusion for those who do not fit into these groups.

Additionally, some employees may not want their preferred temperature to be known to others. Despite the fact that ENVI was designed specifically to allow for private self-reflection, it is still possible for others to recognize patterns based on an individual's response to certain temperature levels, indirectly gaining access to private information.

In shared office spaces, it is particularly important to consider the needs and preferences of all employees present when it comes to temperature. It is possible that there may be multiple people working in the same space with different preferences, and it is important to find a balance that allows everyone to work comfortably and efficiently. This may be particularly challenging if one or more employees are introverted and may not feel comfortable expressing their preferences.

Overall, it is important to be mindful of the potential for social disruption when using ENVI in the office and to ensure that the needs and preferences of all employees are considered and respected. By finding a balance that allows everyone to work comfortably and efficiently, it is possible to create a positive and productive work environment for all.

DISCUSSION

Conceptual

Envi has been developed as an aesthetical data physicalization artifact that allows office workers to get feedback on the temperature status in the office through scientific guidelines and self-reflecting. Research has shown that there is room and need for such data physicalization, yet proper implementation will be key. Users need to understand the functionalities, yet just as much the social risks that potentially occur in communal offices.

ENVI can be used in multiple different contexts, for example in a communal space but just as good in a private office, making it easy to implement.

Process & Results

During the design process, a lot of time was lost on gaining materials. The thermochromic ink is difficult to get, with bad delivery times. As a result of this, the midterm concept was not as advanced as hoped for, and the midterm had to be done with the initial concept.

Although the potential for creating awareness can clearly be seen, the study up till now is not extensive enough to be able to actually draw conclusions about whether behavior change will actually occur. To be able to state that ENVI actually causes behavior change to improve work well-being, longer in-depth field testing and research is needed. This was unfortunately given the limited time unfeasible, therefore the decision was made to focus on getting office workers their initial thoughts and reactions through the recent simulated experience test.

As a result of my job working with lease cars, I got the opportunity to get in touch with many different offices. This allowed for studies and tests to be done in a wide variety of offices, resulting in better insights because of the diversity of offices. On the other hand, the sample sizes were relatively small. To validate some of the conclusions drawn, for example regarding the social aspect, which is now based on 6 participants, more extensive testing is mandatory.

FUTURE WORK

There are a couple of aspects that need to be considered for the continuation of ENVI. While being very insightful, the simulated experience did not supply a conclusion about whether this will actually influence people their well-being or behavior, a more extensive in-field user test, directly with office workers, is needed to get insights on the true efficiency on those aspects.

After that, the question becomes what direction to take with ENVI, should it remain awareness focussed or is the next step to connect it to the office environment control system, to convert it from awareness focussed to resolve focussed. The answer to that dilemma will be based on the insights gained from the in-field test.

It is also important to proceed with more in-depth research into the social effect of ENVI, since this can be both positive or negative depending on how ENVI is interpreted and used, therefore this requires additional research and testing.

CONCLUSION

Topic and importance

Studies have shown that thermal comfort is a key factor in determining work performance, yet many offices do not have an effective way to monitor and display temperature. Proper environmental conditions in the office are critical for employee satisfaction and productivity, and can help reduce absenteeism and turnover rates. Office workers turn out to be aware of the importance of environmental conditions, yet lack the opportunity to gain insight into the current environmental status.

Approach and solution

Through contextual inquiry, provotypes, and user interviews and experiments with office workers, opportunities have been found to create awareness through an aesthetical data physicalization artifact allowing both scientific and individualistic self-reflecting to occur.

Contributions

By proposing a potential solution to the missing awareness on the current environmental conditions, this project contributes to the solving of a large environmental problem in office environments. Hereby improving work conditions for office workers.

Further work

Future work could be done on researching the practical effectiveness of ENVI, as well as potential connectivity with the environmental control system. Also, it is really important to look more in-depth into the social applications of ENVI.

Broader context

With this explorative data physicalization design project, a foundation has been created for data physicalizations in office environments, to improve awareness about environmental conditions. This has the potential to result in better working conditions for office workers, as well as an improvement in mental and physical well-being.

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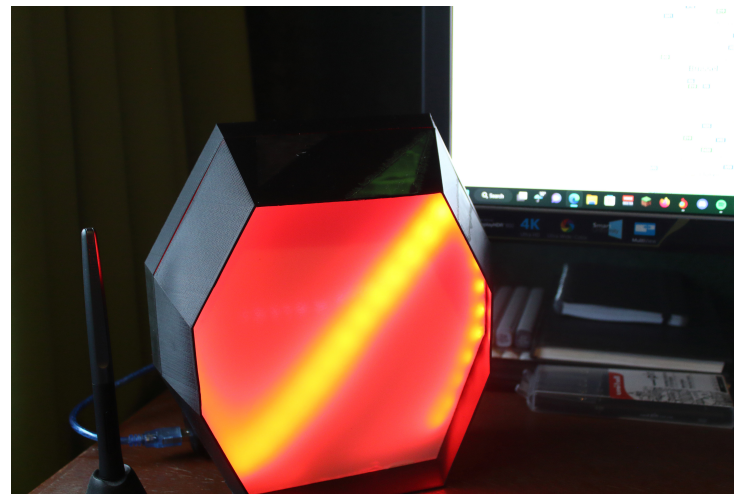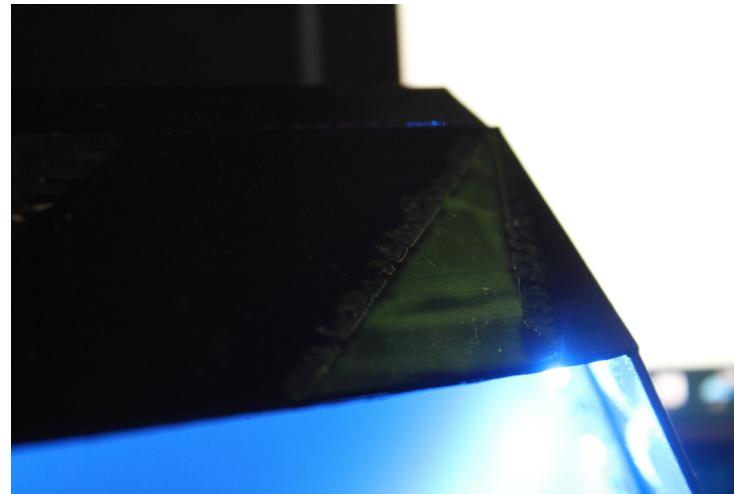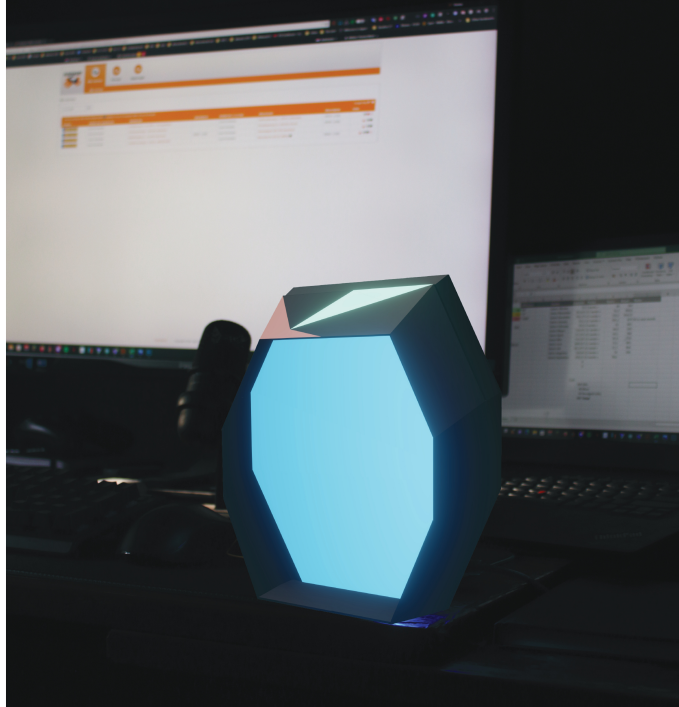
APPENDIX 1 - DELIVERABLES

- Poster of demo-day

- link to the video of Demo day:

- https://youtu.be/muTSMO0Kfa8

- high-quality pictures of your prototype (including at least one in context)
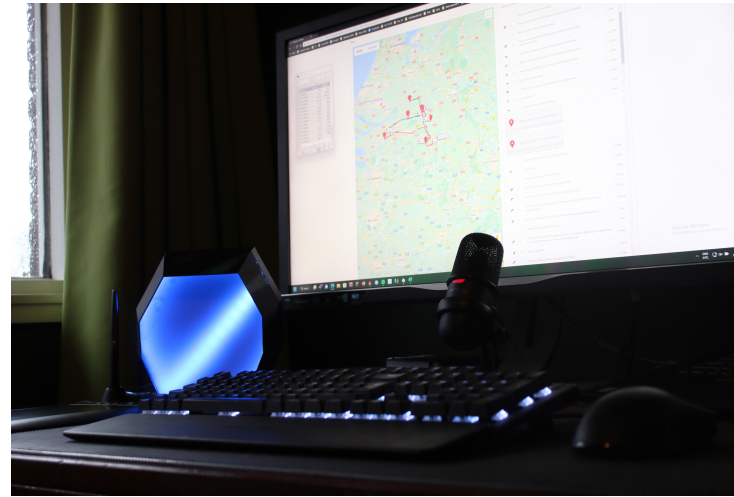
Gaining insight into environmental conditions in the office

WORK, SENSE, ACTION
ENVI

STUDENT NAMES:
Thomas Wezel

COACH:
Hans Brombacher
Steven Houben

SEMESTER:
FBP

Environmental conditions play a significant role in the mental and physical well-being of people working in an office, also directly influencing their work efficiency. Working in an office with inadequate environmental conditions unwittingly results in a feeling of discomfort and therefor a lesser ability to focus on tasks.

Especially because this is an often unnoticed phenomenon, that is therefor not properly dealt with, a data visualising design, with both statistical and subjective feedback, can create the missing awareness and corresponding trigger.

APPENDIX 2 - CONSENT FORMS

NOTE: TEMPLATE FORMAT CONSENT FORM; STUDY DESCRIPTION CHANGES PER STUDY

Informed Consent Form

Gaining insight into environmental conditions in the office

Introduction
Dear Sir/Madam,
You are asked to take part in a scientific study. Participation is voluntary. Participation requires your written consent. Before you decide whether you want to participate in this study, you will be given an explanation about what the study involves. Please read this information carefully and ask the investigator for an explanation if you have any questions. You may also discuss it with your partner, friends or family.

1. General information & purpose of the study
This study is designed by an Industrial Design student at the Eindhoven University of Technology.
- Thomas Wezel - t.s.wezel@student.tue.nl

  With support of: Hans Brombacher – j.g.brobacher@tue.nl

The goal of this study is to gain insights into office workers and their perception and awareness on environmental conditions in the office. To be more precise, through the study data will be collected about your awareness regarding the impact of environmental conditions and knowledge on current status of environmental conditions in the office

1. What participation involves
During the study, the following will happen:
- Data is collected through a range of questions and observations, this data will concern your knowledge on the environmental conditions in your office

2. What is expected of you
In order to carry out the study properly it is important that you follow the study instructions. It is important that you contact the investigator:

- if you no longer want to participate in the study.

It is up to you to decide whether or not to participate in the study. Participation is voluntary. Participants require to be older than 18 years old and have no pre-existing health conditions.
If you do participate in the study, you can always change your mind and decide to stop, at any time during the study. You do not have to say why you are stopping, but you do need to tell the investigator immediately. The data collected until that time will still be used for the study.

3. Usage and storage of your data
Your personal data will be collected, used and stored for this study. This concerns data such as your name and opinions. The collection, use and storage of your data is required to answer the questions asked in this study and to publish the results. I ask your permission for the use of your data.

Confidentiality of your data To protect your privacy, your data will be given a code. Your name and other information that can directly identify you, will be omitted. Data can only be traced back to you

with the encryption key. The encryption key remains safely stored in the local research institute. The data that is sent to the coach will only contain the code, not your name or other data with which you can be identified. The data cannot be traced back to you in reports and publications about the study.

Access to your data for verification Some people can access all your data at the research location. Including the data without a code. This is necessary to check whether the study is being conducted in a good and reliable manner. Persons who have access to your data for review is the student and coach. I ask you to consent to this access.

If you have questions about your rights, please contact the person responsible for the processing of your personal data. For this study, that is the investigator.

4. Any questions?
If you have any questions, please contact the investigator.
If you have any complaints about the study, you can discuss this with the investigator.

5. Signing the consent form
If you give permission, I will ask you to sign this consent form. By your written permission you indicate that you have understood the information and consent to participation in the study. The signature sheet is kept by the investigator.

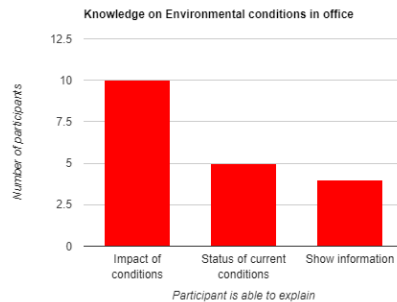Signature Participant _____ Date _____

Thank you for your attention.

CONTEXTUAL INTERVIEWS

12 participants - Office workers

Statistical data:

(Somebody got busted for claiming to know about the currect conditions, yet when he had to show, he had to search for 10 minutes before finding the thermostat)

Relevant quotes(Dutch):

"Ik weet wel ongeveer hoe warm het is binnen, maar wat ik daarmee moet, geen idee."

"Er zou hier ergens een thermostaat moeten hangen."

"Ik krijg redelijk snel hoofdpijn, dus voor mij moet het eigenlijk altijd wat frisser zijn."

"Ja, ik heb eigenlijk geen idee hoe warm het bij ons is, is dat zo belangrijk dan?"

"Waar zou ik dat moeten kunnen zien dan?"

"Thuis hebben we zon kastje, zon slimme thermostaat met een groot scherm, dat zouden ze hier ook wel eens mogen ophangen."

"Ik hoor wel vaker dat het belangrijk is inderdaad, maar wat ik daar zelf aan kan doen, dat zou ik niet weten."

PROVOTYPE-INDUCED DISCUSSIONS

20 participants - Office workers & Design students

Relevant comments(Dutch & English):

"Did you consider the difference in preferences between man and woman?"

"It looks really attracting, definitely catching attention."

"Will this device automatically connect to the thermostat to change conditions?"

"Nou, ik vroeg me wel af, hoe weet ie dat ik het met m eens ben? hij kan bijvoorbeeld prima zeggen dat het koud is, terwijl ik het zelf gewoon prima vind omdat ik het niet graag warm heb."

"Dat kun je oplossen door een self-learning element eraan toe te voegen, en een feedback knop voor mee eens of niet mee eens."

"Het feit dat je zo puur op een awareness confirmation trigger focust is interesant, ik ben wel benieuwd wat daar uit gaat komen."

"Hoe voelt het voor de gebruiker? kun je op een of andere manier bevestigen of de feedback ook echt is hoe je je voelt?"

"The challenge for your design is how you can deal with human preferences. People yound and old have different preferences. Do you take the average of what is it based on?"

"I feel like this design has a lot of potential, yet misses an element of personalization"

"Will this device be personal, so that we have like 10 devices in a communal office, or will it be more like one per space or per table? Its good to think about that."
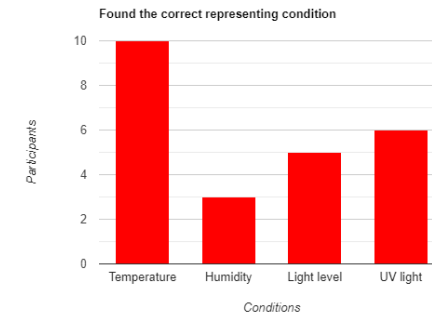
"Maybe it is fun to create a projection on glass, like turn the entire office into feedback"

"Het is erg interessant welke andere doelen zoiets kan dienen, mensen kunnen bijvoorbeeld een kantoor indeling maken op basis van deze data"

CONTEXTUAL INTERVIEWS

10 participants - Office workers

Statistical data:

(All participant discovered the temperature sample, while only 3 participant found the humidity one. All three by exident because it was raining outside.)

Relevant quotes(Dutch):

"Het temperatuur blokje had ik zo goed als gelijk door, ik liep mijn kantoor uit naar de kantine en hij veranderde gelijk, de rest had ik meer moeite mee en die ene laatste heb ik niet kunnen vinden."

"Het is een interessant concept, alleen let goed op dat je het niet te veel doet, ik was al in de war met deze 4 blokjes los, en dan zit er nog niet eens een echte betekenis aan."

"De meeste had ik vrij snel door, UV light wordt snel zichtbaar als je je verplaats in een kantoor met een raam, en temperatuur kwam ik achter toen ik datzelfde raam open ging zetten"
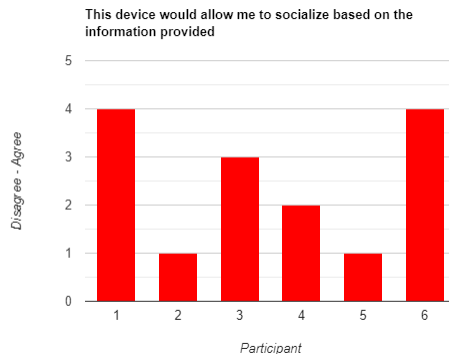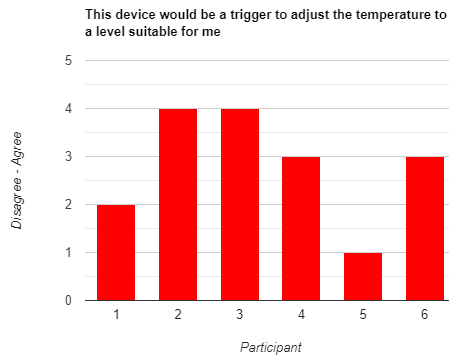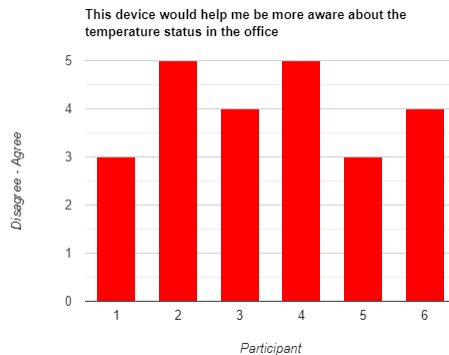
"als ik hoorde wat je van plan bent, zou ik persoonlijk zeggen, hou het bij 1 of 2 van die conditions, anders gaat het denk ik heel snel verwarrend worden. De temperatuur op zichzelf vond ik erg duidelijk, maar dingen als luchtvochtigheid had ik zelf nooit bedacht."

APPENDIX 3 - STUDY RESULTS

SIMULATED IN-FIELD EXPERIENCE

6 participants - Office workers

Statistical data participants:

This device would help me be more aware about the temperature status in the office

This device would be a trigger to adjust the temperature to a level suitable for me

This device would allow me to socialize based on the information provided

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This device would help me be more aware about the temperature status in the office: 4 - Agree

This device would be a trigger to adjust the temperature to a level suitable for me: 2.8 - Neutral

This device would allow me to socialize based on the information provided: 2.5 - Slightly Disagree

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Relevant quotes(Dutch):

What information does the device tell you about the current temperature?

"Hoe warm het is natuurlijk, vergelijkt het met kamer temperatuur? 20 graden?"

"Het lijkt me een soort futuristische thermostaat, het maakt me wel nieuwschieriger dan gewoon zon ding aan de muur

"De blauwe en rode kleuren spreken vrij voor zichzelf, maar hoe die andere kleuren bovenop werken, dat snap ik nog niet helemaal, de kleur groen is voor mij geen temperatuur associatie, tenzij je doelt op goed."

How could this design influence the social situation in an office?

"Ik kan me wel voorstellen dat mensen hierop afkomen, het is nieuw, ziet er interessant uit, en zeker als je weet wat erachter zit kun je zelfs nog wat leren over elkaar."

"Het lijkt me wel interessant om te zien wat er gebeurd als je op basis van deze informatie mensen gaat samen plaatsen, werkt dat goed, gaat dat juist botsen?"

"Dit is zeker wel gespreksstof, maar aan de andere kant zie ik dit ook nog wel fout lopen, het verschil tussen introverte en extraverte mensen kan hierdoor wel heel erg duidelijk worden."

"Ik deel een kantoor met 3 andere mensen, maar alsnog is het eerste wat ik doe als ik binnenkom, de verwarming op een lekkere stand zetten voor mezelf. Ik denk dat dit plan mogelijk wel positief kan bijdragen aan de sociale flow, maar misschien nog wel meer negatief, door verschillende voorkeuren die nu opeens wel heel duidelijk naar voren komen"

How could this design influence well-being for office workers in an office?

"qua welzijn zal het wel een goede toevoeging zijn, tenminste als het klopt wat je net allemaal uitlegde."

"Als hierdoor de temperatuur enzo ook echt beter in de gaten gehouden kan worden, en er ook op gehandeld wordt, ja dan zal het zeker wel een impact maken."

"Voor mij is het een beetje de vraag hoeveel hier daadwerkelijk mee zal gaan gebeuren, het idee erachter is goed, maar als ik mijn collega's ken, dan weet ik niet of die de tijd zullen nemen om zich hier daadwerkelijk mee bezig te houden. Het is al zo druk op kantoor."

"ik zelf zou het op zichzelf al wel fijn vinden om wat meer te weten over de plek waar ik werk, nu kost me dat heel veel moeite, maar met zon apparaat zou dat wel een stuk makkelijker worden ja."

Extra Comments:

"Heel modern ontwerp, het trekt zeker de aandacht van mensen die het nog niet kennen"

"Het is erg interessant om te zien hoe mijn mening compeet anders is dan dat dat apparaat adviseert. Ik heb het bij zulke temperaturen door een open raam nog totaal niet koud en hij zegt al dat ik aan het bevriezen ben. Leuk detaill, dat is misschien wel iets om meer mee te doen."

"Hoewel ik het wel interessant vind om te weten, weet ik niet hoelang die wetenschappelijk adviestemperatuur relevant blijft. Zodra je dat eenmaal weet, veranderd die data niet meer, en zou je het wel af kunnen met die andere visual voor mijn gevoel."