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Methodology to develop interfaces to help office users better understand control strategies of climate systems

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SAMENVATTING

Om onze klimaatdoelstellingen te halen, maken we gebouwen steeds slimmer. Slimme regelingen gekoppeld aan sensoren en aangestuurd door algoritmes proberen onze kantoren zo energiezuinig mogelijk, en het binnenklimaat comfortabel en gezond te maken. Ondanks al deze regelingen willen kantoormedewerkers hun werkplek kunnen aanpassen aan hun eigen behoeften. In de praktijk zien we dat dit tot conflicten kan leiden: Bewoners begrijpen niet wat het systeem doet, weten niet altijd hoe ze moeten ingrijpen, zijn zich vaak niet bewust van de gevolgen van hun acties en ondernemen daardoor regelmatig contraproductieve acties. In het project Brains4Building onderzoeken we hoe we de interactie tussen gebouwsystemen en gebruikers kunnen verbeteren. Het doel is om slimme gebouwen en gebruikers beter te laten samenwerken, zodat ze samen zorgen voor een efficiënt, comfortabel en gezond gebouw.

Om dit te bereiken hebben we een methode ontwikkeld waarmee we immateriële gedachten, wensen en behoeften van gebruikers van kantoorgebouwen kunnen vastleggen, die we zullen gebruiken voor de ontwikkeling van meer gebruikersgerichte interfaces. Deze gebruikersgerichte interfaces bevatten feedback van het systeem aan de gebruikers die hen zal helpen te begrijpen wat het systeem doet en wat ze effectief kunnen doen als ze zich ongemakkelijk voelen.

De methode die wij hebben ontwikkeld, inclusief de resultaten na het testen van de methode, worden beschreven in het eerste deel van deze deliverable in de vorm van een conferentiepaper dat werd gepresenteerd op de Healthy Buildings Conference in Aken (Duitsland) in juni 2023. Een kopie van dit document is in dit verslag opgenomen.

De methode (die in de paper wordt beschreven) resulteerde in clusters die de basis vormen voor het interfaceontwerp. Deze clusters categoriseren de immateriële gedachten, wensen en behoeften van de bewoners. De clusters zijn weergegeven in paragraaf 3.2 van de paper. Op basis van deze clusters hebben wij een reeks ontwerpvragen ontwikkeld, die de feitelijke input vormen voor het interfaceontwerp in de volgende stap van het project. Aangezien deze stap na het schrijven van de paper is uitgevoerd, hebben wij deze ontwerpvragen als bijlage bij deze deliverable gevoegd. De doelgroep voor de ontwerpvragen is het team dat betrokken is bij taak 3.4 van het Brains4Buildings project.

SUMMARY

To meet our climate goals, we are making buildings increasingly smart. Smart controls linked to sensors and driven by algorithms try to make our offices as energy efficient as possible and the indoor climate comfortable and healthy. Despite all these controls, office employees want to be able to adjust their workplace to their own needs. In practice, this can lead to conflicts: Occupants don't understand what the system is doing, don't always know how to intervene, are often unaware of the consequences of their actions and, therefore, regularly take counterproductive actions. In the Brains4Building project, we investigate how to improve the interaction between building systems and users. The goal is to make smart buildings and users work better together to provide an efficient, comfortable, and healthy building.

To achieve this, we developed a method to capture office building users' intangible thoughts, wishes and needs, which we will use to develop more user-centric interfaces. These user-centric interfaces will contain feedback from the system to the users that will help them understand what the system does and what they can do if they are uncomfortable.

The method we developed, including results after putting the method to the test, is described in this deliverable as a conference paper presented at the Healthy Buildings Conference in Aachen (Germany) in June 2023 (Annex I). The method (that is described in the paper) resulted in clusters that form the basis for the interface design. These clusters categorise the occupants' intangible thoughts, wishes, and needs. The clusters are given in paragraph 3.2 of the paper.

Based on these clusters, we developed a set of design questions, which form the input for the interface design in the project's next step. Since this step was performed after the paper was written, we attached these design questions as Annex II to this deliverable. The target group for the design questions is the team involved in task 3.4 of the Brains4Buildings project.

ANNEX I: HEALTHY BUILDINGS 2023 CONFERENCE PAPER

Methodology to develop interfaces to help office users better understand control strategies of climate systems.

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Abstract. To meet our climate goals, we are making buildings increasingly smart. Smart controls linked to sensors and driven by algorithms try to make our offices as energy efficient as possible and the indoor climate comfortable and healthy. Despite all these controls, office employees want to be able to adjust their workplace to their own needs. In practice, we see that this can lead to conflicts: Occupants don't understand what the system is doing, they don't always know how to intervene, are often unaware of the consequences of their actions and therefore regularly take counterproductive actions. In the Brains4Building project, we investigate how to improve the interaction between building systems and users. The goal is to make smart buildings and users work better together, so that together they provide for an efficient, comfortable and healthy building. To achieve this, we developed a method that allowed us to capture intangible thoughts, wishes and needs of office building users, which we will use for the development of more user centric interfaces. These user centric interfaces will contain feedback from the system to the users that will help them understand what the system does and what they effectively can do if they are uncomfortable.

Keywords. Feedback, interface, office climate systems, user centred design, co-creation.

1. Introduction

1.1 Background of the study

The climate systems in offices become more and more complex. The use of data and sensors for smart and automatic control of the indoor climate becomes more common. The aim is to save energy while improving the indoor comfort and respond more flexible to optimize the use of renewable energy that is not available at all times. The introduction of the Smart Readiness Indicator (SRI) by the EU shows strong reliance on digitalization in making buildings sustainable (Fokaides et al., 2020). One of the consequences of this digitalization of the climatization of buildings is that they do not necessarily make it more easy for users to play a role in this process, while this role is of the utmost importance to adapt the climate in an office to the user's needs (Schweiger et al., 2020; Yang et al., 2018; Day & O'Brien, 2017). Ideally the smart climate system can provide a good indoor climate for its users. However, it is obvious that in reality there is a clear need for user interaction, because indoor comfort depends on too many factors that cannot and are not all monitored, including physical building parameters, but also clothing and activity level and the user's psychological state (Karjalainen, 2013). Simply providing local controls is not going to solve the issue. Karjalainen & Koistinen (2007) for instance show that although local controls for temperature are commonly available in offices, the users are often still dissatisfied with their thermal comfort and control options.

1.2 Aim of the study

As part of the Brains4Buildings project (https://brains4buildings.org), we are studying how to give the user a more central role in the climate control of buildings. The hypothesis is that office building users are more satisfied with the comfort in their workplace if the climate system decides more with them than about them. Therefore in this research we aim to find what features the interfaces of climate systems should contain, that help these systems to better interact with the building users. In other words: what relevant feedback can help end users accept and understand complex control strategies so that together they can provide for an comfortable and healthy building, to reduce complaints and increase energy savings.

To examine this, we developed a methodology using cultural probes, co-creation and synthesis of the data via affinity mapping and applied this method to a selection of building occupants of five offices in the Netherlands.

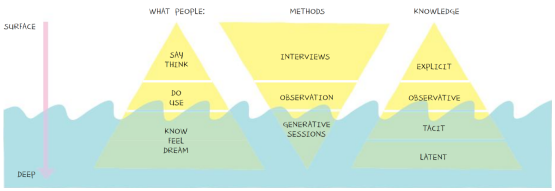
2. Method

To design interfaces for building occupants to interact with the building system, we chose a participatory approach to learn directly from the occupants about their (latent) knowledge and needs regarding climate system use. In this research, generative methods were used to help people express their thoughts. This implies a playing field in which the participants have a more active role and are more equal to researchers, in contrast to a more traditional, research-led approach in which researchers merely inquire from the users.

In their Convivial Toolbox, Sanders and Stappers (2012) explore the way in which saying, doing and making can bring to light tacit and latent knowledge about the design context of the user (**figure 1**). In our research, building occupants were asked to use their own work environment as they normally would (do), create artefacts related to that context (make) and explain or describe what they had observed, made or done (say). Using these three elements in tandem enhances the insights we gathered, and enabled participants to make tangible what they could otherwise not describe easily.

Figure 1

Accessing different levels of user self-knowledge through observational and generative methods (say, do, make) (Sanders & Stappers, 2012)



Exploring these intangible thoughts, wishes and needs of the occupants is especially useful at the start of a design process. Here, there are still a lot of unknowns about the user and their context. And surprising, ambiguous, and inspiring input created directly by occupants ideally sparks new directions for the design of interfaces.

However, this method of generating input from users in a creative, convivial way is not something that many people are used to, or open towards. Special consideration had to be taken to design the activities in such a way that they were accessible and fun, providing enough guidance to the participants, as well as freedom to express themselves.

Our approach consists of 3 steps with accompanying methods. First, we *sensitize* the participants through cultural probes. Then, participants *ideate* in a co-creation session. Finally, we *synthesize* our findings using *affinity mapping*.

2.1 Participants

We recruited participants from buildings among three of our project partners, as well as from our own organisations. The project partners are universities, knowledge organisations and companies in the building management system domain. We provided an information brief detailing the research activities and contacted partner representatives to recruit participants from their buildings for us. Our inclusion criteria consisted of people who regularly work in the same building, with a wish to include employees and staff of different functions. Although we hoped this would alleviate some of the bias of climate technology knowledge present in our population, they still represented the bulk of our participants. With input from the participants, a date for the co-creation session was then picked from several options.

One of the universities did not manage to find participants in time. In five buildings, 37 total participants were recruited. Of these, we collected 160 completed probes, and hosted a total of 23 participants in our co-creation sessions.

2.2 Sensitizing through cultural probes

Sensitizing activities stimulate participants to think about, reflect and explore their own context and behaviour through performing small tasks and exercises related to the questions or field researchers are interested in (Sleeswijk Visser et al., 2005).

For this research, we use *cultural probes* as our sensitizing tool. Cultural probes are kits with assignments that are distributed to participants and tailored to the use context. Cultural probes were originally conceived to be a source of inspiration and a novel way to open a dialogue between designers and elderly people (Gaver et al., 1999).

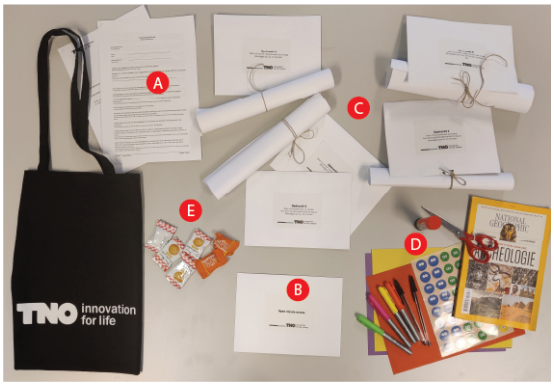
Since then, the approach has been adopted by several industrial and academic research and design groups around the world (Gaver et al., 2004). Examples can be found in the fields of child care (Riekhoff & Markopoulos, 2008), domestic technology use (Wyche, 2020), assistive healthcare (Brown et al. 2014), education (Spiridonidou et al., 2010) and in the museum context (Lange et al., 2019).

Unlike traditional methods that deal with self-reporting and ethnographic research, the design of cultural probes requires special care towards making the contents more open-ended in nature. This provokes participants to think for themselves and supports self-reflection, while also allowing the process itself to be user-centred with little direction from the researcher involved. This is further enforced by the fact that participants work with the probes in their own time, over longer periods and directly in the relevant context of use and without prying eyes from

observers and researchers. In practice, a balance needs to be found between the open-endedness of the contents, while also staying within reasonable distance of the research topic. As Wallace et al. (2013) remark, "*Probes are part-made objects explicitly awaiting closure, which offer a participant both openness to share whatever she feels appropriate and clear boundaries to respond within.*"

Figure 2

The probe contents were designed to fit in a tote bag and included an informed consent form (A), an introduction envelope containing a brief explanation and instruction marked read me first (B), five envelopes with creative assignments (C), creative materials to use with the assignments (D), and some chocolates and treats (E).



When first receiving the probe, a participant unpacks the bag and finds the instructions envelope. The instructions explain the general goal and idea of the probe. Five numbered envelopes are physically tied to different types of assignments; one for each day. The envelopes have visible clues of to the expected time required (around 10-20 minutes) and suggested time of day to open. Several materials such as scissors, glue, stickers, magazines and coloured pens were included to help with these assignments. Treats were included as a small reward for completing assignments. For an overview of the probe's contents, see **figure 2**.

The assignment in the first envelope presents an empty floor plan onto which the participant uses coloured stickers to mark the places in the building where they had been during the day, and the corresponding levels of climate comfort experienced.

In the 2nd envelope, the participant is asked to provide a diary of a working day using a template consisting of timeslot, location, climate comfort level and additional notes.

The 3rd envelope yields a template of a person in a circle. The participant may then think about the things that influence climate comfort, and if these things lie inside or outside their 'circle of control'.

Envelope 4 builds on the previous template, inviting the participant to think about their actions regarding their climate comfort inside the circle, as well things they wish they could do outside the circle (see **figure 4** for an example of a result).

The 5th and last envelope contained an empty canvas. The participant use the magazines and other materials in the bag to create a visual collage representing an ideal indoor working climate (see **figure 5** for an example of a result).

Because participants reported to often work part of the week from home, we gave them two weeks to complete the assignments on the days they worked at the office, after which we would collect the probe.

While the probe was primarily used as a tool to sensitize and prime the participants for further ideation, we also wanted to use the material as an inspiration source for design. Therefore, in the follow-up ideation session, we briefly asked participants to present and talk about their generated content. This allowed a group discussion, which gave us insights to how the participants approached the subject.

Including participants in the discussion and analysis of the probes also caters to some of the criticism of a lack of user-centred focus in the very first iterations of cultural probes (Mattelmäki, 2006), in which the participant explanation was intentionally avoided to use the probes' ambiguity as inspiration by designers.

2.3 Ideation through co-creation

The next step was to engage participants in a co-creative ideation session. While we asked them to come up with ideas and solutions during the session, our focus was on the underlying reasoning and motivation behind their wishes for the building system. Again, we employed fitting techniques to have participants make, do, and say to elicit conversations about intangible, latent knowledge (Sanders & Stappers, 2012).

We designed the session to take place in 2 hours to maintain a reasonable level of attention from all participants. Within these 2 hours, we defined 4 steps.

Step 1: Revisiting the probe and design context. After a short explanation of the research and the ideation session, we visited one of the office spaces of at least one of the participants. There, we asked them to show how they usually interact (or don't interact) with the climate controls. Then, all participants were asked to describe the collage they had made (day 5 of the probe kit).

Being in the physical context supported participants' recall of their own behaviour in detail and helped us and other participants to articulate their needs and struggles. Participants engaged in the conversation,

providing insight into their behaviour, routines and needs. Some stated that filling in the probes had helped them get sensitized to their own behaviour and context, saying: *"I wasn't aware there was a remote to control the light temperature. Filling in the probes got me talking to a colleague, who told me about those controls."*

Step 2: Design challenge. After visiting the workspace, the group defined needs and situations that were shared amongst the building occupants. One of the situations was chosen to define a design challenge. To keep the challenge constrained within the scope of our research, we focused the challenge on feedback from the system to the occupant and the other way around. For example: *How can occupants be made more aware of their options to assert control over their climate comfort?*

Step 3: Ideate solutions. First, the group defined relevant actors that influenced the situation in some way (e.g. occupant, air conditioning unit, windows, wall display, thermostat). In line with Latour's Actor-Network Theory (2007), we consider actors as elements with agency that can be either human or non-human. Each participant then took on the responsibility of one actor and was asked to come up with a solution on how their actor could contribute to the chosen challenge.

Participants were provided with a wide range of materials to create tangible prototypes of their ideas. Materials included paper, cardboard, magazines, spices, LEGO bricks, fairy lights, videogame controllers, glue, ribbons and stickers (**figure 3**). These were chosen to inspire participants to go beyond writing down their ideas (say) and instead make their solutions tangible in other ways (make and do). We provided unexpected objects such as the videogame controller to further spark participants' creativity.

We use ideation as a stepping stone to articulate ideas and facilitate discussion. As such, it is not the designed solutions that are the main interest here, but rather the rationale behind them and the reactions they spark. In this light, we assured participants that they had the freedom to envision an ideal solution, and not worry too much about technical or practical feasibility.

Step 4: role play. Finally, participants were asked to play out the solution for their actor in a roleplay setting. One of the researchers acted as a building occupant, while participants positioned themselves and their prototype interfaces in the room. The 'occupant' would enter the workspace, playing out the scenario. They thought out loud to provoke feedback or interaction with the different actors, for example: *"My co-worker just arrived by bike and now we're struggling to find a comfortable temperature for both of us."*

Figure 3

A collection of materials provided to aid the ideation process of participants.

2.4 Synthesis

To make sense of the qualitative data that was gathered during the sensitizing and co-creation activities, we held a half day-long affinity mapping session to code, categorize and cluster all our findings. Affinity mapping is a data-driven approach that aims to gain insights by letting the data speak for itself, rather than trying to verify predetermined categories or answer research questions directly (Beyer & Holtzblatt, 1999).

We used the raw data from the completed probes and our minutes from the co-creation sessions to create over 200 sticky notes, such that every note would hold one single quote or piece of data.

Next, we started placing notes on the wall based on their relation towards each other and our personal associations with the data (see **figure 7**). During this step, we specifically did not try to explain our rationale to each other to gather new insights and recognize patterns, rather than finding the best fitting match.

When all notes were placed, we engaged in open discussion to clean up the wall, eliminating duplicates, splitting larger clusters, and identifying broader themes and connections.

3. Results

The method as described in section 2 was applied to five office buildings. The buildings included an older buildings with limited control, several buildings that were renovated some time ago or more recently, and a relative new building with high end control.

The results of the study contain the work group assignments (cultural probes), the co-creation results and the results of the affinity mapping.

3.1 Raw data

The outcomes of the work group assignments (cultural probes) and the co-creation session could be seen as the raw data and as such intended as input for the final analysis: the affinity mapping. It is interesting to see some of the products the participants of the study produced, since it shows the diversity in output. **Figure 4** and **figure 5** provide examples of the contributions that participants made to two different working group assignments: one in which they were asked about what influences their comfort in their work place, and one in which they were asked to make a collage in which they showed what a good indoor climate means to them.

Figure 4

Example of the working group assignments made by a participant in which they were asked: "What influences your comfort in your workplace and what do you have control over?

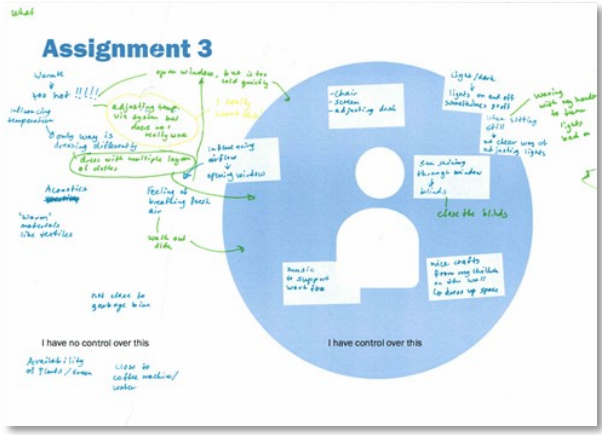


Figure 6 shows one of the creations made during the co-creation sessions in which the participants were asked to show for a part of the climate system how that system can communicate its operation to its users, so that the users understands what it is doing and can make informed adjustments.

3.2 Synthesis results

To make sense of the raw data from the cultural probes and the co-creation sessions, the data were clustered using affinity mapping, as described in section 2. For the affinity mapping statements made by the participants on (or with) the working group assignments and during the co-creation sessions were used. This resulted in more than 200 sticky notes with statements made by the participants, also see **figure 7**.

The result of the clustering process during the affinity mapping is shown in **table 1** and includes the categories formed by the researchers according to the method described in section 2. The titles of the categories were based on the typical content of the clusters. Examples of this content are also given in the table.

Figure 5

Example of a working group assignment made by a participant in which they were asked: "What does a good indoor climate mean to you"

Figure 6

Example of the creations made during the co-creation sessions

Figure 7

Overview of the sticky notes used in the affinity mapping; picture of the final result after the clustering

Table 1

Result of the affinity mapping: final clustering

Clusters

Examples of statements
Colleagues seek consensus
"There is mutual agreement among colleagues to lower / raise the blinds", "Can the interface mean anything in the case of conflicts between roommates ?"
Users experience different indoor climate 'zones'
"It depends how warm the area is where I'm sitting, whether I'm on the left or right side of the floor", "There are different levels of control for the sun shading based on settings"
Users experience problems with local air
"The air is not completely fresh in every room and floor", "User long for good air flow"
Shading has conflicting effects on users
"Priorities differ between wanting daylight and sunlight getting on the screen", "I don't want the building to decide for me if I should have sun at my workplace"
Users want to know what to do/don't do
"Do not open the window when the radiator is on", "what does that [number on the dashboard] actually mean? What is ideal?"
Users want to know why
"Users want to be made aware of a decision the system makes and what it is based on", "What causes the blinds to close doesn't really make sense to me."
Users want to set up a personal workplace
"Wants to personalize office", "I want a clock"
Building forces user to stand up for their interests
"Users sometimes forget to open the blinds, they then stay closed all day", "Users find it cumbersome to control every action through their phones"
Climate system can be anticipatory to the user
"I would like the blinds to be down automatically before I come in in the morning", "I want settings linked to my calendar"
User wants to have the last word
"The system should decide how, but I want to be able to override it.", "Users want (a feeling of) control"
User must be adaptive
"I have to turn around when the lights go off", "I have to move my head to avoid being blinded by the sun"
User wants manual climate control
"Wants ability to influence system", "The simple analog system of the blinds is very convenient, can the other systems be the same?"
You can keep controlling, but it will never be perfect
"Indoor climate is never perfect: just keep calm & go on", "Trial and error is not sustainable"
Users experience that their actions have no effect
"The buttons on the wall panel don't seem to be doing anything", "I have no trust in the app", "the remote does not work and/or is unpredictable".
The climate control must be in a convenient place
"the display is located at the workstation on the desks", "physical panels with adjustable buttons instead of an app",
Users experience daylight as pleasant
"users long for daylight", "a lot of light is nice"
Noise pollution affects climate control
"I think the ventilation system is too noisy", "I often set the temperature low to avoid noise from the system: rather quiet than hot"
Comfort is not only determined by indoor climate
"I want a place where I can be inspired to think better and solve problems", "want to be close to nature", "users long for flexible environment"
Users seek homeliness
"inviting office", "users find cosiness important"
Users experience restrictions from the system as challenging
"If it's windy you can't use the blinds", "a blue light on the window switch indicates it can't be opened"
Users want an active role in the learning process of the system
"make sure to report your preferences and the system will learn", "the system could learn your range for comfort"
Users want a constant temperature
"I feel the temperature is very unpredictable and not constant", "I need a constant temperature"
Users want greenery/plants/nature
"I want to look outside / green", "users long for

plants"

Users want to experience fresh air

"users find smell important", "want healthy/purifying/fresh air"

4. Discussion

The clusters that result from the affinity mapping form the basis for the interface design. They categorise the intangible thoughts, wishes and needs of the occupants. Of course there are many different users with many different needs and wishes, so each cluster will not necessarily apply to all users. The same applies to the buildings and the climate systems in the buildings: also these are different everywhere and that too can lead to different wishes and needs. One of the noteworthy things we saw was that users of buildings with many automatic controls indicated that they would like to control more themselves while users of buildings without automatic controls would like more aspects to be controlled automatically. We saw this back in different clusters (**table 1**): "Climate system can be anticipatory to the user" and "User must be adaptive", but on the other hand: "User wants to have the last word" and "User wants manual climate control". This is in line with the findings of Karjalainen (2013), who found in his study that full automation is not suitable for indoor climate control and that "*decisions on the level of automation should be made carefully, taking into account the special qualities of each system without neglecting individual differences between the users.*" (Karjalainen, 2023, p.124). Different levels of automation will thus undoubtedly also lead to differences in the interface that should be linked to it.

That brings us to the question of whether the method is sensitive and reliable. The method appears to be reliable since it gives us the results we expected to get, being the intangible thoughts, wishes and needs of office building users, which we will use for the development of more user centric interfaces. Whether the method also is sensitive is more difficult to answer, since we have not tested that explicitly. To test this, we would have to repeat the method several times with different groups. While we would expect to find different clusters, we would also expect the tenor of the clusters to be essentially the same, although we cannot substantiate this without repeating the experiment. The question is whether it is a big deal if partly different clusters emerge: the method helps us to make feedback interfaces more user centered, which happens when we ask users for input. At this stage, it is not yet the goal to be generic. Given Karjalainen's (2013) findings above, it is also not possible to be generic.

Another notable finding which we also clearly saw back in the study of Karjalainen (2013) is the issue of mistrust. One of the clusters (**table 1**) states: "Users experience that their actions have no effect", which was formed out of statements from almost all buildings, such as: "*The buttons on the wall panel don't seem to be doing anything*", "*I have no trust in the app*" and "*the remote does not work and/or is unpredictable*". Another illustrative example of this finding is the following: In one of the buildings the users were very confident that the thermostat was not working: "*You can see the thermostat is put on 30°C, where it is on for months now and clearly it is far from 30°C in here, so the thermostat is not working.*" While in fact the thermostat did work, but can only adjust the indoor temperature with + or – 2°C. The design of the interface in combination with its functionality clearly can lead to mistrust, while mistrust can lead to behaviour that is less energy efficient or result in a poorer air quality (Spiekman et al., 2022).

Two other interesting clusters (**table 1**) that resulted from the study are: "Users want to know what to do/don't do" and "Users want to know why". Both connect to the idea that users like to have information about their options to improve their comfort and to be able to make informed decisions that will not interfere with other goals. This is especially important when actions can have multiple consequences, for instance sunshade controls (cluster: "Shading has conflicting effects on users", **table 1**), which influence temperature, daylight, artificial light, view and sometimes the possibility to open a window. Herschong and Day (2022, p.43) also highlighted this aspect by pointing out that "*users always benefit from information about current environmental conditions, and immediate feedback about consequences of any action they take*". They argue that this feedback will only work when it is so simple and clear that even children understand the connection, which will be an important specification for the design of feedback.

In their study on feedback messaging and thermal comfort perception, Li et al. (2019) suggested that we might use feedback to make office users think about how exactly uncomfortable they are, and to motivate them to accept thermal condition. This was also reflected in our clusters (**table 1**): "User must be adaptive" and "You can keep controlling, but it will never be perfect": users are aware that the system cannot do things completely perfect, and that sometimes you have to accept that. They also understand that they have to do actions themselves to improve their situation (e.g. sit somewhere else, or put on or take off their jumper). With the high energy prices in recent months, we have also noticed people accepting more discomfort. This will be a new discussion: do we still want to give users optimal

comfort at all costs or are we going to ask users to accept more discomfort, for instance by using the above mentioned feedback messaging studied by Li et al. (2019).

Another outcome from the clustering that is worth mentioning is the cluster (**table 1**): "Comfort is not only determined by indoor climate", which relates to the cluster: "Noise pollution affects climate control". In the introduction we already argued that there are too many factors that determine comfort which can never all be monitored and controlled (Karjalainen, 2013). We saw here that users are aware of that and indicate that their actions are motivated by other things than thermal comfort alone, such as noise pollution, glare, wanting to be in contact with the outside, feeling fresh air, etc. It is clear that priorities also can differ among users. Therefore users hope that a user centered designed interface might even help to solve conflicts between roommates when this happens (cluster: "Colleagues seek consensus", **table 1**). This is an interesting challenge for the next phase of our research.

5. Conclusion

The study resulted in a method that allowed us to capture intangible thoughts, wishes and needs of office building users, which we will use for the development of more user centric interfaces. The next step of the study will be to translate the clusters into a program of specifications and a functional design of specific interfaces. Then, together with manufacturers, we will further develop and test these interfaces in living labs, using an iterative design approach, to see whether the interfaces do indeed better meet the needs and wishes of office users.

6. Acknowledgements

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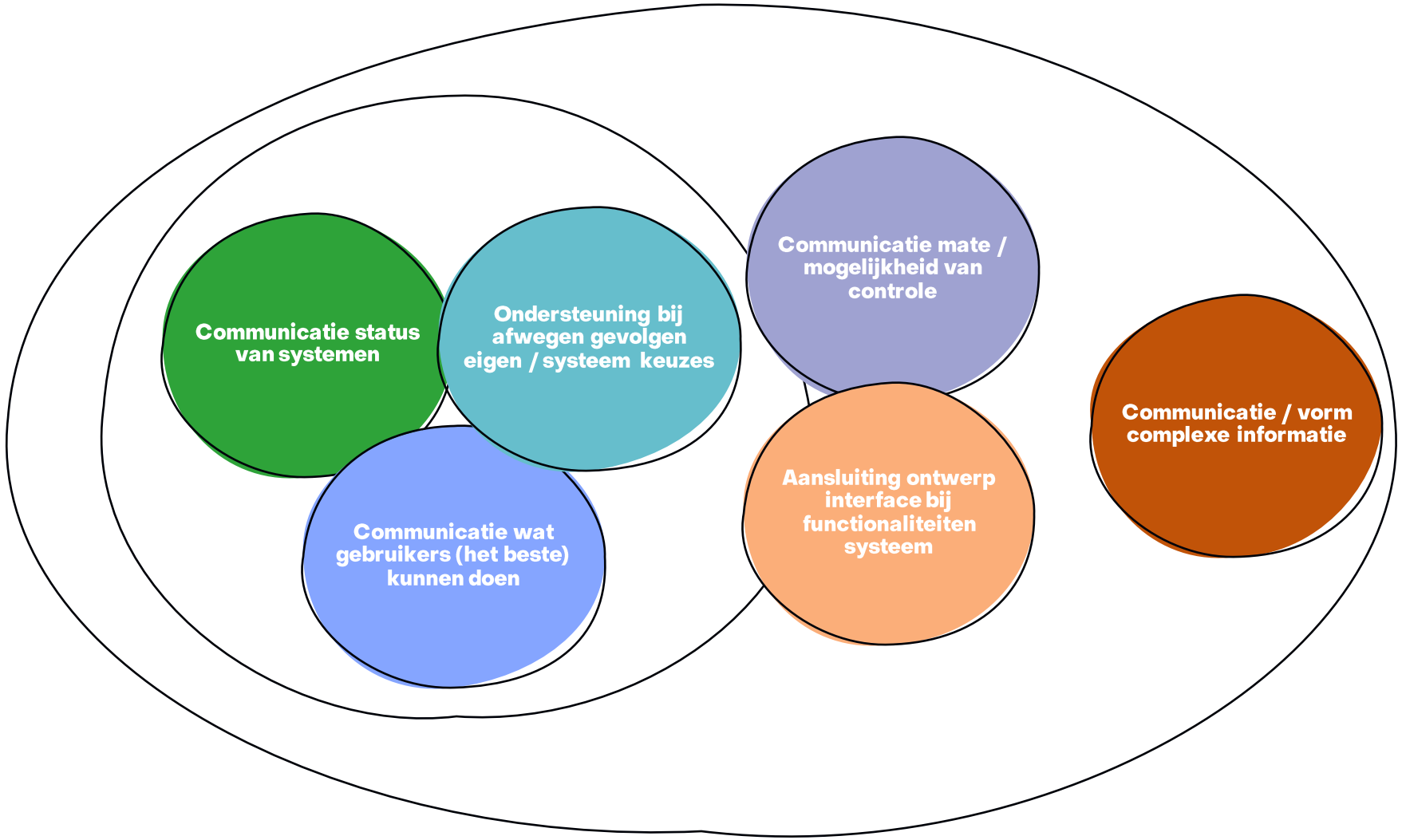
ANNEX II– DESIGN QUESTIONS

Clusters ontwerpvragen



Status

Vragen:

- Hoe communiceer je de status van de systemen?
- Hoe laat je het effect van een instelling zien?
- Hoe communiceer je dat het systeem werkt?
- Hoe kan de interface de status van het systeem laten zien, zodat gebruikers ervaren dat hun acties effect hebben?
- Hoe communiceer je het verloop in de tijd / hoe lang het nog duurt tot het eindpunt is bereikt?
- Hoe communiceer je over binnen luchtkwaliteit (bestaat uit aspecten die je als gebruiker niet / moeilijk waarneemt)?
- Hoe kan de interface de 'zones' van het binnenklimaat (en de context/redenen) inzichtelijk maken voor de gebruiker?

Waarom

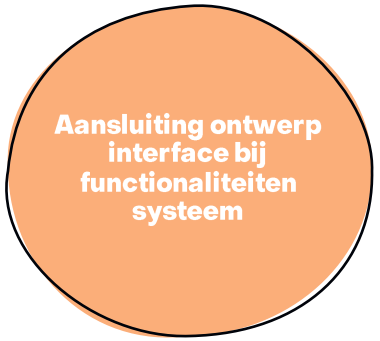
Vragen:

- Hoe kan de interface gebruikers ondersteunen bij het afwegen van gevolgen van zowel eigen als systeemkeuzes?
- Hoe kan de interface gebruikers informeren over de onderbouwing/achtergrond van systeemkeuzes/-advies?
- Hoe communiceer je waarom?

Wat

Vragen:

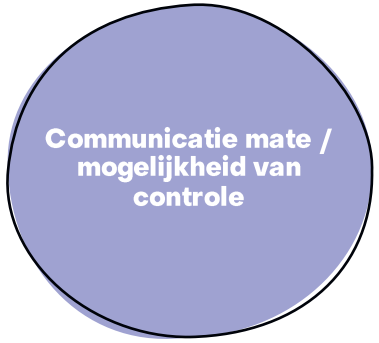
- Hoe communiceer je wat gebruikers wel / niet moeten doen?
- Hoe zorg je op basis van de feedback / informatie dat gebruikers geen conflicterende beslissing nemen?



Technische beperkingen

Vragen:

- Hoe sluit je het ontwerp van de interface aan bij de functionaliteiten van het systeem?
- Hoe geef je de gebruiker een weloverwogen laatste woord?



Controle

Vragen:

- Hoe zorg je ervoor dat de gebruiker de controle kan nemen (dat de gebruiker het begrijpt)?
- Hoe kan de interface ervoor zorgen dat de gebruiker systeemkeuzes kan verwerpen?
- Hoe communiceer je over de laatste woord vs. automatic control? Welke stand, hoe lang, etc.
- Hoe kan je opkomen voor belangen laagdrempelig maken?
- Hoe kan het system pro-actief zijn?

Hoe (algemeen)

Vragen:

- Hoe communiceer je complexe informatie?
- Hoe ga je om met de veelheid aan informatie?
- Hoe vaak wil je weten waarom?
- Is de informatie direct toegankelijk / moet je ernaar zoeken?
- Hoe kan je meerdere gebruikerstpye bedienen?
- Hoe frame je de boodschap (niet mogen /advies/ overwegingen)?
- Hoe communiceer je naar de gebruiker zodat hij durft in te grijpen? (positief / negatief benaderen)
- Hoe zorgen we ervoor dat het systeem als laagdrempelig wordt ervaren en gebruikers niet afschrikt?
- Welke plek is optimaal voor de interface?