

Thermal aware design: Design with temperature traces

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1 ABSTRACT

Our research project is about the future of home energy. Temperature regulation impacts household energy consumption. However, it is currently approached with uniform solutions, such as setting one temperature for an entire house with a thermostat. With this exploratory research project, an alternative approach is proposed. The collective house temperature is broken down into its small contributors; temperature traces. Based on the qualitative data collected by the cultural probe kit, our result views the occurrence of temperature traces based on four interconnected perspectives: location, object, individual, and social perspective. We incorporated the perspectives into a new approach called Thermal Aware Design Model (TADM) to better assist the design community. While emphasizing personalized experiences for temperature regulation in communal living and the collection of qualitative data from the users, TADM simplifies the analysis process of qualitative data and clarifies the relationship between thermal-related design and the complex needs of communal living residents.

2 INTRODUCTION

2.1 The ongoing energy crisis and its innovative solutions

In the past decades, heat has been the most prominent application among energy consumption in the Netherlands, representing a substantial portion of household energy use[1]. Despite technological advancements and increased attention towards sustainability, current methods of home temperature regulation often employ a one-size-fits-all approach, such as setting a uniform temperature for the entire house via a thermostat [23]. However, this traditional approach overlooks the interactions between various contributing elements within a household. It mainly looks at the 'techno-hedonist' perspective[5]. By letting an intelligent agent make these decisions would lead to mistakes due to the social complexity not being taken into account[21]. For the purpose of this study, the resulting small contributors to temperature change are called Temperature Traces. They bear significant implications for designers, allowing for a more thermally-aware design and creating new opportunities for innovation around in-depth personalized temperature-related solutions. Unfortunately, they are incompletely considered in conventional energy management strategies, contributing to energy inefficiencies and overlooking opportunities for optimization. Hence, this highlights a critical problem: the existing methods of household temperature regulation are overly simplistic and do not account for the complexity of temperature traces. The need to address this issue becomes even more pressing in light of our growing climate challenges [15] and the imperative to transition towards more sustainable, efficient energy practices.

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2.2 The temperature traces in the communal living environment

In this design research paper, the initial focus was on exploring the dimensions and complexity of temperature in shared student homes, specifically investigating temperature traces. To gain deeper insights, an exploratory research approach was adopted, employing multiple methodologies including first-person perspective and cultural probes. The cultural probe kit study enabled participants to engage in activities and document their temperature-related experiences. The kit design was based on the sub questions such as identifying the locations of temperature traces in shared households, understanding the feelings associated with these temperature traces, examining the role of materiality in shaping temperature traces for shared household inhabitants, exploring the influence of participants' practices on temperature traces, investigating the impact of social aspects on temperature traces, and identifying the skills required to effectively utilize temperature traces. This method allowed for engaging participants and capturing their experiences and insights regarding temperature traces in communal living environments.

2.3 The shift in the study

The findings from this study unexpectedly shifted the research direction, leading to a new research question: "How can the approach to temperature in communal student homes be enriched in relation to temperature traces?" This change was driven by the insights obtained through the probing method[18], emphasizing the importance of exploring novel perspectives and potential avenues for improving the temperature experiences of students in shared living environments. The research continued to investigate the possible implications of the findings in light of design methods, using the core elements of temperature in a communal living environment and delving into non-conventional methods of adjusting the temperature from the perspectives of home inhabitants. Those findings underline the proposed terminally aware approach to home design.

3 RELATED WORK

3.1 Persuasive technologies sustainable behavior

While the academic community has widely explored persuasive technologies for promoting environmentally friendly behaviors. These technologies simplify complex behaviors around energy use[4]. Their focus lies on the provision of information[3], expecting informed individuals to make rational, environmentally friendly choices. In contrast to Gustafsson and Gyllensward's work on ambient technologies[12], this research seeks to understand the experience of temperature without explicit persuasion. This adds a new dimension to the study of temperature and energy consumption, offering an alternative approach that emphasizes context-specific understandings. Our paper aligns with research emphasizing personalized models and context-specific approaches [9] [13]. This enriches the academic discourse with a unique perspective, capturing nuanced and individualistic temperature experiences without relying on persuasion. It enables a deeper understanding of thermal awareness.

3.2 Occupants' behavior and energy consumption

Zhu et al. [33] investigated the energy consumption patterns and social dynamics in shared living environments, such as college student residences. The researchers found that descriptive norms, or the actions of other group members, had the greatest impact on individuals' energy-saving behavior in shared spaces, while direct feedback or suggestions had minimal influence. Although this study provides valuable insights into the unique aspects of shared living environments and the role of group dynamics in influencing energy-saving behavior, it does not directly address

the role of temperature traces in energy preservation, the potential applications of these traces in communal living settings, or explore future possibilities.

The importance of occupants' behavior in energy consumption has been highlighted in previous research, such as the work by Yun and Steemers [6], who studied the impact of occupants' behavior on energy consumption and indoor thermal comfort in residential buildings. From research, they also highlight that many areas had an impact. Though this is from a building perspective and just an energy perspective. It was highlighted that social and personal aspects are overlooked by the research community. Our research builds on this. Elizabeth Shove and Gordon Walker [29] also argued that research about energy lacks social complexity. Research in this area is still slim. By looking at temperature with a social aspect our research builds on this insight.

3.3 From a homogeneous home to a 'heterogeneous home'

Related to our view on temperature is the approach from Aipperspach, Hooker, and Woodruff [2]. They extensively investigated and criticized the increasing homogeneity of the domestic environments. The proposition of the 'heterogeneous home' concept is the key contribution of the article and their envisioned domestic environment. However, heterogeneity in temperature change is not mentioned as one of the elements to create heterogeneity. With our insights, this could be implemented in this 'heterogeneous home'.

3.4 Thermal comfort models

Research on thermal comfort models offers insights into human metabolic heat and its implications for energy consumption in residential buildings. Zhu et al. [34] reviewed thermal comfort models that consider human metabolic heat, providing a foundation for understanding. They found human body produces enough heat to warm up a room. Nicol and Humphreys [25] discussed the concept of adaptive thermal comfort, which is influenced by occupants' behavior and can help reduce energy consumption in buildings. These insights are mainly focused on improving the 'homogeneity' of the home temperature, but create a new thermal comfort, explained by Kuijer as: 'a new temporal comfort, can then be created if instead of focusing on maintaining a standard quality of life. Changing temporal comfort is possible'[20]. From history point of view, it shows that people learn new skills and adapt their expectations continuously[22]. Thermal comfort is one of these adjustments. Though this paper does not solely focus on thermal comfort, it discussed the current skills and stories of personalized temperature changes.

3.5 Practices temperature at home

This paper is related to the findings of Kuijer, S. C. who provided an exploration of a personalized view on Dutch cooling practices[19]. In the extended work given solutions are provided [20]. While the work provided valuable insights into the design and user interaction of wearable and furniture-integrated heaters and a personal view on cooling, both focused on the resourcefulness of temperature. It also provided a social lens, though the stories are less related to mundane Dutch weather. This study is more focused on stories and the interconnections between the categories, thereby providing insights on the understanding of temperature and temperature regulation.

3.6 Material Traces

Material traces already have been previously defined by the HCI community [28]. This previous study investigated how the aesthetic and sentimental value of an object can be enriched through wear and tear, thereby fostering a deeper connection between the user and the object. The study proposed a concept product named 'Chiocciola', which allowed users to develop and accumulate

memories associated with their everyday objects. Through this study, the physical traces of material can be expanded by adding the temperature aspect to them.

3.7 Summary of related work

The related work demonstrates the importance of understanding occupants' behavior and the influence of temperature traces on energy consumption in residential buildings. However, there is a notable gap in the literature regarding the role of temperature traces specifically within communal living environments and their potential applications for energy preservation. By addressing this gap, our research aims to contribute to the broader efforts to improve energy efficiency and foster sustainable living practices in shared living environments. Along with this aim, the research emphasises a subjective perspective to the largely technical and objective focus of the existing body of work. In conclusion, our research builds upon and adds to these areas of existing work, with a focus on understanding individual temperature experiences, encouraging sustainable behavior, and examining the role of temperature traces in shared living environments.

4 METHODS

4.1 First person perspective

In our research, we employed a first-person approach, a qualitative research method that positions the researcher as the subject of investigation, emphasizing their firsthand experiences of a phenomenon [7]. This approach was adopted to investigate the practices of temperature adjustment within a communal living environment. This method allowed us to delve deep into the experiences, practices, and challenges connected to keeping warm and cool at home, providing valuable insights into the aspects relevant for our research. Recognizing the complexity and personal nature of the desired data, we decided to use a cultural probe kit (Figure 1) "a common method in design research to gather qualitative data based on participatory user self-documentation" [30]. We firstly continued with the first-person approach to explore various data-gathering techniques, such as material collection, marking objects and locations, and documenting personal experiences (A.1). These activities founded a foundation of the design of the cultural probes created.

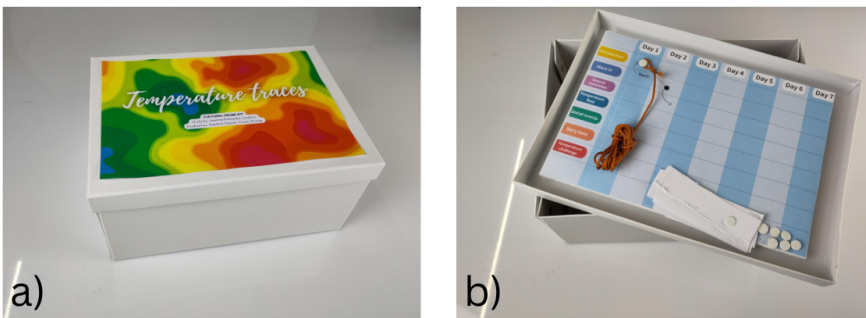


Fig. 1. Cultural Probe kit. a) Kit container, b) Journey Mapping

4.2 Cultural probe kit

The cultural probe kit was chosen as a research method. Despite several perceived disadvantages [30], such as the complexity of the gathered data, the potential for interpretation, and the inability to directly compare results, this method provided us with a comprehensive understanding of individuals' perspectives and practices within the context of their homes. Conducting the research directly in participants' homes allowed us to gain valuable insights into their lived experiences. Furthermore, it presented our team with a valuable design challenge, inspiring us to design a kit that would provide the designed insights and learn how to conduct such research.

4.3 The study

4.3.1 Participants. A total of six participants participated in the study, ensuring a sufficient sample size to obtain meaningful insights. The selection process was conducted with an intersectional approach in mind, aiming to diversify the participant pool as much as possible. Three participants were from the Netherlands, while the other three represented different countries. To further diversify the sample, the participants belonged to various academic disciplines.

4.3.2 Study procedure. The study took seven days, in order to allow participants to become acquainted with the topic and have sufficient time to provide diverse, in-depth data. Each day they were asked to complete daily maps as well as a unique task tailored to a different perspective and type of data we were aiming for, they were provided with a journey mapping tool (a visualization of the process that a person goes through in order to accomplish our study [8]) to give first-hand feedback on tasks and stay on track with the study. Later this was also used as a reflection tool. Our participants were given a set of tasks, each represented by a card set, embedded in a probe kit, which they were to complete over a specified period. Participants were asked to choose a card set each day and complete the tasks, which varied from writing observations to placing stickers on a map. While it was suggested to allocate approximately 15 minutes per day for each task, flexibility and freedom for participants was given to adapt the time-frame to suit their preferences. They had the autonomy to determine the pace and sequence of tasks, allowing for personalization in their approach. Participants were even encouraged to revisit tasks at a later time or complete multiple tasks in a day if they desired. It is important to note that, in this study, the quality of responses was prioritized over the quantity of completed tasks. Thus, providing an in-depth response to a task held greater value within the context of our research, as it allowed for more meaningful insights, rather than simply focusing on completing all the tasks. This was explained in an initial interview where initial questions about their living situation were asked and their daily map was personalized. After the 7-days a final interview was held. To let the participants further elaborate on their experience and answer some questions on their newly formed insights.

4.4 Tasks

While the form of research allowed for freedom in provided data, our focus was on tailoring the tasks to gain meaningful results, therefore the kit was designed to specific following areas of interest. Details about the creation of the tasks can be viewed in Appendix B.4.

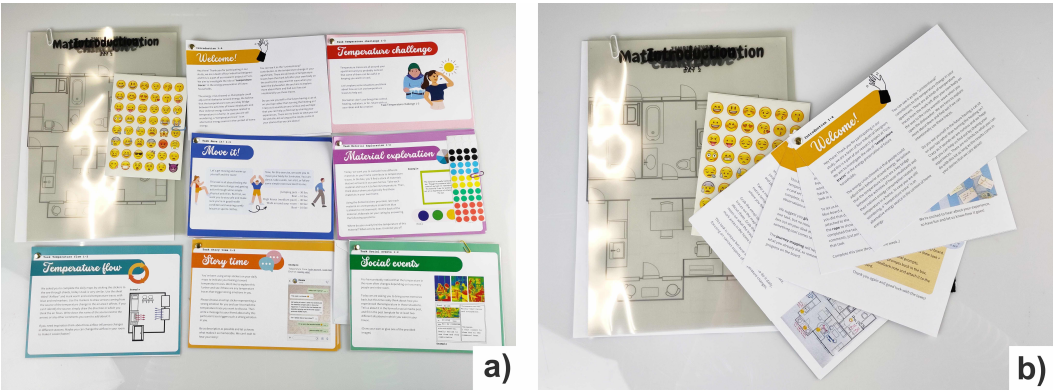


Fig. 2. Probe kit contents introduction. a) All tasks (See Appendix B.4), b) Welcome task (See Appendix B.4.1)



Fig. 3. Probe kit Daily tasks. a) Material Exploration (See Appendix B.4.4), b) Move it (See Appendix B.4.3), c) Temperature Challenge (See Appendix B.4.5), d) Temperature Flow (See Appendix B.4.6), e) Social Skills (See Appendix B.4.7), f) Story Time (See Appendix B.4.8)

5 RESULTS

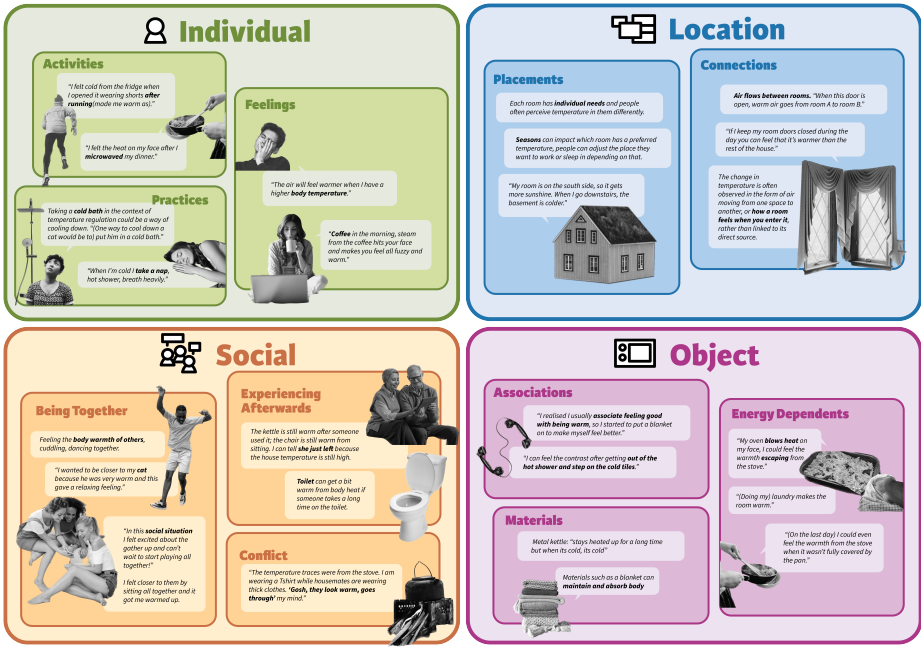


Fig. 4. The four perspectives of the probe kit results. External images are from [31](creativecommons licence)

5.1 Individual perspective

Participants reported identifying temperature traces in various practices and activities. Activities create temperature traces as a side product. Common activities include running, moving around, cooking, and drinking alcohol. For example, cooking is an activity that is approached differently by people. It is told by the participants that “I felt the heat on my face after I microwaved my dinner” and “I felt cold from the fridge when I opened it wearing shorts after running (which had made me warm)”

Practices are skills that people use to create temperature traces and support body heat regulation. For example, Taking a cold bath is suitable for cooling down, derived from one participant’s words that “(One way to cool down a cat would be to) put him in a cold bath.”).

Feelings create an alternative perception for the participants. This perception of temperature traces is an important contributor, as people can perceive the same situation differently. For example, in the context of how being in a room with people can make them feel like it is warmer or actually make the room temperature higher, derived from quotations such as “the air will feel warmer when I have a higher body temperature” and “the steam from the coffee hits your face and makes you feel all fuzzy and warm.” Additionally, associations with materials also create a difference in perception (continue at 5.4).

5.2 Social perspective

Another aspect of temperature traces is around social events. This highlights how the presence of others can change the experience of the indoor climate. These social events also include other

inhabitants for instance a cat: "I wanted to be closer to my cat because he was very warm and this gave a relaxing feeling." It was even mentioned as creating a closeness feeling for friends: "They impacted I felt closer to them because sitting all together got me warmed up."

In general, this perspective stimulates interactions and sometimes debates between roommates in communal living space, such as "it is warmer if someone is cooking while someone else is eating at the table". Discovering temperature traces left by others sometimes brings discomfort. For example, entering the bathroom when someone just showered or the toilet seat is still warm. Furthermore, shared objects, such as chairs and couches absorb body heat, creating a feeling of presence even after the person has left. ("Chairs, couches, bed, clothes are affected by my body heat", "Body radiates heat which also remains for a while after leaving the area")

For some participants, the communal area and private area are experienced differently. For one participant, there was a conflict between interests: "The shared areas were obviously warmer because people like warmth more. We also have a lot of guests so the living room is usually sweaty and warm. In my room is very cold because I like cold." For another participant, the temperature in private rooms is influenced a lot by seasonal cold climates compared to the warmer shared space.

5.3 Location-based perspective

Rooms with different functions bring various temperature expectations for the participants. Within the same day, one participant described the wind coming into the bedroom as "cold wind" and resulting "difficult to sleep well", but the participant then described the wind coming into the living room as "cool wind" and "nice and refreshing". Different attitudes towards different rooms confirmed that people may hold different expectations of comfortable temperatures in individual rooms. The seasons can influence the preferred temperature in different rooms, allowing people to adjust where they choose to work or sleep accordingly. For instance, one might choose to relocate to a different room in the afternoon as compared to the morning, based on the changing temperatures throughout the day.

Often, the shift in temperature is experienced as a change in the airflow from one space to another, or as a distinct feeling when entering a room, rather than being directly associated with its source. ("if I keep my room closed during the day you can feel that it's warmer than the rest of the house.")

5.4 Object-based perspective

Energy-consuming appliances that are not explicitly designed for heating can nonetheless influence the indoor thermal environment. ("(Doing my) laundry makes the room warm"). This occurs with computing devices, laundry machine, cooking appliances, blankets, and even mirrors. "Mirror reflects sunshine and warms the room."

Moreover, different materials provide various sensations for the participants. Interestingly, participants often described materials as "cool" if they were reminiscent of a location that is typically cool, with remarks like "makes me think of areas which have to remain cold." All participants perceived blanket material as being quite warm, attributing this to the material's ability to hold and absorb some degree of body heat ("(blankets turn) warm from my body heat"). Since materials can convey a sense of temperature, they can be effectively utilized to create or eliminate desired and undesired associations with temperature. "I realized I usually associate feeling good with being warm, so I started to put a blanket on to make myself feel better."

These material-based experiences can lead to either positive or negative associations, depending on past experience or the desired temperature at that particular moment. "I can feel the contrast after getting out of the hot shower when I step on the cold tiles." While materials may inherently be

cold, their perceived temperature and ability to hold onto heat can vary based on the environment: "It would not be very warm but because of the heat of the shower I would not mind".

5.5 Others

As demonstrated in this section, all these factors are interconnected and interact with each other. Individual experiences can vary from participant to participant. Even similar situations can lead to slight differences in experiences based on whether the entire room’s temperature was slightly adjusted or the temperature varied across the room.

These categories can influence all aspects of the same situation, for example: "In this social situation I felt relaxed and a little bit sleepy from lying on the couch. The temperature traces were mainly heat traces from everyone under the blankets. Also quite a draft from the opened window that went to the door which made the heat traces from the blankets more important. They impacted my ability to concentrate since I was either too warm (sleepy) or too cold." At times, these categories can even conflict with each other, as in the instance where tiles are typically perceived as cold but showers as warm, resulting in a conflicting sensation in the same area.

Additionally, the process of completing the kit raised awareness about these phenomena for some participants. One participant observed a change in their social behavior, noting: "I knew this but now that I am more aware I actually want to invite friends in the winter more now." Another participant remarked: "I really never thought of specific materials having an effect, it made me more aware of looking into material for temperature change," highlighting the increased awareness of the influence of materials on perceived temperature.

6 CONCLUSION

6.1 Thermal Aware Design Model - TADM

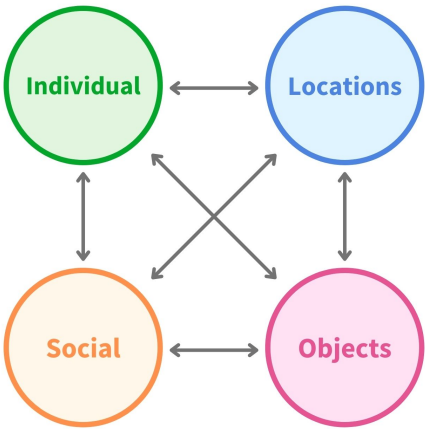


Fig. 5. Thermal Aware Design Model

The key insights from our research exploration After looking closely at our research findings, introduce a model that captures the key insights from our research exploration (Figure 5). The Thermal Aware Design Model (TADM). This model, rooted in the concept of temperature traces,

digests our understanding of how individual perceptions, social interactions, object characteristics, and location-specific aspects intertwine to shape our thermal experiences.

TADM provides a comprehensive and interconnected approach to thermal-related design. It emphasizes personalized experiences for temperature regulation in communal living and the collection of qualitative data, such as the verbal description of life details, from target users. TADM consists of four fundamental perspectives, Individual, Social, Object-based, and Location-based, and they simplify the analysis process of the qualitative data from user study. Based on the processed data, TADM helps create user scenarios with temperature changes as the key element, and eventually produce a highly-personalized user-centered design approach.

6.2 TADM Perspectives

Individual perspective: This aspect focuses on how different activities, practices and personal feelings create unique temperature traces. For instance, common activities such as cooking, running or even drinking alcohol all result in distinct temperature changes that individuals perceive differently. The perceptions of these temperature traces can be influenced by the individuals' activities, feelings and associations with different materials, leading to varied thermal experiences.

Social perspective: This perspective emphasizes how the presence of others in a shared space can influence an individual's experience of the indoor climate. Social events, communal living situations, and even the presence of pets can impact how warmth is felt and distributed within a space. For example, shared objects like chairs and couches can absorb body heat and create a feeling of presence even after an individual has left. The contrast between communal and private areas can also result in different thermal experiences.

Location-based perspective: The location perspective highlights that rooms with different functions bring various temperature expectations. For instance, the same wind might be described as "cold" when entering a bedroom but "cool" and "refreshing" in a living room. People's expectations and experiences can vary significantly depending on the room they're in, the time of day, and the season. Moreover, transitions between different spaces can create distinct thermal experiences, sometimes experienced more as a change in airflow than as a direct temperature change.

Object-based perspective: It looks at how various appliances and materials within a space can influence the thermal environment. Appliances that consume energy, such as laundry machines or computing devices, can unintentionally affect the room's temperature. Materials also play a key role, as they can convey a sense of temperature and create associations with warmth or coolness.

6.3 The interconnectivity of the four perspectives

It was noticeable that the four perspectives, individual, social, objects and locations, rarely operate in isolation in the real-world contexts. For instance, an object, such as a kettle, used to heat water may later be noticed by another person to retain residual heat. This is a combination of social and objects perspective. Therefore, interconnectivity is essential to the TADM model.

The interconnectivity of the TADM model has the following features:

- Any given perspective has the potential to be connected with the other three perspectives.
- A perspective may have a minimum of zero connections, and a maximum of three.
- The scope of this interconnectivity is confined to objects or activities within the home environment.

Through the implementation of the interconnective feature, the TADM model can now more accurately represent the intricacies of domestic activities. At the same time, it maintains clear and user-friendly categories within the model.

6.4 Application of TADM

While considering the design of shared housing, applying TADM assists in maintaining a continuous awareness of temperature traces. A new design in a form of a product or service can be placed in the middle of the diagram and connect to the proposed categories.

To give a clear example of applying TADM in real design cases (Figure 6), we assume being a designer and we have just conducted a user study, which provided us with qualitative insights. Now, we would like to bring in a new design of an armchair with the aid of TADM.

- Starting with the Individual perspective, the conventional way of sitting on an armchair by an individual person provides a seat, a pair of side armrests, and a backrest. The user prefers to rest his feet on the floor, which as we know from the collected data that it might make him feel cold. An possible design opportunity regarding temperature would be providing a feet rest piece, which would warm up the user's feet while at a lowered position.
- Continue to Social perspective, we know from the conducted study that there might be multiple people sharing the living room under the communal living context. An example of design opportunity would be adjusting the placement of the armchairs, so the chairs face each other and have a shared feet rest in the middle. This could bring the roommates closer, as they stated during the study.
- From the Location perspective, we consider that the user prefers watching TV or performing different activities in his room. Therefore, we could identify an opportunity of detaching the feet rest component form the armchair, and now put it against the wall next to the heater. This newly adjusted design would interact with the Object perspective, connecting both the object heater and the initial object armchair. This connection could open up further opportunities, such as creating a home where detachable components of the armchair is the major source of heating.

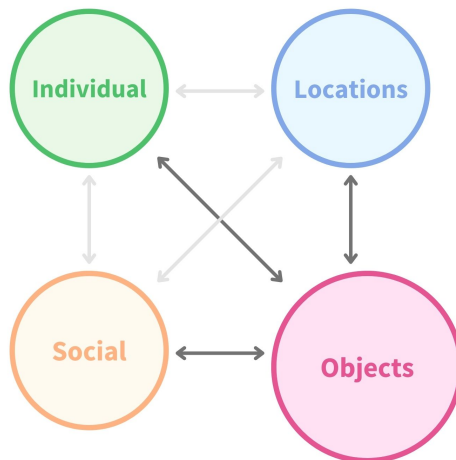


Fig. 6. Applying TADM from the Object-based perspective

7 DISCUSSION

7.1 Kit evaluation

The cultural probe kit developed for this study was designed with an exploratory intent rather than for comparative data analysis or the extraction of clear-cut conclusions, thus creating limitations. To begin with, participants interpreted the tasks differently, devoting unequal time and effort to completing the tasks. This resulted in a substantial quantity of valuable data predominantly originating from certain participants. Consequently, the attempt to represent different cultures in the sample did not attain the desired level of success. While some elements of the probe kit facilitated long narratives and meaningful insights, some did not. For instance, a "text message" to a friend was meant to clarify the emotions the participants felt about a specific temperature trace, however, the link between tasks was not clear enough to draw any conclusions. On the other hand with the airflow tasks the opposite happened, there was no room for textual explanation and therefore the data could not be well interpreted either. A learning point here is that similarly to the "social events" task there needs to be a balance between participant output and level of synthesizing in the task itself, in this specific case using temperature-related images was helpful in supporting the story.

7.2 Related work

Moreover, this research introduced a novel aspect of temperature exploration. This paper mainly builds on temperature complexity provided by related work but expanded it with tiny already existing temperature changes with a model to create a design for temperature awareness. Still, small temperature traces and complexity are not highlighted yet in research. Due to its novelty, this research could not fully build upon pre-existing studies, therefore some assumptions were made when designing the study. The initial sub-questions were formulated based on a first-person perspective study and personal experience, which could influence the results. However, it was necessary to construct the probe kit.

7.3 Results

The results articulated within this paper have been framed based on data interpretation, with an emphasis on identifying interesting results through inductive research rather than conducting a systematic analysis, which was unattainable within the scope of this study. As a result, the derived conclusions should be regarded with caution and require further research.

7.4 Employment of the study

Another contributor to the results of the study was time and location. The climate in the Netherlands impacted the results, together with the specific weather on the given week. For further development of this study, it would be advised to repeat it in different seasons, or regions as there was a diversity in results from cold and warm days. This study was conducted in spring and the results were oriented around "warm traces" there might be an opportunity to identify more "cold traces" in different weather. Additionally, expanding the study to more than 6 students would unravel more perspectives and diversity in the data. The participants all lived in shared, however different houses. The perspective of multiple people in one shared home or more individuals would depth to the findings of this study.

7.5 TADM Limitations

The above-mentioned limitations of the study reflect on the proposed TADM model. Therefore it is recommended to conduct additional user studies before applying TADM to propose personalized

solutions. However, the model relies on subjective thermal experiences, which will never be uniform for all participants. While the model offers an opportunity for addressing the complexity of temperature, it requires simplification as different individuals perceive temperature in unique ways. It should be emphasized that a generalized design strategy can not include all subjective experiences.

7.6 Research evaluation

This design research initially set out to investigate Temperature Traces and narrowed down to the implications of Temperature Traces for design. Resultantly, a deeper understanding of the acquired data and its impact on the future home was researched. However, it caused a limitation in time dedicated to improving this study in the exploration stage. While an understanding of Temperature Traces has been reached, an iteration of the Cultural Probe Kit would enable implementing insights, which is now suggested with the use of the proposed model. Additionally, the final interview was conducted too early in the data analysis stage. Which lead to a missed opportunity for follow-up insights on the data provided through the probes.

7.7 Future work

During the research many areas of temperature traces were explored, providing interesting and unexpected findings. One area that unfortunately exceeded the scope of this study was the social aspect of perceiving temperature. In this paper, it is highlighted that temperature change can be observed directly as a consequence of people being together in a room or sharing body warmth and after another person used a shared space. This results in many social implications on the level of privacy and could lead to a deeper understanding of the dynamic of a shared home. Another inspiring lead it to continue looking into the materials and how they store or relate to temperature. This research unraveled some qualities of materials to store heat on a perception level. There might be opportunities for utilizing temperature traces in heat preservation through materials.

The conclusion proposes a design method for terminally aware design. For future work, this should be future tested out. And the study should be expanded in different seasons, households and in different countries. Additionally, also not just on student-shared households but households that also include others social groups.

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A APPENDICES

A.1 Pictorial

The intention was to create a method that our research team could collect and consider a first-person analysis of keeping warm or cool. At first, a grid approach was done which was from our perspective too time-consuming. Therefore, new methods were analyzed and created. This leads us in multiple directions. For the most part digital and physical analysis.

A.1.1 Collecting materials as design probe. This method worked as followed. Collecting physical residue of items that kept one cool or warm is done throughout the day and one is left with a mini pile of collectibles. This collage or put in containers. The intention it came from is physically holding and feeling material that has helped you throughout the day. From the literature, multiple collections of material gathering can be found as probes. For example by proving containers with questions on them [26]. Where the user can be creative with material input. What is different from this existing method is that it is only collected and categorized per day. And that the material gatherings had a purpose before. Another example is for example a 'material probe' [16] where general material is used as a probe. What is different from this existing method is that it is not collected from the participants themselves.

The advantage of collecting the materials as a method compared to the other methods is that one can physically touch a version of the item that impacted them. Though most collected materials are too small to hold. Additionally one can have a broad overview due to the scale of the items.

However, there were some limitations noticed. Some items can not be gathered materials tiny pieces from for example a heater. Additionally due to the scale of the items one could not remember what it was. At last, just in general though only materials must be gathered one can forget certain items during the day.

A.1.2 Photos of item collection. This method was creating a physical collage at the end of the day of all the materials that regulated one's temperature. In literature, this most compared to a camera probe [26] where the participant has to take pictures of each instance. So this method most aligns with 'Autophotography' [10] which is a method where participants take pictures of the problem or solution. Compared to the digital collage one has to take more pictures but it has the advantage of being taken into context.

The advantage of this method is that bigger items also can be put on the collage and still gives a brought overview. though they can not physically be touched anymore. It could be an easy and fun method due to search these items and create an overview of items. Additionally, creates a connection between the items and their behavior.



Fig. 7. Moodboards referring to warm and cold

The overview for a few days already led to just multiple a pile of clothes. So one could say this is the method to stay warm. Though other items that could not be collected also impact this. A heater can not be collected and some items one just forget about at the end of the day like a jacket or towel. Additionally, explanations or values are not mentioned.



Fig. 8. Moodboards referring to warm and cold

A.1.3 Fabric data gathering. The group noticed that materials impacted our experience of temperature. In this method counting, crossing, and layering could be found as ways to track. Tracking on fabric is in literature also used as probe[26].

The advantage is that it can connect the participant to the material. An opportunity could be that this material is gathered on a blanket which has the additional function of keeping warm. And could have interesting interactions.

Although there are limitations. Not all participants can sew. And no values are collected in this method.



Fig. 9. Moodboards referring to warm and cold

A.1.4 Visual Infographic Data Gathering. An infographic is a graphic depiction of data or information that conveys complicated ideas in an easy-to-understand manner. Infographics are a great way to convey ideas clearly and rapidly, making them suitable for a variety of uses. [14]

In this method, the participant has to use a chart, to record data on what helps him feel warm or cool. Using the qualitative matrix from the chart, he selects the temperature he feels, then he should place into the chart the object that helped him feel this cool or warm (accordingly with the time he felt it).



Fig. 10. Overview methods

The advantage of this method is that it is easily understandable by the participant and easy for the designer to interpret loads of data that he may gather over many days. It can help the designer

perform a thematic analysis based on the keywords of the objects mostly selected by the participant, it is also possible to deduce outliers through the line chart. Moreover, an additional line could be added that shows the actual recorded temperature of the room, by doing a comparison of the two lines over time, the researcher could deduct which objects act more rather than materialistic but also ritualistic elements to warm or cool the user.

Cumulative heat map While the air in a room shares a similar temperature, the user of the room can usually feel a "sensorial" or "emotional" temperature. Following the purpose of finding the specific factors that influence this subjective feeling, making a heat map is suggested. (Fig. 2)

The heat map is based on the floor plan of the room/space where the user stays the longest or is the most familiar with. By coloring the image from blue (coldest) to red (warmest), the heat map helps the user to find the factors that influence the temperature feeling. The factors can involve location, touching, lighting, or the duration of staying.

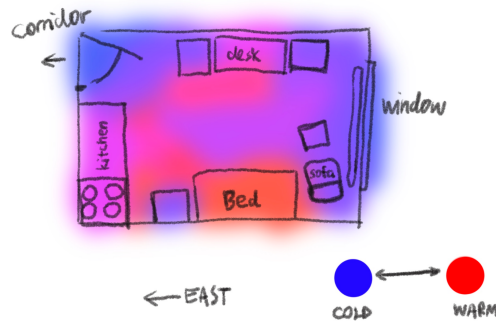


Fig. 11. An example drawing for coloring a room floor plan based on the subjective temperature

However, a few means below was used to improve this method of data collection. Firstly, it's good to combine the heat with time so the change upon a duration of time is also traceable. [17]

The reference made the heat map into grids, which contains already two axis. By displaying three variable together, the directed trend is clear. Moreover, one can generate the heat map from a more reliable source, such as surveys, to support the formation of the heat map. [11] Also, it's practical that other elements such as an approach path, which indicates the physical movement, is displayed together with the heat map. [24] This method also described the use of video pre-processing to generate the aggregated, temporal, path, and pose overview, under either flat or 3D models. [24]

A.1.5 Collecting photos of material texture. Similar to the method of Collecting materials as design probe, this method is integrated for a more convenient way of collection and towards a broader range of materials. As a method derived from the camera probe, a macro camera plays the critical role of collecting close-up pictures of any items that keep the participant cool or warm and make the participant feel a temperature change. For example, when I sit down at home, I put a piece of blanket on myself. Then, I take a close-up picture of the blanket, showing the detailed texture of the blanket, because I feel warmer than before I put the blanket on.

Compared to the conclusion of the literature review on the method of Collecting materials as design probe, this method is applicable to a broader range of materials in which collecting residues or linens is impossible, such as synthetic materials or metals. Also, the participants spend less time on the action of the collection by just taking pictures and can be more efficient in organizing the collection because of the nature of digital files. However, the participants lose the opportunity to touch the actual material later. The ease of reorganizing and reviewing makes this method

possible for a longer term of application, so choosing an appropriate method between this one and Collecting materials as design probe will depend on their advantages.



Fig. 12. An example application of Collecting photos of material texture

A.1.6 Daily diaries. The described data collection method is a form of self-reported daily diary, the collected data should involve different types of days, including weekends and weekdays. In this study method, the researcher records their daily activities related to staying warm or cool in a diary sheet daily. The diary sheet includes information about the time of the activity, the energy that was used for the activity, what was the purpose of the activity, and how it relates to their values.

The daily diary method is a well-established research tool that has been used in studies in different fields of research to examine changes in behavior or psychological processes over time [5]. It has several advantages over other methods, such as recall bias, as it allows participants to report on their experiences in real-time [6].

To conduct a daily diary study, researchers need to consider several factors. Some of them are the length of the diary period, the number and type of required tasks, and the mode of data collection [7]. In this method, the diary entries are stored in a table format, which allows for easy analysis and interpretation. Moreover, the days can be easily compared.

The purpose of this data collection method is to understand the patterns of energy usage and how they relate to the researcher's values and motivation behind energy use. Such as their commitment to sustainable living or collective energy use. This information could be used to identify areas where energy consumption could be reduced or optimized by adapting to house inhabitants' behavior.

Overall, the diary method is a valuable tool for understanding behavior and psychological processes over time, and it has many applications in various fields of research [5,6,7].

When using this method, we observed that while this data collection method results with consistent and reliable results, which can be easily compared, words do not fully explore the subtle differences between types of activities of motives behind them. To engage in the emotional part of household energy use and explore deeper insights we chose to leave it behind in favor of more exploratory methods.

Date	25/02	What kind of day?	Weekend day
time	Event: what energy was used + practice keeping warm/staying cool	Goal: what was the purpose of the action	Values: what is important to me? Why do I do this?
9:00	Stay under bed blanket	Stay warm and cozy	It is very relaxing in the weekend to just stay in bed
10:00	Making eggs	Food which was also warm	Nutritious delicious food is important for my wellbeing and mindset.

Fig. 13. An example drawing for diary approach

A.1.7 Moodboard. The described research method is a self-reflective data collection method. A mood board is a visual representation of data, typically used in creative fields, to compile and organize images, colors, and textures that capture a particular mood or feeling. In this case, the researcher uses a mood board to reflect on their own activities, which regulates the body temperature in the researcher’s household.

The researcher collects data on their activities by identifying the actions they take to stay warm or cool. They assign each type of activity to an image on the mood board. Some examples of activities could be drinking warm or cold beverages, using a blanket, or taking a hot shower. Additionally, the researcher considers the materials used in their home, such as wooden floors, lighting, carpets, and warm clothes, as they impact their ability to regulate their body temperature.

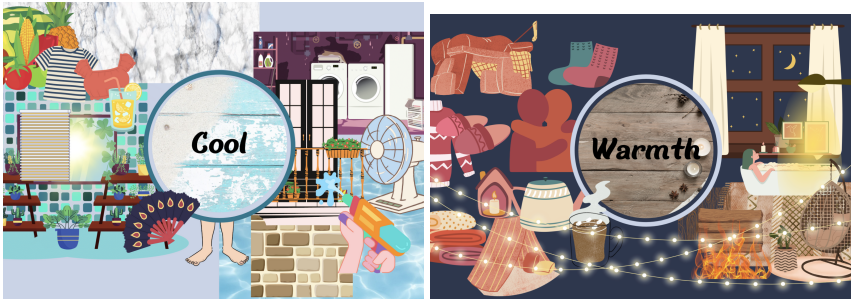


Fig. 14. Moodboards referring to warm and cold

This data collection method is a first-person study, additionally, the data is not collected throughout the day but is instead an overall reflection of what the researcher finds significant in order to regulate the perceived temperature at home. The mood board can be used to identify themes that emerge from the researcher’s insights, such as what they consider significant. And which activities they recall in the long term as influential. Additionally, it gives an implication of the overall awareness of staying warm and cool. Mood boards facilitate the articulation of complex feelings and experiences and visually represent participants’ emotional states. [8] Which can be used to analyze the values behind household energy use. However, the user-centered design research results with the use of mood boards present some risks, such as the potential for bias in the interpretation of mood board content. [9]

A.1.8 Discussion. These methods all have different intentions of tracking and analysing behavior techniques for keeping warm/staying cool. Each method can be put in 3 categories: material relation, presenting values and item relation. Which can also be seen in the fig 27.

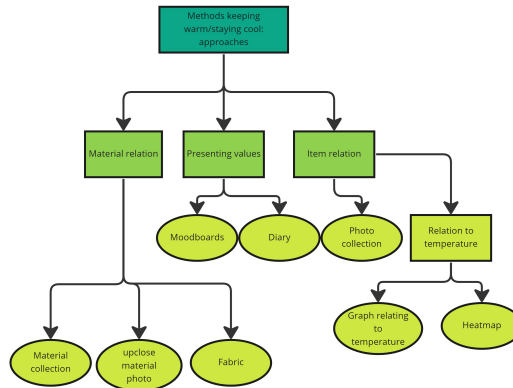


Fig. 15. Overview methods

A.1.9 Material relation. Materials can have an impact on the experience of feeling warm or staying cool. As all materials have different properties. These can be documented with fabric, material collection, and photography but all track what material has an impact on the experience.

A.1.10 Presenting values. Moodboards and a diary both present the values of keeping cool and staying warm. Though both can be biased due to being a reflection of activities. Both can give insights into which values the participant represents.

A.1.11 Item relation. Items also can be tracked to analyze which had an impact on the experience of keeping warm/ staying cool either in relation to temperature experience or not.

A.1.12 Conclusion themes. A combination of these categories would be ideal to have all lenses highlighted of the subject. All have a unique quality that gives insights in their own way. Although not all methods create equal insights they must be considered in the context which is best suited.

Additionally, more methods should be explored to come to a concrete triangulation. For example, practice analysis is missing. So it should be determined what encompasses staying warm/staying cool on what influences this. Though this is research in itself. Additionally, in the first diary, it was noticed that communal areas and social events had an impact on our temperature. Therefore these also should be addressed to encompass keeping warm/staying cool.

A.1.13 Creating these methods insights. From ideating these methods it was noticed that perception of temperature has an impact on these methods. A 'sensorial' or 'emotional' temperature. Not just the temperature itself. For example in the heatmap method. This is an interesting insight to be more explored.

From performing the first diary study a first-person perspective it was noticed that aside from values materials, items, and communal areas had an impact on our experience of keeping warm keeping cool. These materials and items were put into methods. All are interesting perspectives to take on the research. So each theme represents an interesting lens for keeping warm/staying cool.

A.1.14 Design Brief. We began our research project with a focus on exploring alternative energy futures based on the research brief. The main takeaway for us was that we needed to consider the role of in-home energy technologies and how they can be re-imagined supporting more sustainable, equitable, and user-driven energy practices. Rather than simply increasing energy efficiency to design innovative solutions that empower residents to adopt energy-saving strategies and adapt to new ways of living. Acknowledging the need for a situated understanding, we committed to

exploring the lived experience of our alternative energy futures. This involved adopting first-person or participatory research methods, enabling us to comprehend the rhythm and feel of daily life with the things we developed.

In the initiation phase of the project, we created a team canvas to set the stage for our collaboration. This included identifying our shared values, such as creativity, inclusiveness, sustainability, and user-centrism. We agreed upon rules that would ensure mutual respect, open communication, and effective time management. We also recognized the importance of balancing our individual strengths and areas of expertise, which are diverse yet complementary.

B PROCESS

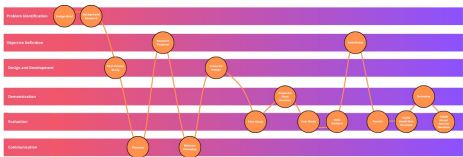


Fig. 16. Design Process overview [27]

B.1 Background Research

Following the project’s initiation, we dove into a thorough background research phase. We investigated a variety of relevant subjects, including current energy approaches, communal energy solutions, behavior change theories, research methods, and existing design projects that aligned with our focus. Our first step was to understand the existing ways of producing, distributing, and using energy, along with their related challenges. This gave us a broad view of the energy sector, forming a solid base for our design work. We examined other design projects that were related to our challenge. This provided us with inspiration and insights into how others have tackled similar problems.

We also dedicated time to familiarize ourselves with the research methods we intended to use. These included design probes, low-fi technology probes, speculative design, first-person, and participatory research methods. We learned about their strengths and limitations, and how others applied them effectively. In summary, this comprehensive phase of background research was vital in expanding our understanding, sparking our creativity, and guiding our design process.

Background research

Contents

Questions to think about:	1
Energy approaches	1
Communal energy solution:	2
Behavior change:	2
Research methods:	6
Examples of design projects:	8

Fig. 17. Initial background research

B.1.1 Pictorial. As mentioned in the method section: "In our research, we employed a first-person approach, a qualitative research method that positions the researcher as the subject of investigation, emphasizing their firsthand experiences of a phenomenon [7]. This approach was adopted to investigate the practices of temperature adjustment within a communal living environment. This method allowed us to delve deep into the experiences, practices, and challenges connected to keeping warm and cool at home, providing valuable insights into the aspects relevant for our research." This approach also allowed us to identify potential opportunities and challenges associated with measuring behavior around temperature and energy use. This hands-on, experiential research method enriched our understanding of the subject matter and informed the development of our research. We then wrote our insights in a pictorial format A.1.

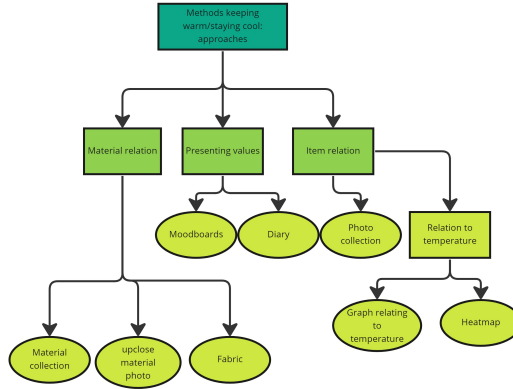


Fig. 18. Overview methods in pictorial

B.1.2 Research Proposal. Upon completion of this first-person perspective phase, we found ourselves equipped with a more nuanced understanding of temperature dynamics. With these insights in mind, we crafted a research proposal entitled "The heat footprint of a human in the shared household experienced by co-inhabitants." Our proposal encompassed several sub-questions aimed at exploring different aspects of the theme. Firstly, we wanted to explore individuals' experiences of sharing self-generated heat in a household. We sought to understand the emotional responses to this sharing, the factors contributing to discomfort, and the implications for future scenarios with more communal accommodations. Secondly, we aimed to identify what leaves a heat footprint in a household. We wanted to understand which objects convey heat, where these heat footprints could be found, and how the location and source of the heat influence comfort levels when using these objects after someone else. Lastly, we proposed to investigate heat preservation as a means of energy saving. We aimed to explore how heat could be preserved in everyday objects, how sharing and reusing warmed objects could contribute to energy reduction, and whether this might represent a futuristic solution. Through learning about new stories these heat traces was turned into "temperature traces" which also could create such scenarios. Which were later also found in the results. Reflecting on these sub-questions and connecting them back to our earlier research and experiences, we distilled our final research question: "What role do the 'heat traces' left by the house's inhabitants play in students' communal living experience? Where can the 'heat traces' be found? After what activities and which objects are they left? How do the co-inhabitants of the house feel about finding them?" This process of formulating our research proposal was highly iterative and reflective, requiring us to connect our first-person experiences, background research,

and the objectives of our design challenge. It was a critical juncture in our project that set the direction for our subsequent design activities.



Fig. 19. Scenario explained at the midterm

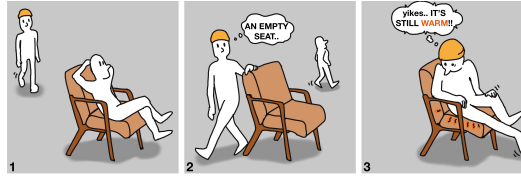


Fig. 20. Temperature traces explanation visual midterm

B.1.3 Probe kit iteration.

B.1.4 Probe kit box design. The design of the probe kit started with defining kit dimension and the content. The team made several prototypes of the kit box, using printing paper, cardboard and color paints, referencing some commercial packaging design. Many different dimensions and inner compartments were tested. The first optimum that was decided was A3 paper sized box with compartments. However this box took too many hours to make, was hard to travel with and was very fragile. So after looking at ready-made boxes to solve this problem a4 box was chosen after creating the first box. The final box that was chosen was store bought from HEMA. Due to the ease of assembly and sturdiness. After a test print, the team realised that building boxes and covering it with theme pattern was not practical because of the amount of work it requires, so we turned our head towards pre-cut boxes available in supermarkets. Eventually one of the boxes was picked. The final box is in A4 size viewing from the top for carrying convenience, and has the theme pattern and title glued on the top. To avoid messing up the task cards after printing, the team utilised an edge indexing on every card and involved theme colors for cards belong to the same day.



Fig. 21. prototypes of the probe kit box

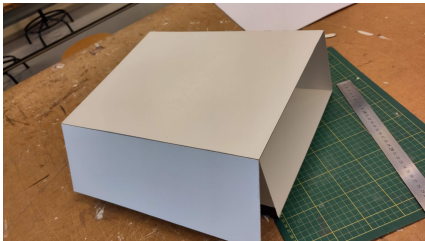


Fig. 22. A working prototype of the probe kit box

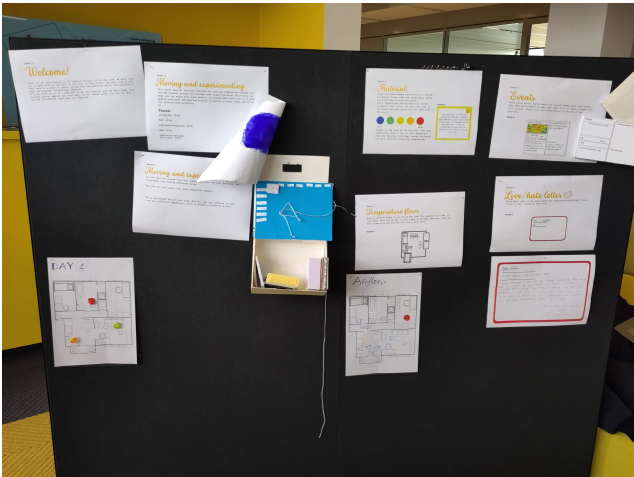
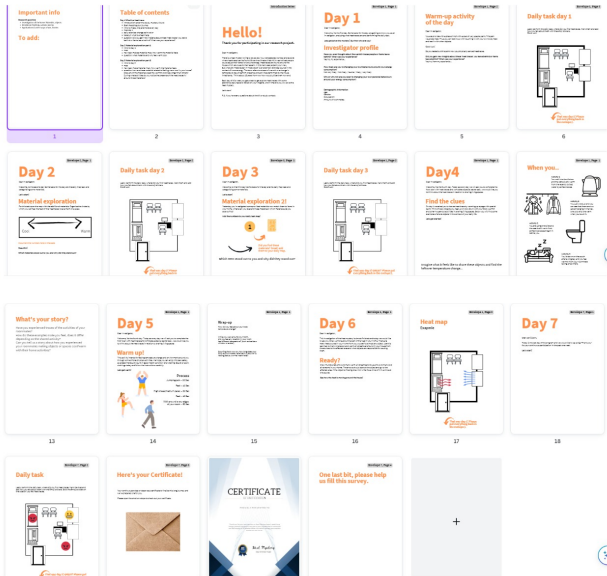


Fig. 23. Many versions of the probe kit were created

B.1.5 Iteration of probe kit overall concept. The probe kit was carefully designed to meet a great experience for the participants in their approximately 7 days of probe test duration, and some iterations are mentioned here. Moreover, we modified the prompts of each Daily Maps task to fit them with the the tasks of the day, so that reduced the chance that the participant fills out identical maps over days and more insight is gained on each aspect.

B.2 iteration tasks

B.2.1 Task: Daily maps. To enhance the personalization of the probe kit experience. The team decided to customise each participant maps. Compared with providing a default floor plan to every participant, the team believed that a customised one provides more empathy for the participants. The initial plan was to provide the participants with a blank paper and many furniture stickers, so the participants can finish the floor plan by themselves. However, after several internal testing, the team decided to move everything to Canva,for better flexibility. We tested the feasibility of guiding the participants to verbally describe their floor plan and that became the initial step before using Canva. In general, the team created a customised yet effective method to draw the floor plans.

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Fig. 24

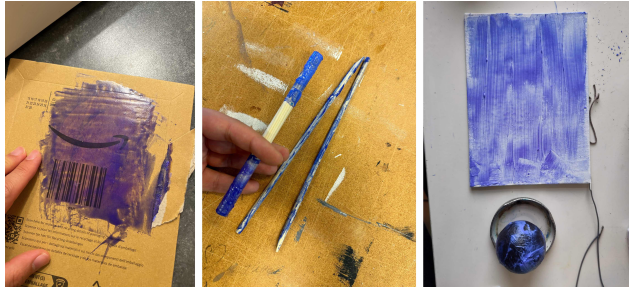


Fig. 25. Testing the thermochromic pigments on different material

B.2.3 Graphic design: probe kit. After evaluating the practical sizes and ease of carrying around, the team defined the task pages to be A5 double-sided cards, instead of a stack of A4-sized pages. All layout editing was done in Canva. However, the cover printing for the kit box was completed through Adobe Illustrator for a more accurate size control. We made a vector theme pattern that simulates the thermal camera effect in Adobe Illustrator, and the pattern was used for the box cover, the backs of all task cards, and as a place holder of all project documents. The vector file allowed the pattern to be scaled to various dimensions.



Fig. 26. Probe kit box covered by the theme pattern

B.3 Probe Kit Design Choices

B.3.1 Creation of the probe kit. The probe kit was designed by students for students. Materials where chosen that felt familiar to the researches for the "material task" and from a first-person perspective tasks were chosen that reflected the researchers own experience with temperature traces. The graphic design of the box and of the cards was chosen to give yet a clean look but still approachable to personalize and adjust. So that the participant did not feel threatened to use the probe kit. designed in an informal manner using graphics that encouraged participants to freely write, doodle, and provide diverse data. Colors and visuals were used to facilitate task identification

and create a temperature-related mood. Personalisation was also kept in mind by creating the maps together instead of a general map.

B.3.2 Probe Kit Container. For the kit a shoe size box was used with a study poster attached to it on the outside and a journey mapping board on the inside, where they were encouraged to give feedback and add comments by pinning notes to the board. Different box sizes and shapes were tested, the resulted choice was easy to carry, sufficiently big to fit the cards in a readable text size, and mark days and tasks on the map. This box was also the most accessible and easy to replicate.

B.4 Probe Kit Tasks explanation

B.4.1 Welcome Task. The introductory segment of the cultural probe is crucial for setting the context, outlining study objectives, and providing instructions to participants. As synthesis was a major challenge considering the exploratory nature of the research and the unfamiliarity of the topic. The kit was tailored to introduce more depth to the topic with each exercise and many examples were used to support the participants input. During the initial meeting, the research topic was introduced and the study procedure was explained. The probe kit contained a repetition of the introduction, which gave again an explanation to look at when necessary. On the first 2 days the participant had to complete 2 days that were assigned. This was the first day just doing the daily tasks, the second-day creating body heat and sensing the difference with paint.

B.4.2 Daily maps (maps as a probe). Where are temperature traces typically located, and what feelings are commonly associated with them?

Each day the participants were asked to complete a map with emoji stickers and blue and red markers. These maps were created together with them to resemble the layout of their own homes, enhancing accuracy and reliability. The markers served the purpose of indicating temperature traces in various locations and on objects, allowing participants to describe or comment on them. The stickers acted as prompts, stimulating participants to reflect on the associated feelings they had towards these temperatures. This exercise provided valuable insights into the participants' personal connections with these temperature traces. The mapping activity was framed as a follow-up exercise to other daily tasks, which allowed them to put a different lens on every day, including the impact of other people, materials, airflow etc. In order to compare the daily input for each participant, see-through sheets were used, which could be placed on top of each other marking cooler and warmer areas.

B.4.3 Move it. The team utilised some thermochrome (colour changes along temperature change) pigment as part of the warm-up activity. The team tested the paint on cardboard, paper and wood sticks, then tested them with various temperature from fridge to kettle. Although the product description mentioned that temperature change happens at 31°C, obvious colour changes is only possible at a bigger temperature difference, such as from fridge temperature to body temperature. Therefore, the final prompt suggests to store the pigment-covered wood stick in the fridge for a while before touching it. In the beginning the task was mainly used just to let the participants play with various things but this would have been unclear. After reading the paper "Making Design Probes Work"[32] this was changed to a more literal task. In the task where its used the body temperature heats up the stick. The participant then gets sensitised with their body heat and this is an example of temperature traces.

B.4.4 Material exploration. This task was designed to investigate the role of different materials in the generation and retention of perceived temperature traces in participants' homes. The fundamental idea was to understand what impact the associations with the objects and their material have on their perceived temperature. Each participant was provided with a set of diverse materials,

selected based on our first-person research (See Appendix 1). Participants were asked to touch each material to perceive its temperature, then consider where in their homes they might typically encounter these materials, how warm they feel and what temperature-related associations they have with it.. Using a spectrum of dotted stickers, from blue (coldest) to red (warmest), participants were prompted to rate each material on a temperature scale. To deepen the exploration, participants were asked to answer two questions on the back of each material sample: "Where do you usually feel the temperature of this material?" and "What activity does it remind you of?" These questions aimed to stimulate participants' memory and sensory experiences, linking the physical properties of materials to everyday activities and routines.

B.4.5 Temperature Challenge. What are existing skills in utilizing temperature traces to be warm/cool? The temperature challenge task was designed to examine whether in a crisis/abstract situation the skills relevant to alternative temperature adjustment would appear. The participants were asked to imagine different scenarios where temperature poses a threat to their plant and pet by overheating and freezing. What would they then do to prevent it from happening? They were asked to propose a step-by-step plan. By analyzing this plan we could learn the impact of being faced with a challenge on the ability to use alternative thermal solutions.

B.4.6 Temperature Flow. Where does the temperature flow, what is the source and direction of it? Finally, with the airflow exercise we wanted to ensure that the participants do not focus solely on the objects and amenities in their home and consider where the temperature change is coming from and also where can it be felt as a result of airflow. The participants were asked to draw arrows from the source of the temperature to the area it is affecting using red and blue markers.

B.4.7 Social Events. How do social situations affect perceived temperature?

This task was centered around the participants' recollection of their social experiences within their homes, particularly focusing on how the presence of people in a room might affect temperature changes. This task was aimed at examining the potential correlation between social interactions and their contribution to temperature traces. Participants were asked to recall at least two different social situations that had taken place within their homes. They were encouraged to consider not only the event itself but also their experiences with temperature changes during these events. By reflecting on how the temperature was influenced by the number of people present, participants could gain a deeper understanding of how human presence contributes to temperature traces. To translate these memories into a tangible form, participants were instructed to create social media posts using the provided post templates. They could either draw their own images or use the ones provided in the kit to better illustrate the situations they were describing. The use of a social media format provided a contemporary and relatable medium for participants to express their experiences. Moreover, by linking temperature changes to social events, this task encouraged participants to understand temperature traces not as isolated phenomena, but as part of their everyday life and social interactions, which supported further data generation from that perspective in the daily maps.

B.4.8 Story Time. What feelings are associated with temperature?

In this task the participants were asked to share a story via a text message with their friends where they experience some extreme temperature-related feelings. This exercise was designed as a follow up to marking their feeling on the map daily to elaborate on what is the context of the situation where they have such feelings and how the associations are made. A text message format was selected as an iteration from a letter, as it is more relatable to the age of the participants and links to the emoji prompts used in the study.

B.5 Pilottesting

Before conducting the study. It was first pilot tested on ourselves. Then the combined kit exercises were pilot tested. Then each exercise was retested. This created feedback to change the probe kit. At last the probe kit had 6 versions.

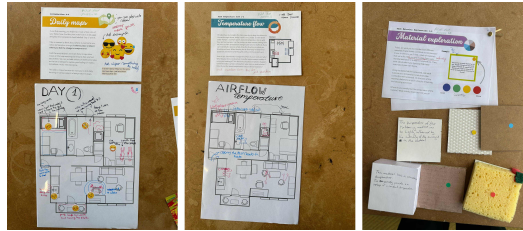


Fig. 27. Pilottesting

B.6 Conducting the study

Each participant was first interviewed and given the kit. For the introduction, the team suggested that there needs two researchers for the best efficiency. It's because when one staff finishes guiding the participant to verbally describe the floor plan, the other staff can standardize the floor plan in Canva and print it out. Overall, the participant doesn't need to wait. In this initial interview the probe kit was given. Then the researchers had to wait for them to finish the week. Then conducted a final interview where a few more in-depth questions were asked and there was room for further explanation.

B.6.1 Data analysis. A thematic approach was most fitted to analyse the probe kit due the qualitative data. The core of the research was exploratory thus an inductive approach was implemented. Each probe kit was analysed by 3 researchers each applied a sticky note to highlight their understanding to the probe and sticky notes to highlight what was interesting. Then the researchers compared notes and wrote down the interesting aspect of the findings from each participant. Then note from each probe from the participants were compared with each other. This resulted in insights for example on materials and social activity. Then the overall participants results were compared. These were highlighted into themes with different stories told by each participant.

B.6.2 Experimenting with insights: speculative design? Having looked at the results based on the analysis we could identify certain categories and themes in the data. We wanted to convey the results in a valuable way, so we started by thinking about how to add depth through temperature into the home. We decided to reverse our thinking and break down the home into the elements of it that mattered to this study. The home would consist of the spaces and rooms, people living in it, and different objects. Now we looked at the meaning of it in the light of our study and proposed the four categories, individual, social, location, and object. It is also important to mention that at this point we were introduced to a lot of relevant literature in our process and it supported us in being selective in what information should be further conveyed.



Fig. 28. Practice based

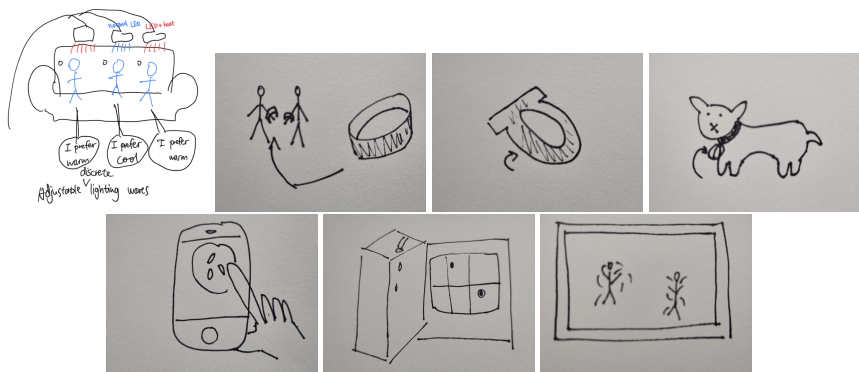


Fig. 29. Social

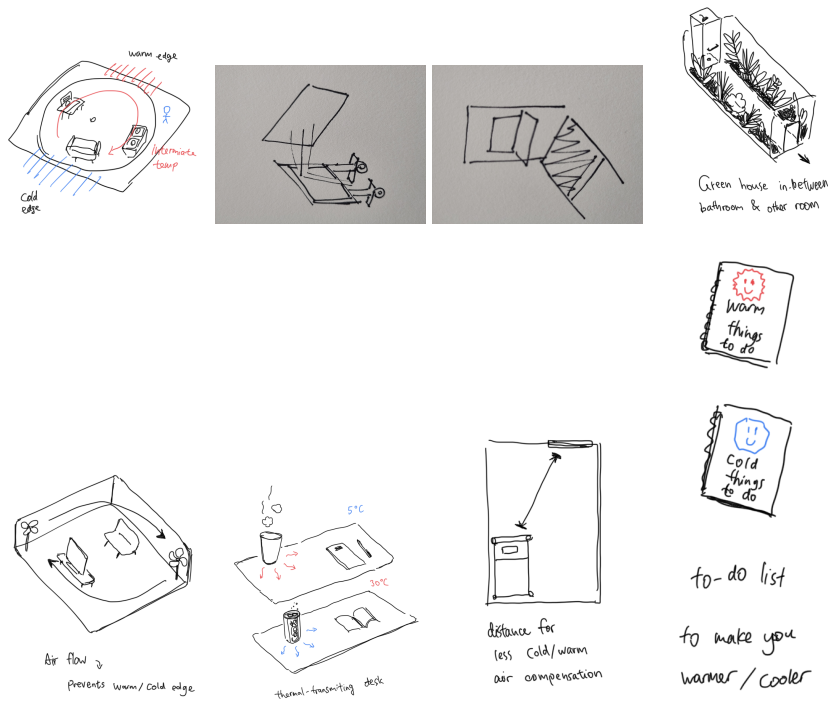


Fig. 30. Location based



Fig. 31. Object based

B.7 TAMDR model



Fig. 32. Demoday stand

On the demo day, we presented our conclusion in the form of the four categories, whit together could be used in a form of a thermally aware design framework. We took the received feedback

into consideration and continue to reframe it to achieve a model. We asked questions, such as what would be a value for a designer from our findings? Why did we choose to present certain results and what makes them interesting? This led us to propose a TAMR model. We made this model in an attempt of highlighting that while we found the temperature complex, the first step to designing it is just shifting perspective from how perceive temperature. Stepping away from a full house approach there are objects and locations and people who interact with them at a very simple level can already bring in a lot of new ideas to the table, as well as questions. We realized that a home requires a certain temperature for its inhabitants to "feel comfortable", but there are many ways to feel warm, or maybe even to feel exactly 21 degrees. Not to mention that each home has individual desires, which might be different than that. At a certain point, we decided to finish the development of the model and place a time stamp on the thermal aware design.