Shared Spaces: Towards Shared Responsibilities

DBM160 — Data-Enabled Design

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ABSTRACT

This pictorial describes the application of the *Data-enabled Design* approach in the identically titled elective. The aim of this work is to progress towards creating healthier living environments for shared spaces by focusing on establishing a feeling of shared responsibility. This pictorial is split in two parts: in the contextual step we use two data probes to gain insights on the design context. Then, we discuss the design of a system that addresses the outlined problems. We evaluate the concept in two situated design evaluations, where we discuss the concept's inability to increase responsibility among inhabitants of the shared house, which we attribute to an apparent lack of trust in the system. Reflecting on this, we conclude this paper by presenting a number of suggestions to support future projects.

AUTHORS KEYWORDS

Data-enabled design; shared spaces; co-responsibility; air quality.

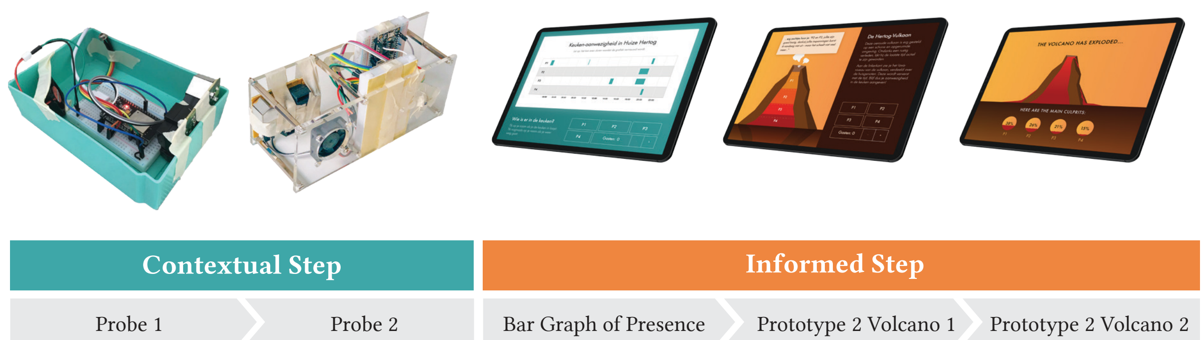

Figure 1: An overview of important design artifacts created throughout the two steps of this project.

1. INTRODUCTION

Shared housing is a common reality for young people worldwide [3]. In this household model, two or more unrelated persons live together in a house where they share some faculties (i.e. bathrooms, kitchens). The main attractions for this housing model are social- and financial reasons. However, the dynamics of sharing facilities can create challenges in daily interactions: a common cause of frustration is facilities not being cared for well enough [1, 2].

In this project the aim was to *"design a solution that helps in creating a healthier living environment, by either changing the environment and/or the behaviour and experience of the user"*. More specifically, we were interested in healthy living with regards to shared housing. However, the design process towards this aim was not standard. We applied the *Data-Enabled Design* [7] approach to guide our design process. Throughout the process, a strong emphasis was placed on gathering data to inform the design process.

This project consists of two main stages (Figure 1): the *Contextual-* and the *Informed Step*. In the first step we sought to explore the design context by the use of data-gathering probes and qualitative questionnaires. In the second step we aimed to apply the insights gained to work towards creating healthier living environments.

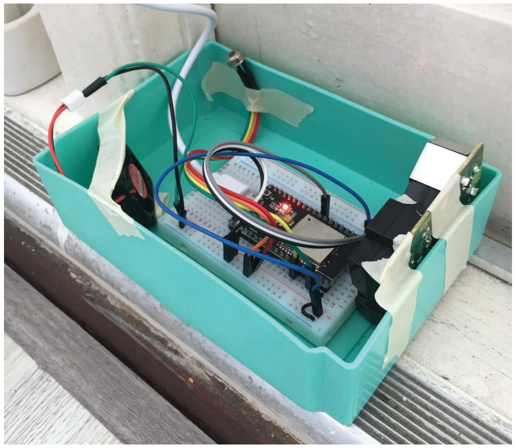

Figure 2: Close-up of the first data probe.

Figure 3: The data probe in the participant's kitchen.

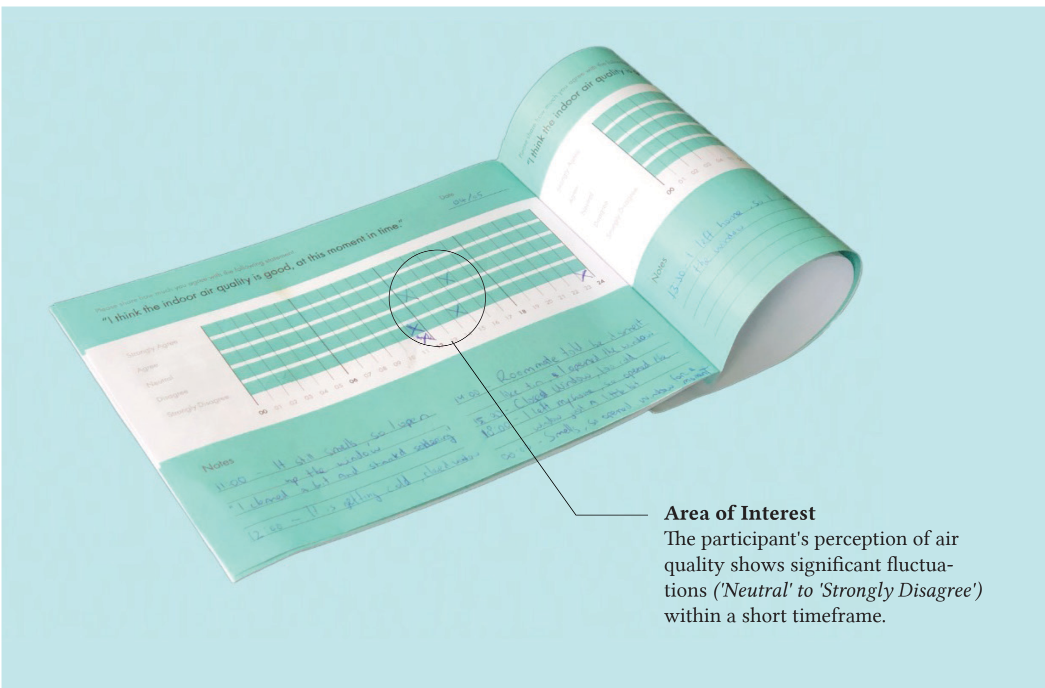

Figure 4: A filled-out data diary. The high variance in perceived air quality signifies a potential design opportunity. In this instance, the participant perceived the indoor air quality as *'poor'* because of the indoor smell.

2. CONTEXTUAL STEP

In order to create value through design, we need to have a thorough understanding of the design context and its actors. The aim of the first phase was to better understand factors that attribute to a feeling of good air quality. We worked towards this aim by deploying a series of devices that register sensor readings of its context. In this paper, we refer to such devices as *Data Probes*. In addition to the data probes we explored the design context through qualitative data: self-reported questionnaires and stakeholder interviews.

A review of literature on air quality and a subsequent brainstorming session resulted in a list of factors that were hypothesized to affect the perception of air quality (Appendix A). This list served as inspiration for data probe sensors that could help us understand the design context.

2.1. Data Probe I

In the first iteration of the *Data Probe* (Figures 2 and 3) we incuded sensors that measured dust *(Grove PPD42NS)* and temperature *(MLX90614)*, and an electrical fan to ensure the probe has the airflow required to make accurate measurements [6]. These measurements were sent in 2.0 second intervals to the *Data Foundry* platform [4] using *OOCSI* [5]. The measurements were saved as a .csv file.

In addition to the data probe, an A4 *Data Diary* (Figure 4, Appendix B) was given to our participant so that they could record their feelings towards the air quality. This diary also allowed them to make notes if they wished to do so. This initial probe was deployed for one week in the kitchen of an apartment shared by two roommates. The data diary was filled out by one participant. This study was concluded with a semi-structured interview.

2.2. Data Probe I — Findings

As we were unexperienced in the skills required to operate a data-enabled design process, we encountered issues when trying to visualise the .csv file (72,000+ entries). We were unable to analyze the sensor data prior to the interview. Instead, we used the filled-out diaries for direction.

The participant seemed to assess air quality mainly on two things: temperature and smell. However, when remembering the humid weather of the past days, they added that humidity was also a factor they found important.

The interview offered an interesting perspective: the participant shared that they often had moments of frustration with their housemate, mostly related to cleaning the shared spaces. We chose to further pursue this problem in later iterations.

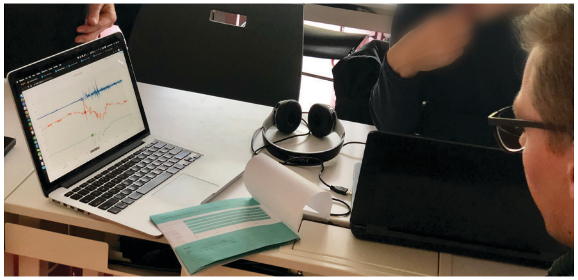

Figure 5: Interviewing Participant 1 using data visualisations.

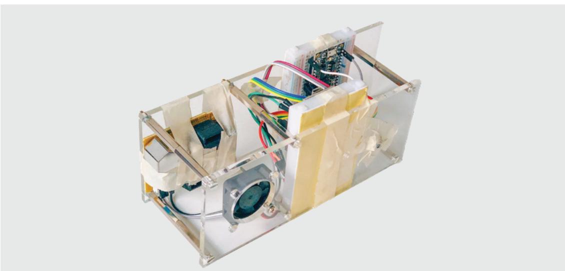

Figure 6: Close-up of the second data probe.

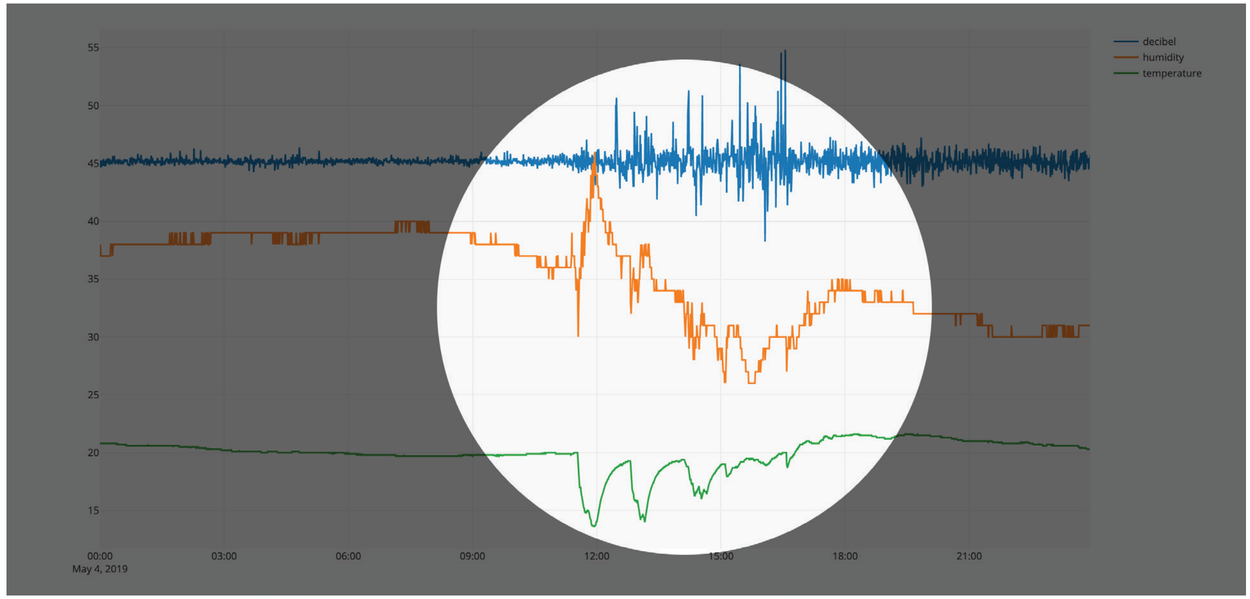

Figure 7: Data visualisation of temperature (green), humidity (orange) and sound (blue) over time.

2.3. Data Probe II

Based on previous findings, we replaced the temperature sensor with an alternative *(DHT11)* as we deemed it not accurate enough. In addition to temperature, this sensor also measured humidity, a factor attributing to perceived air quality according to the previous participant. Moreover, we were looking for a way to detect presence in the room, which is why we added a microphone *(MAX9814)*. Finally, we reduced the data diary size from A4 to A5.

The second data probe and data diary were distributed to a new participant who we will refer to as Participant 1. This participant lived in a student house which they share with nine other roommates. The intent was to further investigate social dynamics in the kitchen, however we found ourselves unable to acquire consent from the others. Therefore, this probe was deployed in our participant's bedroom for one week. This participant was the only one to fill out the data diary.

The data probe's measurements were used to create time-series graphs (Figure 7) where we discovered repeating patterns. At the end of the week we once again interviewed the participant, but this time we presented a number of data visualisations to them to get them to discuss what happened to cause the observed patterns in data.

2.4. Data Probe II — Findings

We learned that our participant's perception of air quality had a positive correlation with the overall cleanliness of their room: they experienced the air quality as *'better'* whenever they had cleaned their room.

The repeating pattern highlighted in Figure 7 was caused by opening- and closing the window. The participant had been soldering in their room, and disturbed a housemate with the smell. They requested the window to be opened to combat the smell issue. The participant did so in intervals, as *"it was too cold outside to keep it open"*.

Although this probe was not deployed in a shared space, most of the participant's recorded behaviour was caused by social motivations. When discussing their shared kitchen, the participant mentioned the nuance of the unspoken rules, such as cleaning up after you have cooked.

All housemates acted in accordance to them, but as the unspoken rules were broken (i.e. a roommate who was in a hurry left the kitchen without cleaning), others followed this behaviour by also neglecting the rules. Especially troubling was the fact that the one responsible often remained undisclosed.

2.5. Contextual Step — Conclusion

We gained three main insights during the entirety of the contextual step. Firstly, we found that perception of air quality is positively correlated with cleanliness (including tidiness, smell and other factors). Secondly, we found that shared spaces often have implicit rules, which direct the social dynamics. Finally, we found that these implicit rules are fragile: violations of rules lead to a loss of control in the shared context.

We hypothesized that in order to create a healthier shared living environment, the inhabitants need to have a better overview of accountability of indivuals. In the next section we focus on applying this hypothesis in the informed step.

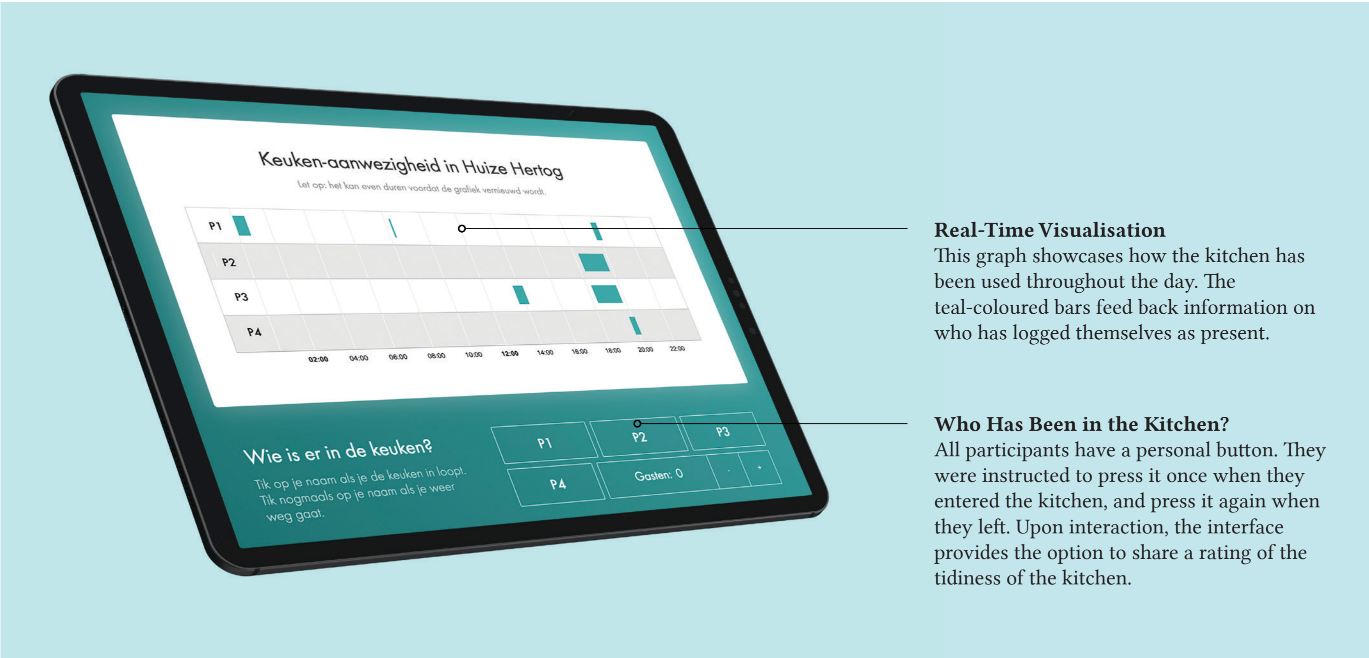

Figure 8: An overview of the web application that tracks- and visualises inhabitant presence in a shared kitchen.

Figure 9: The modal that allows participants to share their perception of kitchen tidiness.

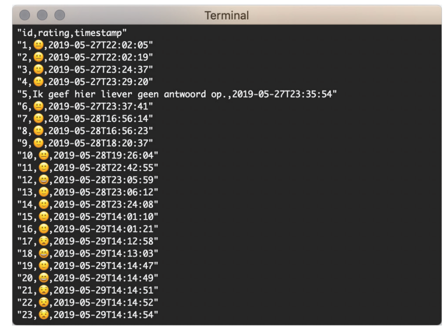

Figure 10: A .csv file containing kitchen ratings.

3. INFORMED STEP

3.1. Iteration I — Overview

In order to create a healthier shared living environment we developed a web application that kept track of how shared environments are used (Figure 8, Appendix C). Upon entering the shared room, a person can use the button containing their name to keep track of their presence. The presence of all users is displayed in a bar chart so that everyone can see who has been in the kitchen.

Additionally, interactions with the web-app provide the option to share an evaluation of the cleanliness of the kitchen. For this, a modal containing emoji-scale ratings that represent a 5-point Likert scale was used (Figure 9). The emojis were used to allow the users to provide more intuitive ratings. All ratings are time-stamped, and saved on our webserver as a .csv file.

The web application was deployed alongside a selection of sensors, based on previously used data probes. In addition to sensing temperature and humidity, we included an *Adafruit SGP30* sensor to measure the levels of CO_2 and *Total Volatile Organic Compounds*, which allowed us to better assess the perceived air quality. We removed the microphone, as it was not able to produce any valuable data that could be used to detect kitchen presence.

Once more, Participant 1's shared house was used in this experiment. In contrast to the previous experiment, consent was acquired from the three other inhabitants which enabled us to use their shared kitchen. The web app and the adjoined sensors were deployed for a period of two weeks. The aim of this experiment was to find an answer to our research question:

> *Will showing their presence make participants feel more responsible for taking care of the shared kitchen?*

This iteration was concluded with an interview with Participant 1, who was once more shown graphics containing visualisations of patterns in sensor data. The next section describes the findings.

Figure 11: Placement of the iPad in the participants' shared kitchen.

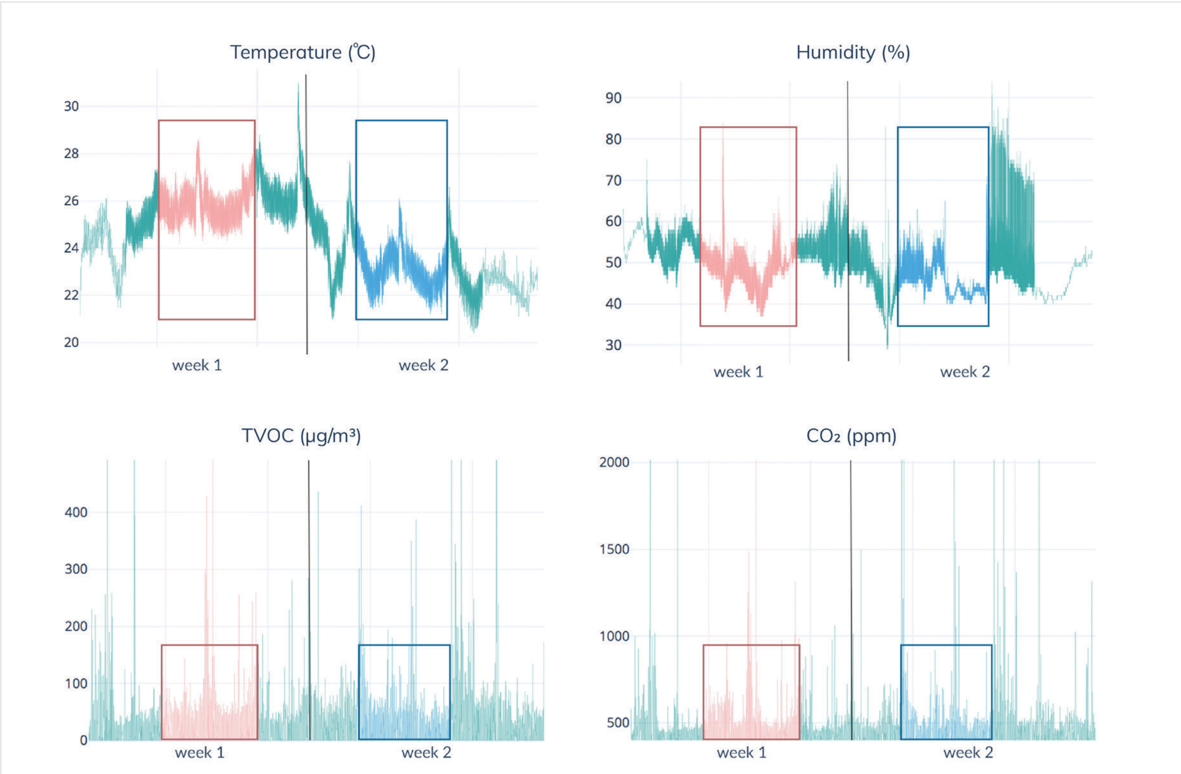

Figure 12: Several time-series data visualisations on *Temperature*, *Humidity*, *Total Volatile Organic Compounds* and CO_2 levels.

Figure 13: Participants communicating on cleaning that is to be done.

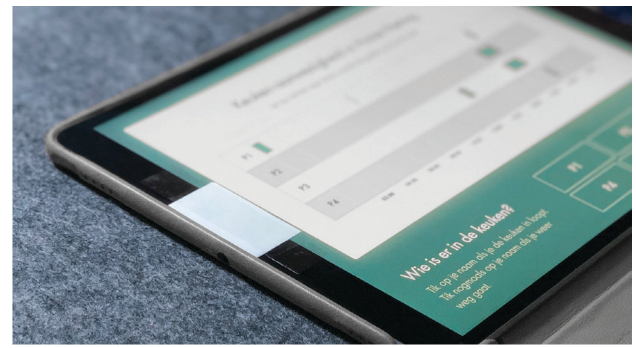

Figure 14: Tape placed over the iPad's camera.

3.2. Iteration I — Findings & Implications

In the data visualisations (Figure 12) we see a number of patterns that repeat in both weeks. Some of these patterns are thought to have implications for the perceived air quality: a rise in Volatile Organic Compounds and CO_2 levels. In our interview we explored these visualisations and the overall group dynamics with the participant.

No Increase in the Feeling of Responsibility. Participant 1 did not see an increase in the feeling of responsibility as a result of seeing others' presence. Instead, they took matters in their own hands: our participant mentioned that sometimes the one tasked with cleaning the kitchen will blame others on the Whatsapp group for messing up the kitchen (Figure 13). We see this blaming behaviour as a way to remind the responsibility in the shared kitchen, which perhaps could be incorporated into the next iteration as a design opportunity. We hypothesize that being able to blame someone publicly increases their responsibility in the shared space.

A Decrease in Participant Activity. During the two-week test,we found that the frequency of self-reported submission decreased over time. The participant interview taught us that this was caused by a lack of reaction: *"Nothing really happened after I reported my ratings"* and *"I'm less interested now"*. Consequently, we expect our participants to be more engaged with the experiment if the prototype offered them more explicit value.

Privacy Concerns. Finally, Participant 1 reported that some had concerns with regards to privacy. The iPad has a web camera, and while it was not used within this experiment, the participants took precautions in preserving their privacy by covering the camera with tape (Figure 14). This signifies the caution required in operating such experiments.

3.4. Iteration II — Overview

For the final iteration, the web app prototype was adjusted to produce more direct value for the people of the shared house. In this app (Figure 15, Appendix C) the participants were able to see how much they contributed to taking care of the shared kitchen. The updated prototype was deployed for one week.

The height of the lava layers visualised the blame given to the individuals for not taking care of the kitchen. As time progressed, the height of the layers were updated, potentially progressing towards an eruption.

In order to do quantize responsibility in taking care of the kitchen, we created an Air Quality Score (AQS) based on user ratings of the kitchen and sensor measurements (Figure 16). By monitoring changes in this score and reviewing who had been present in the kitchen at those times, we were moderately able to assess who was responsible for changes in cleanliness of the kitchen.

The AQS formula made use of weights to adjust the impact of different factors. It's important to stress that the AQS should not be considered a value of absolute truth, but rather as an explorative tool to quantize air quality in this experiment. At the end of this experiment we conducted a semi-structured interview with our key participant to see how our design was received.

Figure 15: Overview of the 'Volcano' prototype and its key functionalities.

3.5. Iteration II — Findings

This experiment yielded mixed results. The overall concept of blame being visualised through the volcano was easy to understand for all participants, yet the way the blame was calculated was not. Participant 1 was close, as they theorized that it might be calculated from the time spent in the kitchen alongside data on CO_2 levels. Participant 1 mentioned that they had a number of discussions with Participant 2 to better understand the mechanics behind the blame, but were unable to figure out how it worked.

The participants were unable to fully develop trust with the system, as the blame scores calculated by the system were impossible to validate. When asked what it would require for them to trust the system, Participant 1 replied that *"transparency in seeing how it was created"* would be needed. Rather than seeing just the system's conclusion, the participants were interested in seeing how the calculations were done.

Something that additionally refrained the participants in building trust with the system was the fact that calculated blame was distributed quite equally among all participants, as can be seen in Figure 15. Participant 1 mentioned that *"The rating were all quite even ... it was hard to tell who the blame was given to in this case"*. As such, they were unsure what would happen when the volcano filled up completely: *"What happens when it* (the volcano) *is full, does the volcano actually explode?"*

$$\mathbf{AQS} = \frac{\mathbf{UR}}{\mathbf{w1}} + \left(\frac{\mathbf{\Delta H}}{\mathbf{w2}} + \frac{\mathbf{\Delta CO2}}{\mathbf{w3}} + \frac{\mathbf{\Delta TVOC}}{\mathbf{w4}} + \frac{\mathbf{\Delta T}}{\mathbf{w5}} \right)$$

Air Quality Score .... AQS

User Ratings .... UR

Absolute deviation in Humidity compared to optimum value .... ΔH

Absolute deviation in Carbon Dioxide compared to optimum value ΔCO2

Absolute Deviation in Total Volatile Organic Compounds compared to optimum value .... ΔTVOC

Absolute Deviation in Temperature compared to optimum value .... ΔT

Weights used to scale impacts of factors .... w[1-5]

Figure 16: Breakdown of the Air Quality Score used during this experiment.

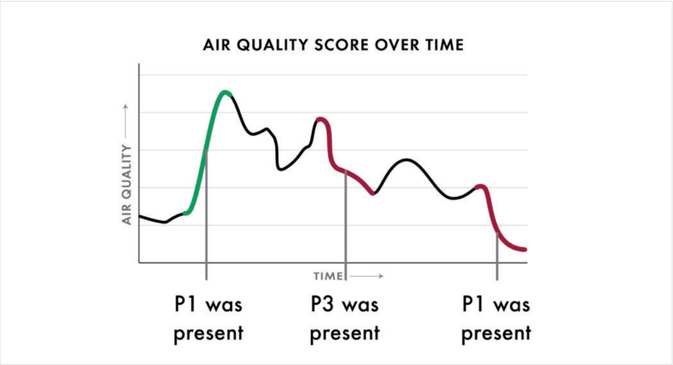

Figure 17: Still of the graph animation justifying the blame given to individuals. In this graph we can see the Air Quality Score over time.

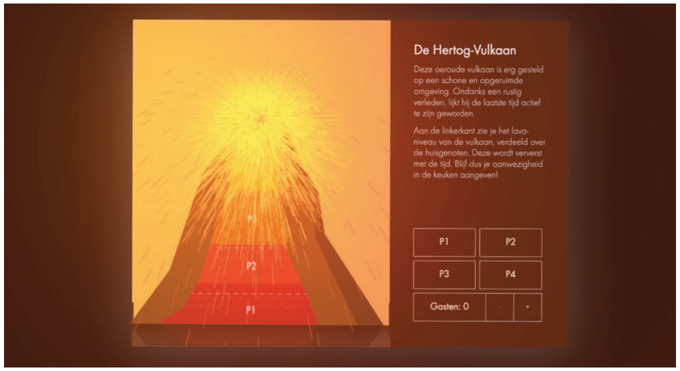

Figure 18: Still of the volcano eruption animation.

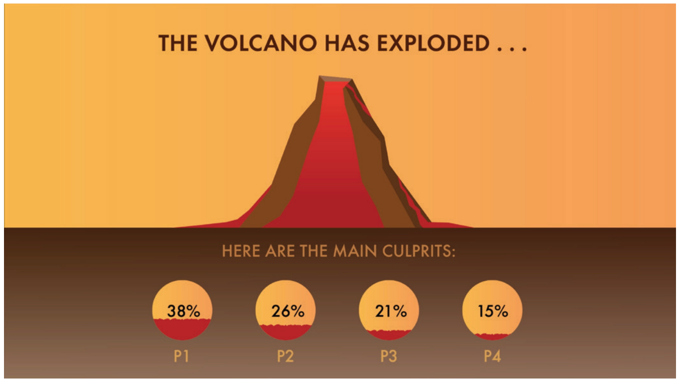

Figure 19: Still of the ending screen, showcasing individual responsibility.

3.6. Iteration II — Implications

In the second iteration of the informed step we found that while the concept of blame being displayed on a shared display was understandable by the participants, a number of challenges remained before it would become a useful tool in creating a healthier shared living environment. In this section we discuss the nature of these design implications, and provide a number of suggestions in addressing these.

Perhaps the biggest challenge is to allow the users of this system to more easily build up trust. As previously discussed, a strategy for doing so could be to improve the system's transparency. For example, the lava levels could contain an option to request a justification as to why they changed. This would show a time-series visualisation of the AQS over time (Figure 17).

Significant changes in its value where one- or more users were also present are colour coded. Improvements in air quality are displayed in green, while declines are displayed in red. In the example, Participant 1 caused both an increase- and a decrease in air quality, although the net result is positive. Meanwhile, the air quality only decreased as a result of their presence. Consequently, their score is negative. This extra step could provide more transparency as to how the system makes its judgements.

Furthermore, the experiment had no concrete ending: lava levels were changed over time, yet they did not amount to anything in the end, making it not impactful. To combat this, we see the opportunity to incorporate more feedback.

As the total amount of lava increases, the volcano will start trembling. This increases, until the volcano erupts (Figure 18). After this, a 'scoreboard' containing the distribution of the blame is shown (Figure 19). This remains visible to incite discussions among inhabitants on shared responsibility.

4. DISCUSSION

The aim of this project was to explore the social dynamics of shared environment in order to find opportunities to create a healthier environment. We turned to factors that affect perception of air quality to enable us to measure the cleanliness of the kitchen through sensor data. In order to assess the air quality of the environment, we created an Air Quality Score, which we discussed in the previous chapter.

However, with the introduction of the Air Quality Score, we made the assumption that this would enable us to accurately evaluate the cleanliness of the room. Throughout the process, we learnt that while the AQS allowed us to estimate the cleanliness of the room, it did not allow us to do so with high precision. As such, the system in distributing *'blame'* to users needed to be moderated by humans.

Changes in the sensor setup can be made to produce more accurate readings of the environment. Cameras could be used to acquire a visual overview of the shared space, although we found that such a solution would not be accepted by the participants, as it would be too intrusive on their privacy.

Instead, we could revisit the previously established link between smell and cleanliness. In [8], Macías et al. present their 'Electric Nose': a portable device that can recognize distinct smells by using a neural network classifier. A similar system can be trained to recognize both pleasant- and unpleasant smells, which would allow our concept to better evaluate the air quality.

Alternatively, the need for a very accurate *Air Quality Score* could be removed. In our design we used *blame* as a motivator to promote a feeling of responsibility. However, giving blame comes with challenges. In order to blame somebody, one needs to be confident they were actually responsible for causing what they are accused of.

Instead of blaming those that did not perform well, the system could instead share praise for those that did: being given a false compliment is certainly easier to handle than being falsely accused. This implies that a system based on praise has less strict requirements on accuracy than a system based on blame.

5. CONCLUSION

In this pictorial we have described our application of the Data-Enabled Design approach towards creating a healthier shared living environment. We explained our exploration of the design context through the use of data probes alongside data diaries. Then, we applied the resulting insights by developing- and deploying two iterations of a system that aimed at improving the feeling of responsibility in shared spaces. In the resulting evaluation we found that the systems were unable to increase responsibility among inhabitants of shared houses mainly due to a lack of trust in the system. Finally, we presented a number of suggestions to support related future projects.

ACKNOWLEDGEMENTS

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APPENDIX A

Brainstorm on air quality related factors

As this challenge is to be executed in the design context of air quality. Before the start of the contextual step, a brainstorming session was conducted to explore the question: *"What factors attribute to a good air quality?"*. We defined the following factors Table A1 and set up criteria.

First we listed some factors that may directly relate to the air quality, including temperature, humidity, airborne particulate matter, smell and oxygen level. Other than that, we also include some factors that may affect the perception of the air quality, for example air pressure or wind.

As we are going to use some sensors to detect some factors listed above, a literature review has been made to gain a basic knowledge of the good circumstances.

The comfort indoor temperature, as according to Burroughs et. al. in paper *Managing Indoor Air Quality* [1], are varied in different season, but mainly between 18-24 ℃. And the World Health Organization's standard [3] for comfortable warmth is 18 ℃ for normal.

The comfort humidity, as according to the *Moisture Control Guidance for Building Design, Construction and Maintenance* of Environmental Protection Agency (EPA) [2], indoor humidity levels should be kept between 30% to 50%, with the sweet spot being 45%.

The airborne particulate matter contains many different types of gas and particles, and the factors that most related to air quality include SO2 (Sulfur Dioxide), HC (Hydrocarbons), VOC (Volatile Organic Compounds), CO2 (Carbon Dioxide), NO2 (Nitrogen Dioxide), etc. According to the Oklahoma Department of Environmental Quality [8], the ambient air quality standards for SO2 is one hour average 75 ppb as primary standard and a three-hour level of 0.50 ppm as secondary standard. As suggested by ASHRAE [6], the indoor CO2 levels should not exceed the outside air concentration by more than 650 ppm, and should be lower than 1000 ppm. As the suggested concentration for NO₂ is <100 μg/m3 [4].

For the other factors, a good perceived air quality should not have bad smells, but can be improved by good smells. A comfortable oxygen level is roughly 20%. A comfortable indoor air pressure should be around 1075 bar, as a low or high air pressure can cause headaches, joint pains and blood sugar instability [5]. Finally, a comfortable wind level is 2-3 on the scale of Beaufort [7].

Factor	Good Circumstances
Temperature	Value between 18-24℃
Humidity	Value between 30-50%
*Airborne Particulate Matter**	
> SO_2 (Sulfur Dioxide)	75 ppb per hour
> HC (Hydrocarbons)	
> VOC (Volatile Organic Compounds)	
> CO_2 (Carbon Dioxide)	<1000 parts per million
> NO_2 (Nitrogen Dioxide)	<100 μg/m^3
Smell	Devoid of bad smells. Good smells can improve the perceived quality.
Oxygen Level	Roughly 20%
Air Pressure	1.075 Bar
Wind	2-3 on the scale of Beaufort

Table A1: Factors related to the air quality and good circumstances

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Data Diary

– Air Quality in the Home Environment

Participant's name ______________

Researcher's names ______________

Contact: ______________

APPENDIX B — DATA DIARY BOOKLET

Instructions

Thank you for participating in this study. For the next few days, we would like to ask you to share how you perceive the air quality around you. Additionally, we have a sensor probe that collects real-time data. We ask you to place this in your bedroom area, near a window.

Every page following this one corresponds with one day, and contains the following statement: *"I think the indoor air quality is good, at this moment in time."*

Please use the horizontal time chart (Figure 1) to mark how much you agree with the statement, at that point in time.

You can use the empty lines in the 'Activity log' section to note down the activity you were doing at a point in time.

Please note that you are free to share as much as you want, there is no need to cross every box. Additionally, if you feel comfortable doing so, please share a photo of the probe set-up, and other things you would like to share.

If you have any questions or concerns, feel free to contact the researchers using the contact info on the first page.

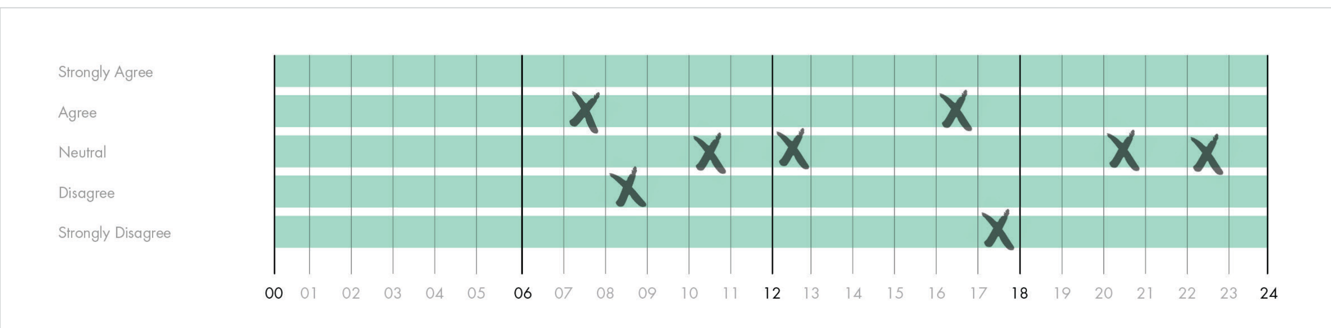

Figure 1: An example of how the time chart could be filled in.

APPENDIX B — DATA DIARY BOOKLET

Please share how much you agree with the following statement.

"I think the indoor air quality is good, at this moment in time."

Date ____________________

	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Strongly Agree																									
Agree																									
Neutral																									
Disagree																									
Strongly Disagree																									

Activity log

APPENDIX C — WEB APPLICATIONS

Web App I — 'Presence Visualisation'

This app is built using HTML, CSS, JS and PHP, and was used to track the participants' presence in their shared kitchen. Participants each have a button that contained their name, which could be pressed to self-report their presence. Additionally, they could share their perception of how clean the kitchen was.

The prototype can be accessed using the following link:
https://arthurgeel.com/data-enabled-design/presence/

Web App II — 'Volcano'

This app is built using HTML, CSS, JS and PHP. Similar to the first app, this allows the participants to track their presence in the shared kitchen. Also, the rating feature as discussed on the left was still present. This app also featured a volcano visualisation of individual responsibility in taking care of the kitchen.

The prototype can be accessed using the following link:
https://arthurgeel.com/data-enabled-design/presence/