Exploring co-performance: Smart devices with better contextual understanding

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ABSTRACT
With smart devices receiving more and more agency to make decisions about our day to day life, a number of studies suggest that users are in need of a way to correct inappropriate behaviour from their devices. That belief is expressed in a design perspective called co-performance. This study evaluates a new implementation of the co-performance perspective using a smart heating device. The goal of this evaluation was to find out what the effect on user experience would be if the smart device was made aware of more contextual information by its user and could thus give a better prediction for ideal temperature. A design was tested with a number of participants in which they provided the thermostat with contextual information through a new set of parameters added to the device. Overall it was found that the user experience diminished through this specific implementation of co-performance.

Author Keywords
H.5.2 [User interfaces]; I.2.10 [User interfaces]; I.2.11 [Distributed artificial intelligence]; K.8.2 [Hardware].

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous; See http://acm.org/about/class/1998 for the full list of ACM classifiers. This section is required.

INTRODUCTION
Smart home systems are making their way into the modern household and are able to regulate the temperature inside homes. These smart heating devices are able to learn patterns of behaviour and use that information to predict preferred thermal comfort (Yang & Newman, 2012). The learning and performing of such smart artifacts is mostly based on previous performances by the user. However, this requires daily-life to be rigid and repetitive, while in reality, it is rather unpredictable. For example, people might get sick or go out for an evening (Kuijer & Giaccardi, 2018).
Smart thermostats are able to learn but are not equipped to take into account these flexibilities that humans would take into account when assessing if the house should be heated or not. (e.g. that they are about to leave). Therefore, these artificial agents may perform inappropriate actions, such as heating the house when the residents are about to leave (Kuijer & Giaccardi, 2018).
Kuijer and Giaccardi (2018) offer a perspective on designing for such artificial agents they named co-performance. Although it is described how the perspective of co-design can be used to design so that these inappropriate behaviours can be corrected by users, we see the possibility to design in order to prevent these behaviours from happening at all. This could be done by making the smart thermostat more aware of the nuances previously mentioned, hereafter referred to as contextual parameters.
To prevent inappropriate behaviour of smart devices from happening, this paper explores the user-friendliness of a design implementation

based on co-performance. In said implementation contextual parameters are added to a smart heating interface that are easily assessable for humans.

We expect that the effort of interacting with the smart device will increase but that users feel that they are better enabled to communicate with the thermostat. In addition, the users may have a better understanding of how the device comes to its conclusion of what temperature is appropriate since the users are inputting the contextual parameters.

RELATED WORK

In related work, we can see a number of perspectives on interaction with a smart heating device.

Snow and Auffenberg (2017) state that traditional smart thermostats have the added capability to calibrate predicted patterns of occupancy with measured patterns of occupancy. They are not fully able to judge whether performed patterns of heating are appropriate for actual situated circumstances. In contrast, Snow and Auffenberg (2017) state that humans are unreliable sensors who will not give repetitive information at certain intervals. Meaning, users most likely tend to only comment on their thermal comfort when it has become uncomfortable. Therefore systems should capitalise on moments when users (are willing to) interact, e.g. in a situation of discomfort. For our research, this would be the case when the user would get active to change the temperature of the thermostat since they are then purposely interacting with a thermostat device to convey their needs. We believe that in that moment of interaction a combination of the best characteristics of both a computational artifact and a person could be combined and explored.

Strenger & Nicholls (2017) explain that smart thermostats are focussed on making life simpler and easier. However, by doing so they neglect nuances and irregularities that are inherent to daily life. Meaning eventually the smart thermostats behave inappropriately since its behavior is derived from a static personal schedule. Therefore it is interesting to investigate a different approach to designing a smart thermostat. Therefore we propose that Co-performance could be explored by using contextual parameters, as to give the thermostat feedback of dynamics schedules.

Several studies (Gatherer, Kuijer, 2016; Kuijer and Giaccardi, 2018) have previously concluded a working definition of co-performance. Although this definition is described elaborately, there is little research on the different possible applications of the perspective of co-performance in design.

Smart thermostats are becoming increasingly able to regulate indoor temperatures. However, they use relatively rigid schedules to make decisions and are not designed to understand contexts in real-time. A perspective on improving this has been created. However, the design implications of this perspective have not been widely explored. Therefore**,** we look to add to this perspective by exploring the effect on the user experience of having users input contextual parameters into their smart devices.

METHOD

The goal of this study was to explore the user experience of an implementation of co-performance, where users could input contextual parameters in a smart heating device. Because of this explorative nature, qualitative research methods were used. These were derived of research of the Norman Group (Flaherty, 2015).

A digital mock-up was built and participants were asked to interact with the mock-up and fill in a questionnaire for a duration of one week. Ideally, users would have interacted with the device whenever they were uncomfortable as they would normally do (log it while it’s hot). However, over the course of the testing period, outside temperatures were relatively high, therefore the participants were asked to interact with the prototype at least twice a day.

To gain insights into the interactions with the prototype a diary was used. After each interaction, the participants were asked to answer a few questions about the situation at hand as well as their overall experience. Deducted from (Moller, Engelbrecht, Kuhnel, Wechsung & Weiss, 2009).

After a week, as a conclusion to the study, an interview was conducted with each participant. In this semi-structured qualitative interview, participants were asked to elaborate on their experiences with the prototype and their opinions on its possible implications.

Participants

In total, six participants took part in this study. All participants were chosen based on the fact that they have a central heating system in their home environment. Four of the participants live in a family household and the other two participants live by themselves. One participant is an electrical engineer who has over 35 years working experiences in the field of thermostat and temperature controls. The other families had no professional knowledge or experience in the field of home heating systems.

Figure 1. Conducting closing interview

Design

The research probe consists of a screen that displays the new suggested temperature when the user changes any settings as well as different coloured rings representing the different contextual parameters. In this iteration of the probe, the setting of the temperature did not have an effect on the actual heating systems of the participants.

The contextual parameters and their respective colors are as follows: (from center to outer ring): *green*, number of persons in the room; *dark blue*, the duration for which heating changes are desired; *orange*, number of clothes that the user is wearing; *grey*, activity level of the user. The rings each feature an indicator that can be moved around the ring to set the parameter to the desired value. These parameters were evaluated as easy to evaluate by humans, but hard to asses without elaborate technologies by a smart thermostat, making them likely to be areas based on which humans would correct their smart device. Moreover, the testing interface featured a send button. If participants completed their interaction, the send button could be utilized to send the quantitative data of the parameters they set to the research database. Each user was also appointed to a color that they were to click every time they sent their data, this would help to match the different datasets to the right participant. *(red, orange, yellow, green, blue or purple*).

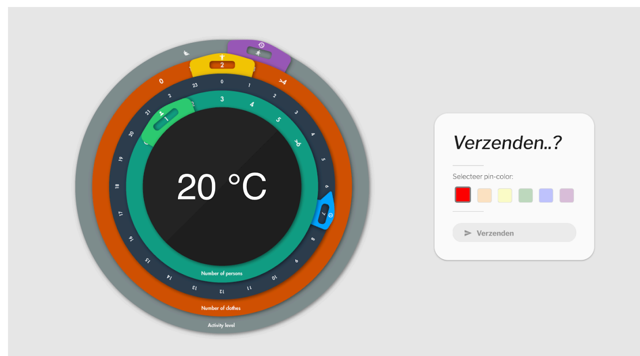

Figure 2. Digital probe

Data analysis

The interviews were labeled with the same color as involved participants were assigned in the digital prototype. Their quotes were codified into different descriptive terms that can be easily recognized. For example Ease of use. The affinity diagram (Holtzblatt, K., Wendell, J. B., & Wood, S. 2005) was used to arrange the insights into a hierarchy that reveals similarities and common issues across all participants.

The collected codes were categorized in order to get refined themes. The software Mindmaple was used to visualize these themes, this helped us to discover the logical relationships such as similarities between these refined themes.

FINDINGS

There are three sets of findings from the study, two of which contain qualitative data about the interactions with the prototype and the third being the quantitative data of what is entered into the prototype. The quantitative data does not provide any new insights as the algorithm behind it was made to be arbitrary. This means that the results are not meaningful as they are not a realistic representation of what would happen with a real smart device.

The qualitative datasets consist of the interview data as well as the data from the diaries. Both sets were searched for user perspectives which can be clustered based on their respective subjects. The main subjects on which perspectives were given can be distinguished as the setting of the temperature, the ease of use of the thermostat, energy saving, smartness of the device and the contextual parameters or research prototype.

Setting the temperature

Participant red concluded that setting the perceived temperature is hard to measure when, he stated:

[...] perceived warmth is not a programmed algorithm that a thermostat can understand and then comfort the person because the perceived ideal temperature is determined by internal and external factors ...

According to the participants, a number of external factors that the device did not take into account influenced their perceived warmth. Participant red mentioned:

[...] external factors like weather and humidity at that moment ...

Also participant yellow mentioned that:

[...] the amount of air flow in the room is not considered ...

Most participants are so used to the normal system that they already have a number in mind when thinking of a suitable amount of warmth. Participant pink mentioned that:

[...] When I filled in the application it worked fine, it always came to a temperature which I thought would be ideal ...

Ease of use

Participants suggested that the current design of a thermostat is highly developed and requires a minimal amount of effort. Participant yellow, a household had difficulties with operating the input parameters from the digital prototype interface:

[...] a better version of the interface would have one ring ...

Energy saving

Participants concluded that the thermostat is not the only thing that can take action to change perceived warmth and as such save costs. Participant red, a temperature control and thermostat engineer, for example, stated:

[...] it is cold outside. If you wear a sweater this will save you 10 euro on energy. If you don't want to do, I will put degree two degrees higher ...

Also, it was stated that although smart thermostats can help save energy their costs frequently do not yet outweigh the cost of the energy saved. When discussing with participant yellow for instance, about why they did not own smart thermostat, they responded:

[...] Smart thermostats are often delivered with new energy contracts, however, if you are a long time customer you do not get these kinds of deals. That means you either pay for the device monthly or you go through all the effort of changing supplier ...

Smartness of the device

Participants made a number of remarks regarding the 'smartness' of the device and how that impacts the interaction they have with the device. Participant red provided some insight on a different approach of constructing the co-performance setup:

[...] having a centralized interaction point and a distributed system will help you to achieve co-performance ...

Some participants also had some experience with systems that did have a form of co-performance built into them already. For instance, participant yellow described a thermostat they have at work as follows:

[...] there is a thermostat in which you give feedback through one or two buttons, this is a smart thermostat that allows you to give feedback on whether or not it is too cold or too warm, that is it ...

It is stated that making the system voice controlled might make the interaction less bothersome and feel more cooperative. Moreover,

participant green, when discussing the interaction of the prototype, mentioned:
[...] I do not want it to take any effort … I want it to be voice controlled ...
Participants explained that they see a role for the thermostat to be more proactive in starting the discussion and negotiating. Participant red mentioned the following when discussing the smartness of the device:
[...] are you comfortable with this current degree? … Do you plan to keep this degree when the outside temperature increased? ...

Contextual parameters
Participants made several remarks on that they felt limitations when they had to input the parameters.
When discussing if they felt they could input the situation correctly into the device. Participant Pink felt the time was not specific enough. Saying :
[...] I am only cooking for 40 minutes, but the shortest possibility is 1 hour ...
They also felt there were shortcomings when they had to input how active they were:
[...] What if I am active, but someone else is not. ... I might be doing something. Although but I am not inactive, but to really say really say I am active ...
When discussing inputting how warm they were clothed participant Yellow mentioned:
[...] Some of the parameters are very unintuitive. For instance, the fact that clothing is measured on an arbitrary scale is confusing ...
When asked how they would normally use their thermostat in comparison to now participant Pink answered:
[...] Normally I would turn on the thermostat and leave it for a few hours [...] I would not play with it in-between …

DISCUSSION
In this study participants show their user experience to be negatively influenced by the introduction of contextual parameters to a smart heating device as a means to better predict ideal temperatures.
This can be attributed to a number of factors.
First of all, the design of the thermostat is one that has gone through numerous iterations over a long period of time, making it so that the effort required to operate it is comparatively low.
Although it was expected that the interaction would take more effort, it was thus received negatively, as the standard is set so clearly for this specific device.
Second, users experienced setting the time as such more difficult. Although most parameters are easy to evaluate, to then communicate said information to a smart device proves to be more complicated. For instance, users found that the parameter for clothing was too abstract compared to their own sensory experience.
Finally, contextual parameters are dynamic, creating a need for the user to interact with the thermostat frequently. Since it is not always possible to predict upcoming activities, as the situation around the house is ever changing.
Having concluded that the addition of contextual parameters to better predict ideal temperatures is an ineffective approach to implementing co-performance principles, one could look at the functional benefits that contextual parameters might bring to other co-performance designs.
Although setting the ideal temperature is an important act, it might not offer as much room to effectively co-perform. An alternative that was considered based on one of the interviews is one where the thermostat uses data from the contextual parameters to challenge ideas on heating behavior. For instance, instead of having clothing dictate the experienced temperature, the thermostat could make a suggestion for a change of clothing to save costs on heating. In that way, we not only apply co-performance to repair system decision making but to help us repair our own inappropriate decisions instead.
This study was made possible by the use of a web-based interface rather than a more realistic physical prototype. Through the use of said interface, it was possible to have a number of users operating the thermostat at the same time. This however made the interaction slower and less clear on its affordances than it would have been otherwise. It should be taken into account

that carrying out the study with a physical prototype might yield different results.
Similarly, the study featured an arbitrary temperature algorithm that did not respond to every parameter the way it would in real life. This may have contributed to participants feeling the system did not assess their situation correctly. This in itself is a result of showing the temperature on the interface. For future designs or studies, It might lead to new insights if one were to consider removing this functionality altogether. The reason for this is that changing the number of the temperature is not part of the user agency.
Participants also raised some questions on the design choices in regards to the parameters. The chosen parameters were not perceived as optimal as some of them had minimal effect on the experienced temperature or were hard to input. Future designs involving co-performance could consider the extent to which different parameters have a notable effect on temperature and if users can actively distinguish and input them. Only if all these requirements are met, one should consider an input parameter.
If asked to a user, they are often able to come up with a large number of different parameters that could influence their decision making. However, there seems to be a trade-off between what users are willing to input and what think they would like to input to contribute to the interaction. If given the choice, participants opted for more options and more precise parameters, even though they had already concluded they found the interaction to be effortful.

CONCLUSIONS

Through the qualitative data collected in an experiment testing the experience with a contextual parameter based smart thermostat, it can be concluded that user satisfaction or experience diminishes with the addition of new contextual parameters to better predict ideal temperature.
In a discussion of the results, a suggestion was created for a different use of contextual parameters than to find the ideal temperature. We believe that the data gathered from these parameters can be used by a smart device to better challenge existing practices or ideas about household heating.
And there is room for exploration of other applications of the perspective of co-performance.

ACKNOWLEDGMENTS

We thank all volunteers. We would also express our gratitude to all the staff members that gave lectures and supported us throughout our research.

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APPENDIXI - INFORMATION ON THE TEAM

Almar van der Stappen

Almar is an Industrial Designer and a BSc. a graduate of the University of Technology in Eindhoven. His design vision relates to commercial smart devices for everyday use. As a designer, he is able to provide quick intelligent prototypes for user testing of high tech products.

Contribution:

Almar conducted research with one of the participants as well as being responsible for the findings, discussion and conclusion in the research paper. More generally, he contributed to all parts of the research.

Matthijs Hoekstra

Matthijs his interest in the design world focuses mostly on designing for smart environments. He has an interest in the Internet of Things, fast prototyping, and developing new and interesting applications.

Contribution:

Matthijs focussed during this project particular on realizing the digital interface, either design and developing it. Furthermore, he wrote most of the method section. Overall he contributed to all parts of the research.

Seiji Bernabela

Seiji is an Industrial Desing BSc. a graduate of the University of Technology in Eindhoven. Mostly interested in user experience and interaction design. He preferably uses low fidelity prototyping to evaluate ideas.

Contribution:

Seiji conducted the research at two participants, made the presentation and presented it. He assisted with the data analysis and drawing conclusions. Overall he contributed to all parts of the research.

Yiwen Shen

Yiwen is an Industrial designer and a BSc, a graduate of Saxion University of Applied Sciences. He interested in multimedia technologies, interaction design, prototyping and applying parametric design solutions in digital fabrication.

Contribution:

Yiwen conducted an interview with one participant. He also executed data analysis and visualization for the research team in order to draw conclusions. Overall he contributed to all parts of the research.

Krishnaa Seck

Krishnaa is an Industrial Designer and a BSc. graduate of the University of Technology in Eindhoven. Her focus as a designer is on social communication and user experience. She preferably uses physical prototyping to aid iterative design processes.

Contribution:

Krishnaa created some different iterations of physical prototypes, that aided in tweaking the final prototype used within this research. Furthermore, did she conduct the research for one participant. Also, she partook in the collaboratively drawn analysis, conclusion, and discussion. Overall she contributed to all parts of the research.

Ruben Brouwer

Ruben is a Creative Technologist and a BSc. a graduate of the University of Twente in Enschede. He is interested in user experience, interaction design and commercial implementations of smart devices.

Contribution:

Ruben designed the booklet and he conducted the research for one participant. Also, he partook in the collaboratively drawn analysis, conclusion and discussion. He assisted in making a visualisation of the data and the interview setups. Overall he contributed to all parts of the research.

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with better contextual understanding

INTRODUCTION

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so that these inappropriate behaviours can be corrected by users, we see the possibility to desi
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PMRIWW SJ E HIWMKR MQTPIQIRXEXMSR FEWIH SR GS TI
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enabled to communicate with the thermostat.

PROTOTYPE

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GLERKIW ER] WIXXMRKW EW [IPP EW HMJJIVIRX GSPSYVIH
IXIVW 8LI GSRXI\XYEP TEVEQIXIVW ERH XLIMV VIWTIGXM
VMRK KVIIR RYQFIV SJ TIVWSRW MR XLI VSSQ HEVO FP
WMVIH SVERKI RYQFIV SJ GPSXLIW XLEX XLI YWIV MW [I
XIWXMRK MRXIVJEGI JIEXYVIH E WIRH FYXXSR -J TEVXMG
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Discussion

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XLSYKL MX [EW I\TIGXIH XLEX XLI MRXIVEGXMSR [SYPH ...
EW XLI WXERHEVH MW WIX WS GPIEVP] JSV XLMW WTIGMJMG HIZMGI
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in their own sensory experience ...
XLIVQSWXEX JVUYIRXP] MRGI MX MW RSX EPIEVP] ...
around the house is ever changing.

About Researchers

REFERENCES

[illegible]

Ease of use

• Participants suggested that the current design of a thermostat is highly developed and requires a minimal amount of effort.
4EVXMGMTERX]IPPS[-E LSYWILSPH ... culties with operating the input parameters from the digital prototype interface:
(...) a better version of the interface would have one ring ...

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• Participant red concluded that setting the perceived temperature is hard to measure when, he stated:
(..) perceived warmth is not a programmed algorithm that a thermostat can understand...
• According to the participants, a number of external factors that the device did not XEOI MRXS EGGSYRX-MR¾YIRGIH X ceived warmth.
• Most participants are so used to the normal system that they already have a number in mind when thinking of a suitable amount of warmth.

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(...) it is cold outside. If you wear a sweater this will save you 10 euro on energy. If you don't want to do, i will put degree two degrees higher ...
• Also, it was stated that although smart thermostats can help save energy their costs frequently do not yet outweigh the cost of the energy saved.

Data Analysis

are you comfortable with this current degree? ... Do you plan to keep this degree when the outside temperature increased?

Smartness of the device

• Participants made a number of remarks regarding the 'smartness' of the device and how that impacts the interaction they have with the device. Participant red provided some insight on a different approach of constructing the co-performance setup:
(...) having a centralized interaction point and a distributed system will help you to achieve co-performance ...
• Some participants also had some experience with systems that did have a form of co-performance built into them already. It is stated that making the system voice controlled might make the interaction less bothersome and feel more cooperative.
• Participants explained that they see a role for the thermostat to be more proactive in starting the discussion and negotiating.

Contextual parameters

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Saying :
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• They also felt there were shortcomings when they had to input how active they were:
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• When discussing inputting how warm they were clothed participant Yellow mentioned:
(...) Some of the parameters are very unintuitive. For instance, the fact that clothing is measured on an arbitrary scale is confusing ...
• When asked how they would normally use their thermostat in comparison to now.

Participants → Data Collection → Data visualization → $éQLW\ GLDJUDP

In total, six participants took part in this study. All participants were chosen based SR XLI JEGX XLEX XLI] LEZI E XLIVQSWXEX ing system in their home environment. *SYV SJ XLI TEVXMGMTERXW household and the other two participants live by themselves. One participant is an electrical engineer who has over 35]IEVW [SVOMRK I\TIVMIRGI thermostat and temperature controls.

8LI VE[HEXE [EW GSPPIGXIH ... EW XLI HEXE [EW GSPPIGXIH ... FSSOPIX X[S SV XLVII ... TEVXMGMTERX HMVIGXP] ... 4VIHIJMRIH UYIWXMSRW ... 3SV XLMW MRXIVZMI[... XLI VIWIEVGLIV [MXL WSPMH IZMHIRGI JSV XLI JYXYVI HEXE EREP]WMW

The interviews were labeled with the ... Interview were transcribed ... descriptive terms that can be easily recog... were then categorized in order ... was recorded as well in order to provide

The main subjects on which perspectives were given can be distinguished as
• XLI WIXXMRK SJ XLI XIQTIVEXYVI
• XLI IEWI SJ YWI SJ XLI XLIVQSWXEX
• IRIVK] WEZMRK WQEVXRIWW SJ XLI HIZMGI
• the contextual parameters
• research prototype.

CONCLUSIONS

Through the qualitative data collected in an experiment testing the experience with a contextual parameter based smart thermostat, it can be concluded that user satisfaction or experience diminishes with the addition of new contextual parameters to better predict ideal temperature. In a discussion of the results, a suggestion was created for a different HQW XVH RI FRQWH[WXDO SDUDPHWHUV WKDQ WR ¼QG data gathered from these parameters can be used by a smart device to better challenge existing practices or ideas about household heating. And there is room for exploration of other applications of the perspective of co-performance.

Yiwen Shen

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At the beginning of this elective, CDR seems to be a mysterious term to me. From what I have experienced in my previous education. When conducting a design research project, I usually invest a lot of time on doing product background research, then collecting & analyzing data and eventually drawing conclusions based on acquired data. The conclusions serve to design a prototype. The goal of this prototype is to satisfy the user's needs in their context.

Working on this research project has brought me totally different experiences. First of all, a well-thought research question needs to be determined, design goal and target group should be also clarified in the research team. The prototype needs to be ready for testing before the pilot setup. The prototype is initiated by the research question and a tool to generate user data. When using the prototype (a laser-cut low-fi thermostat in this project), the more conflicts as we received from participants, the more useful data that could be generated. However, from what I have seen in other research teams, by using the showroom method could offer more conflicts when interacting with the prototype.

Dairy and contextual inquiry were used in this project also to collect data. It was the first time I used dairy study in a research project, which was proven as an effective way to observe daily habits and user's behaviours in a situated context. However, this method also requires that participants have a high level of commitment to your research project. Therefore it is recommended that researchers or designers should to make the setups/dairy booklet easy and enjoyable to use in order to improve their level of commitments. Data analysis and visualization was my major contribution to this project. I used the affinity diagram to cluster and visualize data. When drawing conclusions, this affinity diagram has positively helped the research team to address the most discussed elements.

The value of qualitative field approaches for exploratory design

I strongly feel that there are two types of knowledge are needed when doing research through design: 1)Knowledge of the research product (eg. thermostat, 'co-performance'). 2)Knowledge of the data collection & analysis. In this research project, because we were lack of experience and knowledge of thermostat, the selected parameters could be chosen differently as what we currently used in this prototype. On the other hand, due to the characteristics of the field methodology, which about explores the situated context, we have generated a lot of insights. However, some findings yet only deliver a limited depth due to that the acquired data is not all relevant and valuable to contribute a potential design solution. In the Lab method, the collected data seems to be more scientific and reliable, designers also have a greater deal of control over the context.

Conclusion: This elective helped me to formalize sequences of doing research through design with using the field methodology and tools (eg.dairy booklet). It also raises the awareness of how a suitable method can contribute to a research project. I have learned a lot from this course, not only the theoretical frameworks of CDR, but also gain practical experience to quickly apply these methods to new research projects.