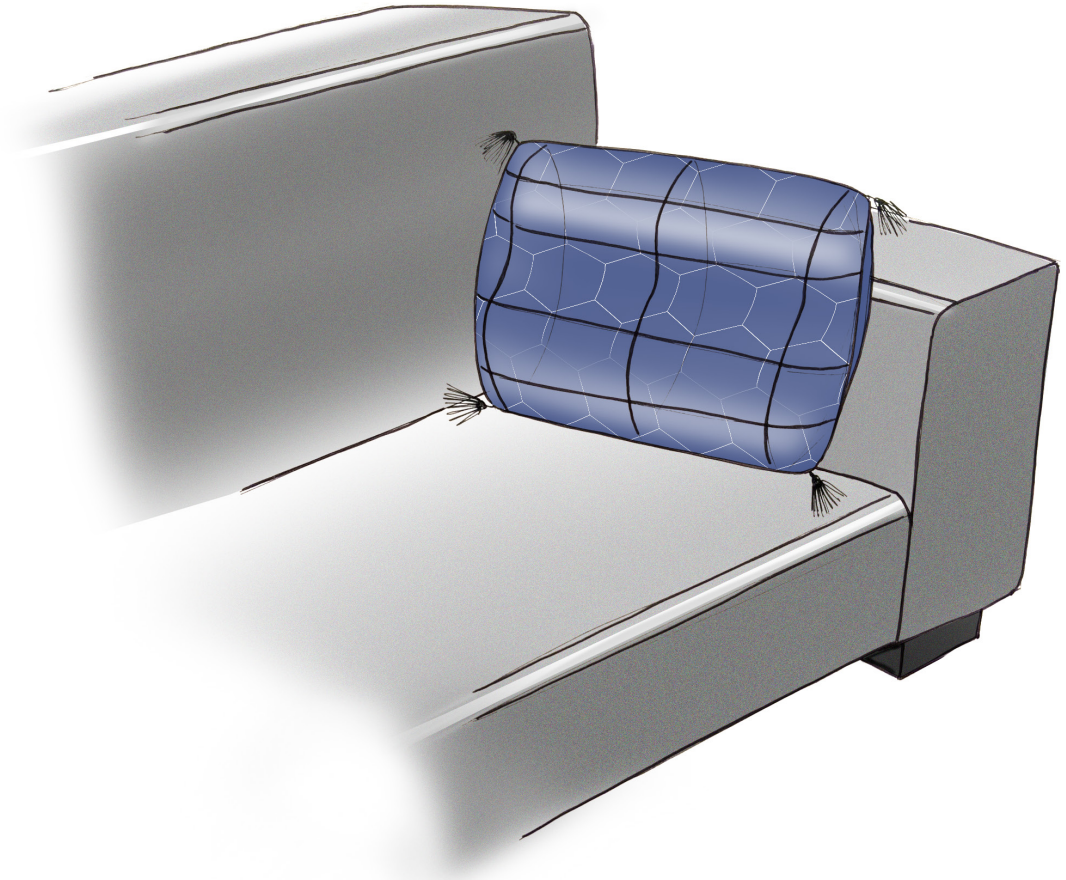
The making of a smart pillow

Designing an object with intent through a data-enabled design process



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Summary

Leisure is defined by the Cambridge dictionary as: “The time when you are not working or doing other duties.” During this time, people engage in a broad variety of activities. They engage in these activities because they want to and because it makes them happy in some way. Newman et al (2013) researched the underlying psychological pathways by which leisure evokes happiness. They proposed five core psychological mechanisms through which leisure promotes subjective well-being (SWB). These mechanisms are detachment-recovery, autonomy, mastery, meaning and affiliation. Which activity triggers which mechanism, can differ per person and one activity can trigger multiple mechanisms.

This project focuses on the mechanism of detachment-recovery. By utilising a user-centred approach, it was found that people were not always satisfied with their leisure time, more specifically with the recovery time they spent on the couch. The dissatisfaction had two main causes. Firstly, they were distracted from the activity they were engaging in. Secondly, they spent longer on the couch then they initially had intended to. To tackle those two causes, a smart pillow was designed.

The concept of a smart pillow came to fruition by using a new perspective on smart objects, the perspective of objects with intent (OwI) (Rozendaal, Boon, & Kaptelinin, 2019). Objects with intent are everyday objects that act as collaborative partners in human activity. OwI’s are a type of agent and they take advantage of the meaning of everyday things as a site for intelligence and agency. Rozendaal et al (2019) prototyped the concept of an OwI by using a wizard of Oz style of prototyping (WoZ). In this setup, the researcher acted as the sensors and intelligence of the Object. In this project, I take a step towards the design of a fully autonomous OwI by applying a data-enabled design approach (J. van Kollenburg & S. Bogers, 2019).

In this project, I explore how I can apply a data-enabled design approach. I show my approach, the tools I use, the visualisations I have made and the insight I have gained. By doing this I aim to inform fellow industrial design students on how they also can apply the data-enabled design. In this process, one specific visualisation was found to be very useful. This was a 3D representation of the prototype of the pillow in which data gathered by sensors in the prototype were visualised on the 3D representations. This representation was an animation which was matched with video recordings of the usage of the pillow.

Acknowledgements

Throughout this project, I have received help and support from many friends and family members, I'd like to thank a few people in particular.

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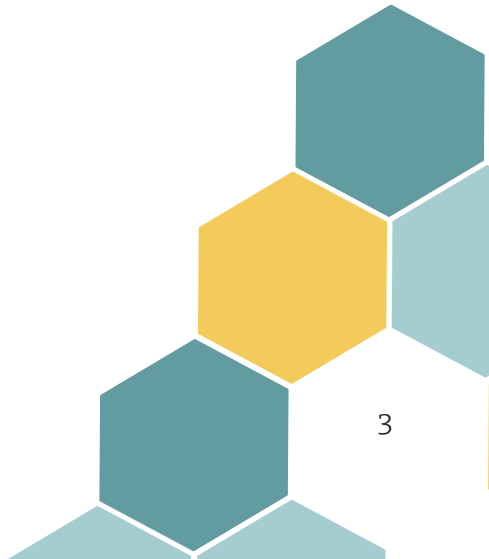


CONTENT

1. Introduction

This thesis presents the work and the results of the graduation project of Tjapko Vermeulen that focuses on the development of an object with intent through data-enabled design that aims to improve people's leisure time. In this project, the research of Marco Rozendaal on Objects with intent (OwI) and the research of Jacky Bourgeois on Data-Centric Design (DCD) comes together with my personal interest in designing something that helps people to deal with their leisure time. These three topics make the three pillars of this graduation project. (1) Leisure: the experience of leisure time and ways in which people deal with this, (2) OwI: a focus on a new perspective on smart objects concerning what they are and how people interact with them and (3) DCD: a focus on new design methodologies that work with machine data. Each pillar has a particular goal in this project and helps to limit its scope. While each has a particular goal, they cannot be seen as separate entities. They are intertwined and form the basis of this project. In the next section, each pillar is explained in more detail by expanding on its goal and the role it will play within the project.

1.1. Pillars

1.1.1. Relaxation in the living room

The role of the first pillar, leisure, is being the context of the project. This was chosen because of two reasons, the first being my personal affiliation with the topic. I always found it interesting to understand how some of my peers found the time to work on personal projects while others spend their leisure time watching Netflix and both of them seemed to be content with how they spent their time. Within this project, I am personally interested to find out what motivates people and what energises them during their leisure time. More specifically, the context relaxation within the living room was chosen as a more practical informed choice.

The second reason for specifying relaxation within the living room has to do with the availability of the comfort lab. The comfort lab is a room within the faculty of industrial design that is modelled after a living room with a remote camera setup for observations. This allows for less time to be spent on organising user tests and more can be spent on actual research and design.

Thus, the goal of this pillar and the overall design goal of this project is to improve the quality of people's leisure time.

1.1.2. Object with Intent

Objects with intent (OwI) is a design perspective on smart objects as being everyday objects that act as collaborative partners in human activity. For instance, a lamp or a jacket, or in the case of my graduation project, a pillow. When such familiar everyday objects are endowed with sensors, computing power and actuation, it allows them to act on their own and be designed to collaborate with people towards a shared goal. For example, when it is time for bed, a lamp can lower its intensity and change the tone to help the user get ready for bed. Stated more specifically, OwI's are a type of agent and they take advantage of the meaning of everyday things as a site for intelligence and agency. (Rozendaal, Boon, & Kaptelinin, 2019). As such, they are a new type of agents that are different from social robots or ambient intelligent environments.

Within this research, there is a design case in which they designed a ball, Fizzy, to stimulate physical play with hospitalized children. From that case, they learned how children actively played with Fizzy intermittently for about 30 minutes when the object performed the 'right' behavioural strategies based upon the 'right' environmental cues. In general, this shows the importance of conscientiously designing the required behaviour of the object when it intends to engage with people in a particular collaborative activity. And how it is crucial to figure out which environmental cues the object needs to pick-up

for it to act as an autonomous agent. Another part of its success can be allocated to the fact that fizzy was versatile and open in play. This was because it was framed as a hybrid character, being a sequence or combination of a thing, tool and an agent. A thing refers to Fizzy being an object of examination and experimentation. A tool refers to Fizzy being used to play games with. And an agent refers to Fizzy being framed as a creature. When designing an OwI in the context of this graduation project, I learned how here too such an object can have different 'faces' and allow for different kinds of interaction.

These insights were gained by deploying a Wizard of Oz style prototyping approach (WoZ). This entails that the researcher was controlling Fizzy remotely and faking its intelligence. Care was taken that the participants did not know the researcher was controlling Fizzy. This allowed a test setup in which Fizzy was treated as an autonomous object without having to make it autonomous.

How does my graduation project build further on the understanding of OwI's? The goal of this pillar is to further the research of objects with intent by looking into how to actually make an OwI autonomous. As found in the case of Fizzy, for an OwI to be effective it is important that it behaves in the 'right' way based upon the 'right' cues. However, the questions that arise are 'What is right?' and 'How does the OwI know it is right?'. Within the case of Fizzy what is right is determined by the researcher, a human. For this case, some movements were designed upfront but the control of Fizzy happened in an improvisational way by responding to play opportunities. The researcher uses its senses, knowledge and intelligence and behaves through Fizzy. While this was an effective way for them to create a test setup that answered their questions and this could be an effective way to find what kind of behaviour could be right, a problem arises when trying to translate the wizard of oz style prototype into an autonomous.

The core of the problem is the current implementation of the wizard of oz style approach, using a human to observe and process the situation to determine the right behaviour. This is an issue because reasoning is not always conscious or explicit and it relies on input and understanding of human behaviour which computers do not have per se. Secondly, even if one could simulate the reasoning of a researcher, one would need to have the same inputs the researcher has. In the setup used in Fizzy this would mean simulating seeing, hearing, tasting, feeling, smelling. Which would not only be complicated and impractical but would also raise a lot of privacy concerns.

Therefore, the research question for this pillar is: How to design an object with intent that can detect cues and respond with behaviour that contributes to achieving its intent? The role of OwI within this project is being part of the solution to the design goal of improving people's leisure time. To obtain this goal we intend to use a data-centric design approach that will now be elaborated.

1.1.3. Data-Centric Design

The second pillar in this graduation project is to find out 'how' to design an object with intent that can detect cues and respond with behaviour that contributes to achieving its intent, and is thus a methodological question. The hypothesis is that a part of the answer to that question lays in thoroughly understanding what the object can sense. As found in Rozendaal et al (2019) part of the success of Fizzy can be attributed to its response to specific cues. In order for it to successfully respond it is crucial to understand what cues it can detect and how they are meaningful in the context of human-object collaboration. To get a thorough understanding of what the object is able to sense and detect, the data-centric design is added as the third pillar of this project. The role of this pillar is being part of the method that designs an OwI that improves people's leisure time.

According to the Delft Design guide: "Data-Centric Design is an approach for generating design-relevant insights from quantitative data, and it complements the qualitative design and research methods." (van Boeijen, Daalhuizen & Zijlstra, 2020, p. 77). To implement this approach in my design process, the dissertation of J. van Kollenburg & S. Bogers (2019) is used as a starting point. In their dissertation, they present two objectives. The first objective is to further develop the understanding of intelligent ecosystems. The second, and main objective, is to develop a data-enabled design methodology.

For the first objective, they first introduce intelligent solutions as a new generation of smart products. The first generation of smart products are products with digital sensing capabilities that provide the user with insights into the data it gathers. However, intelligent solutions go further than that. Their definition of intelligent solutions is as follows:

"An intelligent solution is a product or service, or a combination of these, that uses data and artificial intelligence and algorithms to gain a detailed and nuanced understanding of its context and user. It can develop this understanding over time and can adapt to personalize its interactions and services."

In parallel they see a trend in products becoming more connected and exchanging info and becoming part of a network. They call these networks ecosystems. Finally, they combine these two into intelligent ecosystems where intelligent solutions share their abilities across different elements in the ecosystem.

To develop the understanding of intelligent solutions and a data-enabled design methodology they did three case studies, after each study, they iterated on their methodology. In the first case study, they designed an intelligent solution for tracking bottle-feeding babies. The second case study, they designed an ecosystem that supports parent-healthcare professional interactions, through parent tracked baby data. In the third case study, they designed an intelligent ecosystem around personal health.

Based on these case studies they present the data-enabled design framework (Figure 1). In this framework, they use an 8-shape model to show that they continuously explore and iterate during the design process. They argue for a situated design process where users remain in their everyday life setting. Data allows the researchers to remotely gain contextual, behavioural and experiential insights and data enables them to remotely conceptualize and deploy new design interventions. They also argue that these situated design explorations can have a contextual or informed character. These explorations can run in parallel and continuously follow each other up. Finally, they stress the importance of a multi-step design process, during which a new group of participants is introduced regularly. This helps the intelligent ecosystem to not become bespoke but to become personal on a large scale.

This framework is to be used by design research as handles to help adopt a situated design approach in which data can be used as a creative design material when designing for intelligent ecosystems.

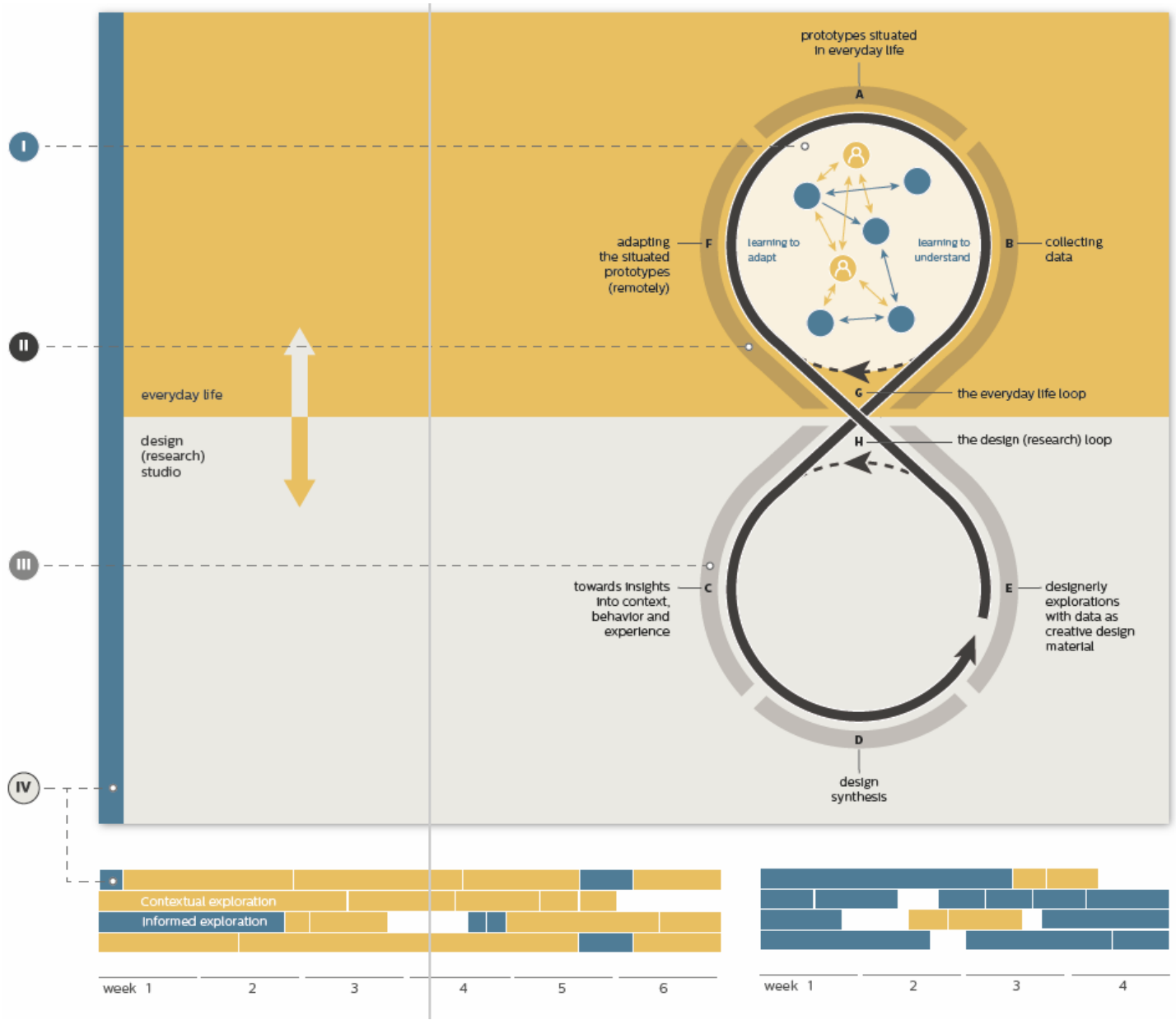


Figure 1 - Data-enabled design framework by J. van Kollenburg & S. Bogers (2019)

While they provide compelling arguments to adopt their framework and employ a situated design approach, I decided to only use their work as a basis to form my own approach.

The first and main reason for this is that they are designing intelligent ecosystems, which have multiple intelligent solutions in them and intelligent solutions are viewed as a new generation of smart products. However, OwI is a new design perspective on smart objects, where smart objects are everyday objects that act as a collaborative partner. OwI's are similar to intelligent solutions in that they use data and could use artificial intelligence and algorithms to gain a detailed and nuanced understanding of its context and user. This understanding could also be developed over time and used to adapt and personalise its interactions. OwI's are however distinctly different in that they are everyday objects, that act as a collaborative partner. Whereas an intelligent solution is a product or service, or a combination of these. In the case study of the baby bottle, most of the interaction with the intelligent solution happens through an IOS application where the users could see visualizations of the data tracked by the baby bottle and they were provided with insight cards. The baby bottle did not have much of an agency and the interaction was more similar to interaction with a chatbot than to interaction with an OwI.

The second reason is the difference in the scale of their project. This project is my graduation thesis, whereas the case studies in the dissertation were for a PhD. Their case studies were run at Philips and had clear business relevance. Figure 2 shows the size of the team and the length of the case study of the baby bottle. While the involvement of people varied, they did have 10 people that have been full-time involved in the project at some point. It also shows the project ran for 9 months. Whereas within my graduation I work individually while being supported by my chair and mentor for 6 months.

Finally, at the start of the first case study, they already had a product, the baby bottle, which they could immediately equip with sensors. Whereas I start out with the context of people relaxing in the living room, a relatively big space compared to a baby bottle. While in the last case study they equipped a household with multiple sensor-equipped products, the difference in scale plays an important role here again.

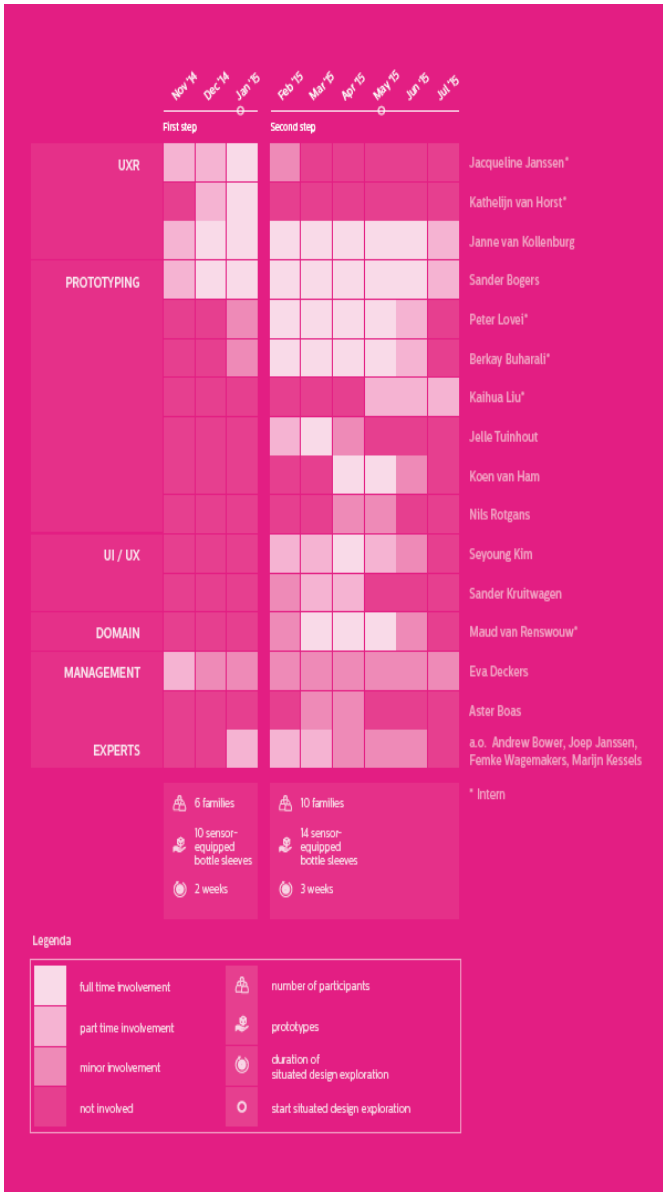


Figure 2 - Overview of the first case study from J. van Kollenburg & S. Bogers (2019)

Although I did not adopt their framework, they did still provide valuable insights into how data can be utilised. This was done by showing a creative and generative approach in which data can be utilized as a creative design material. Whereas other approaches use data more as an evaluative tool. Using data as creative design material allowed them to get a nuanced and detailed understanding of the user and the context. Which is important because an OwI uses this understanding of the context and the user to act upon and only has data to base its understanding on.

They did this by gathering a combination of sensor and qualitative data. They found that the different types of data enriched each other qualitative methods could help interpret sensor data. This led to better and additional insights. They also utilised sensor data in qualitative methods, through a data-enabled interview session.

Sensor data was gathered by making a sensor-equipped prototype. In the first case study, they started with a regular baby feeding bottle and added sensors to it, making it a sensor-equipped prototype. Afterwards, they transitioned into a function prototype which had actuators in addition to sensors.

Insights from the sensor data were gained through data visualizations. By exploring multiple visualisations they could see different perspectives on the data and the context. To

create these visualisations they build a tool themselves.

To summarize, I will use an adapted version of their creative and generative approach in which data is utilized as a creative design material. I will do this by gathering sensor data in combination with qualitative data. This data will be used to create visualizations in order to gain a detailed and nuanced understanding of the context, the users, and an object with intent.

However, when they talked about the dissemination of their research they expressed how difficult it can be to deal with data-enabled design without the proper skills and tools. This was further confirmed for me by the fact that they were working in multidisciplinary teams that included a data scientist. They also utilized custom algorithms and a custom interface for their data visualisations.

Herein lies the challenge for my project, how can I, an industrial design student, use data-enabled design. While creating electrical prototypes is part of my curriculum, working with and visualizing data is not. Therefore the goal of this pillar is to find out how data-enabled design can be used by design students and become part of their designers' toolkit.

I will explore this goal by using a variety of tools in intended and unintended ways. The tools I will use are either freely available, available to TU Delft students, or tools that are already widely used by peers. Throughout this thesis, the use of these tools will be documented. In the end, a reflection will be made of the use of these tools and on what a custom made tool could look like.

1.1.4. Summary

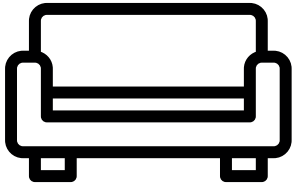
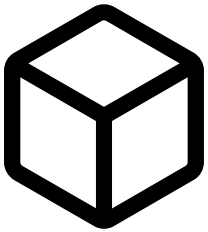
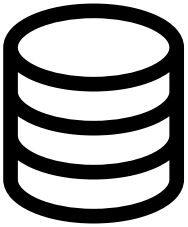
		
Relaxation in the living room	Object with Intent	Data Centric Design
Context	Solution	Method
To improve people's quality of life by improving their leisure time.	How to design an object with intent that can detect cues and respond with behaviour that contributes to achieving its intent?	Dow data-enabled design can be used by design students and become part of their designers' toolkit?

Figure 3 - Overview of the pillars of the project

In figure 3 an overview of all three pillars, including their role and their goal, is given. To conclude, the goal of this project is to design an OwI that improves the quality of life of people by improving their leisure time. To ensure the object is effective in achieving its intent, care is taken in thoroughly understanding the perspective of the object by applying data-centric design. While applying data-centric design, explorations are made on how data can be used by design students and become part of their designers' toolkit.

1.2. Methodology

To achieve all three goals, I engaged in a data-enabled design process that combined the traditional 'staged' design process with the mindset of Agile development. This project is divided into four phases 1) Context exploration 2) Concept development 3) Sensory intelligence 4) Concept design. Although the phases had a different goal, the approach was the same. A detailed planning was created every two weeks working towards the goal of each phase. At the end of the two weeks, there was a coaching session in which progress was evaluated. Afterwards, a new, detailed, planning was created for the next two weeks. By having biweekly evaluations and an agile mindset we were able to be flexible and adaptable to findings and insights throughout the project.

1.2.1. Phases

Context exploration

The aim of the first phase is to enable a first informed design of an OwI. To do so it is deemed important to get a good understanding of the context and a more specific design goal. This phase is also used to get familiar with the collection and analysis of machine data.

This is done through a user observation where the user is observed through a camera and through sensors. Following this observation, people are interviewed to gain additional insight into their experience. The data from both observation and interview is then processed and analysed. In order to validate the findings, they are compared to psychology research. These findings were then used in a co-creation session to gain additional insights. From this, a specific design goal was created.

Concept development

In the second phase, the first iteration and prototype of the design are created. This is done by first determining an intent for the object that would be a meaningful and relevant addition to peoples lives (i.e., being a collaborative partner for people within a particular context of use). Then through storyboarding and by being inspired by the observations, a relevant object is chosen to achieve its intent. From there the shape is designed and a prototype is created.

Perspective discovery

The third phase of the project aims to enable the further development of the concept. This is done by developing an un derstanding of the perspective of the user and of the object with intent. The perspective of the user shows how they view the object as a tool and what behaviour they desire from the object as an agent. The perspective of the object aims to build an understanding of the sensory intelligence of the object.

To find this information another user test is executed. For this user test, a sensor-equipped prototype is created, by making an assassin and implementing sensors that could provide relevant information to the OwI. The test itself starts out with an observation of the usage of the object. Following the observation, users are interviews about their experiences with the pillow and are asked to co-create together with the designer. During the observation, sensor data is gathered about the usage of the object. Afterwards, the sensors data, the observation and the co-creation are analysed and conclusions are drawn.

Concept design

Based upon the findings in the third phase a final concept design is proposed. First, the conclusions from the previous phase were used to create the design. Then, through a storyboard, the usage and the behaviour of the concept are explained. Afterwards, information is given about its sensors and actuators that would be required for the object to achieve its intent.

1.2.2. Data

Data plays an important role within this project, however, there are multiple kinds of data. To avoid confusions within the project and in this thesis, three different types of data are made explicit. As can be seen in the figure 4 below, the three types of data are 1) machine data, 2) behavioural data, 3) Subjective data.

Machine data is the data that is collected through sensors. In its raw form, it is multiple lists where each entry has a timestamp and a number. In phase 1 and 3, it is explained how this raw data is transformed into something tangible, inspirational and informative for me as a designer. This data is gathered in order to get an understanding of what an object could sense and detect in its context.

Behavioural data is data that aims to show how people interact in the context and with the object. It is based on researchers' observations of user tests and is combined with machine data to give insight into what kind of behaviour the researcher and/or the machine can see. This data is gathered to find behavioural cues of a user to which the object could meaningfully respond.

Subjective data is collected through interviews with the user. It is data that tells how people see and feel about their current leisure time and how they would like to see it. This data is gathered to learn what kind of behaviour of the user is desired, what kind is not, and how the object should help stir the behaviour of the user towards the desired behaviour.

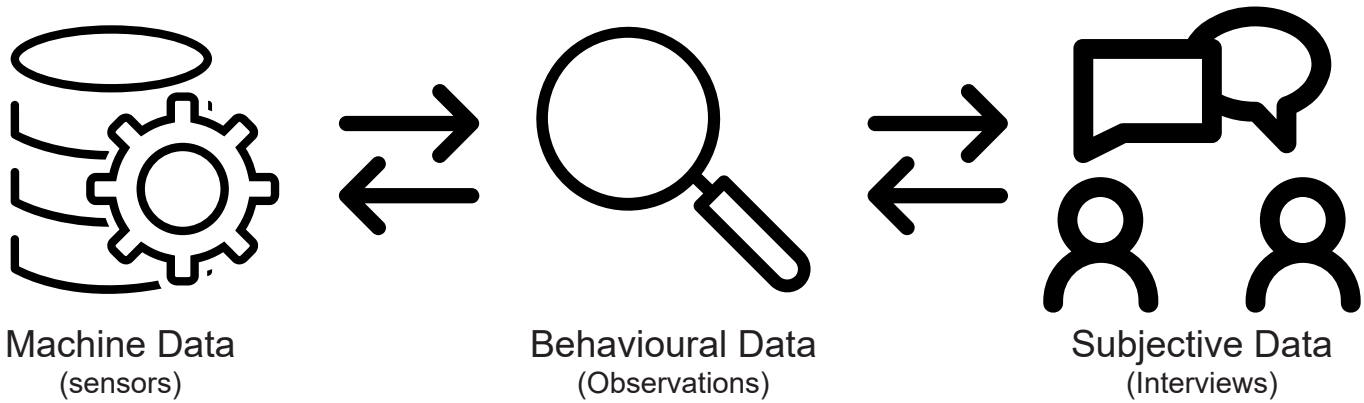


Figure 4 - Overview of the types of data

1.2.3. Data-Centric Design hub

The Data-Centric Design hub (DCD hub) ("DCD Hub - Getting started", 2020)is used to manage the machine data, The DCD hub is a project of Jacky Bourgeois to give designers the right tools to work with data. The main tool is a server running on the TU Delft servers. Additionally, there are Software development kids (SDK's) and an application programming interface (API). This enables me to work with tools I am familiar with, such as Arduino, without having to deal with setting up a server. From the sensors, the data is sent over a secure connection to the DCD hub.

1.2.4. Comfort lab

The comfort lab is a room within the IDE that is furnished like a living room. It has a couch, tv, coffee table, dining table with chairs, a lounge chair and a bookshelf (Figure 6 & 7). Since it is used for user tests it is equipped with a camera which is remotely controlled. The camera can be turned around to allow it to film every corner of the room. The room layout can be seen in figure 5.

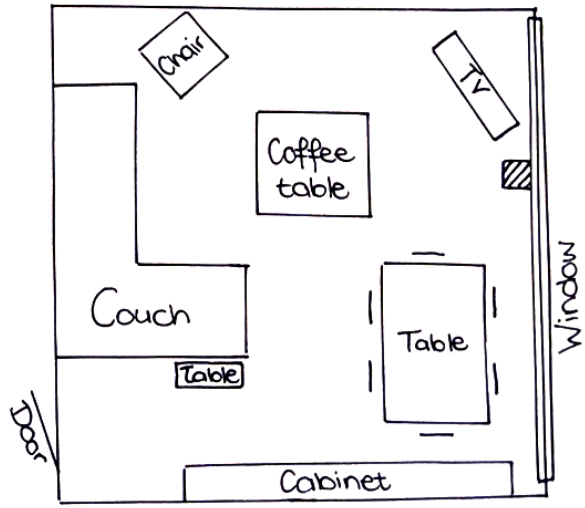


Figure 5 - Overview of the layout of the comfort lab

Figure 6 - Pictures of the comfort lab

2. Phase I -Context exploration:

Exploring relaxation in the context of the living room

Within this phase, the context 'relaxation in the living room' is explored. First, the aim and approach are explained. Then the observation and interview are discussed. Afterwards, the data gathered during the observation and interview is processed and analysed. Next, the results are compared to psychology research. Finally, the findings were used in a co-creation session, to help process and order them, and to make them concrete. All the insights are then brought together in a design goal and list of requirements. Afterwards, a reflection on the usage of data is made.

2.1. Aim

The aim of my research activities in the conceptual phase is to explore how people experience relaxation in the living room; how they act, and how data could be used to meaningfully explore this. This understanding is further informed by insights from psychology that states how relaxation can be seen as an important factor during leisure but is not the only important factor during leisure. Results in this chapter serve as a background understanding of the context and are used to form a design goal that serves as a starting point for my further design explorations.

2.2. Approach

Objects with intent are intelligent objects that try to achieve their intent in collaboration with its user. This collaboration is context-dependent and therefore it is important to properly understand the context. In order to improve this collaboration and for there to be a pleasant experience when using the object, the intent should align with the needs and desires of the user. To discover this, a user-centred approach is taken.

My starting point for this project was to understand how people would relax in the living room environment. The first step was to do a user observation, followed by an interview. The data generated by the observation and interview was then processed and analysed. Afterwards, the results are compared to psychology literature to find needs that were expressed by users and have a grounding in literature. To make the transition from the gained insights towards a design goal the results were used as an input for a co-creation. Based on the insights gained during this phase a design goal and list of requirements are formed.

While this phase is focused on understanding the context and finding the needs and desires of the user, some attention is also given to the sensory capabilities of a hypothetical OwI. At this stage, it is still unclear what the object will be or what intent it should achieve. However, by adding data-centric design at this phase in the project the aim is to allow for informed design decisions when designing the OwI in the next phase. Through this, insights will be gained that help answer the research questions related to OwI and DCD.

2.3. Observations & interviews

In order to gain insights in the context of relaxation within the living room, an observation and an interview are conducted. People were asked to sit inside the comfort lab for one hour and relax however they wanted to. Afterwards, an interview was conducted regarding their experience within that hour and comparing it to their situation at home. After the first two tests, it was concluded that the couch played a prominent role in this setting and thus chosen to be equipped with pressure sensors.

2.3.1. Research questions

The main research question is:

How do participants spend their time within the comfort lab given the assignment to relax for an hour?

To get a thorough answer the research question is split into 5 sub-questions.

Q1: What kind of activities will they engage in to help them relax?
Q2: What is the goal or purpose of these activities?
Q3: Which objects are part of these activities?
Q4: How will people interact with these objects?
Q5: How do they feel about how engaging in these activities to help them relax
  Q5.1: Do they feel more relaxed after an hour within the room?

With regards to developing an OwI through DCD, the following research question is asked.

Q1: What kind of data could be collected during this user test that could provide additional insights?

2.3.2. Hypothesis

The expectation is that the users will spend most of their time on either the couch or the comfortable chair since they provide the most comfort. While sitting at either of these places, they will spend some time on their phone, looking at social media and the news. They will also watch some form of content on either Netflix or YouTube on their own device (e.g. phone or laptop). Some might also walk around and explore the room. Participants will likely do a combination of these things and not for instance only watch Netflix. In between these activities, there might be moments where they get bored and have trouble deciding what they will do next. Afterwards, they might feel more relaxed than before they entered the room, but might not be completely content with how they spend their time.

2.3.3. Participants and procedure

For this research, there were 4 participants (2 students and 2 graduates). Three of which were female and one was male. They were aged between 21 and 26.

Each test will start by giving the participants a short introduction to the experiment (Appendix 8.1). After the introduction, participants were asked to sign a consent form regarding the study and the collection and storage of data. Following this, they spend one hour within the comfort lab. They were asked: "to use the hour in the comfort lab to relax in any way that they want." The test was concluded with a 30-minute semi-structured interview. The interview was conducted in Dutch since that is my native language and that of the participants. The questions can be found in appendix 8.1.

2.3.4. Data gathering

During the study, all three types of data were gathered: Behavioural data, subjective data, and machine data. Behavioural data is gathered by observing their behaviour through the camera. Notable behaviour was written down in order to ask specific questions in the interview afterwards. The camera feed is also recorded and saved for later analysis. Subjective data is gathered through the semi-structured interview. Within the interview, people were asked to tell about their experience during the hour and to compare it to their home situation. Machine data was gathered by placing 6 Force Sensing Resistors (FSRs) on the couch (Figure 7). These were connected to a Particle photon (Figure 8) and the data was sent to the DCD Hub.

Figure 7 - FSR placement on the couch

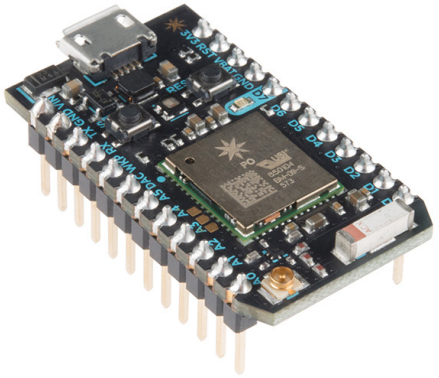


Figure 8 - Particle Photon

Machine data was only gathered during the last test due to hurdles with regards to the technical implementation. Since all three participants up to that point all used the couch the sensors were placed on a different point on the couch (Figure 7). The sensors were then covered using a blanket meant for couches (Figure 9).

Figure 9 - Couch with blanket to cover the FSRs

2.3.5. Research ethics

There were two ethical considerations to be made with regards to the data gathering. The first being with regards to the recording and storing of video material. The recording was deemed valuable for the observation and especially analyses of the behaviour of the participants. The use of the images was limited to this report and my presentation. Whenever the images are used the people are made unrecognizable, by using a blurring filter, to protect their identity. One participant specifically asked for her images not to be used during the presentations. The videos themselves were immediately transferred and are stored only locally on my laptop that is password protected.

With the gathering of machine data, there were two considerations. The first was whether to tell the participants upfront about the presence of the sensors. Due to the influence, it would probably have on their behaviour it was decided that they would not be told upfront. Instead, they were told afterwards in a short debriefing session with an explanation to why they were not informed. Then they were asked if the data could be used or if they wanted it removed.

The second was to ensure the data was sent on secure connections and not stored anywhere else. The data was sent from the photon to the particle server which redirected it to the server on the TU Delft campus. Through customer support, it was validated that Particle did not store any of this data (appendix 8.3). The data from the photon to the particle is encrypted by particle and the connection to the TU Delft servers happens through HTTPS.

Finally, all the data is stored for up to 9 months or until my graduation, whichever happens first. These considerations and agreements were explained in a consent form which was signed by all participants. (appendix 8.2).

2.4. Data processing & analysis

In this chapter, the data that is generated during the user test is analysed. The approach for analysing the data is to create visualisations of each data type. Both the process of creating the visualisation and the visualisation themself are inspiring and provide insights. The three types of data, machine, behavioural and subjective, are covered individually. For each, the method and tools used for processing and analysing the data are discussed. Afterwards, the results and insights of each data type are presented. Then they are accumulated in a final conclusion.

2.4.1. Interview data

The interviews show insight into how participants feel in relation to their behaviour during the test and at home. To gain an understanding of these feelings the interviews are transcribed, analysed, and a model of the underlying needs is formed.

Method

The first step in the analysis of the interview is to create a transcript. This is done using oTrascribe, a free online tool that keeps all your data locally and allows for the use of shortcuts for fast transcribing ("oTranscribe", 2020). The transcripts are exported, adjusted in Excel and through notepad imported into ATLAS.ti (ATLAS.ti, 2020). ATLAS.ti is a qualitative data analysis and research tool. Within ATLAS.ti the interviews are coded. Coding in qualitative analysis is "how you define what the data you are analysing are about" (Gibbs, 2007). For the interviews, the codes were determined upfront based upon notes taken during the interviews. The codes were: relaxation activity, relaxation requirement, effectiveness and satisfaction. While coding additional codes emerged based on recurring themes found while reading the transcripts.

To analyse the quotes and codes the internal tool of ATLAS.ti was first used (Figure 10). However, due to the limitations in navigating and the number of quotes, rearranging and analysing was found unintuitive. That is why all the quotes are printed and cut out for analysis. The method is inspired by analysis on the wall from Sanders & Stappers (2016) but then it was done on a table.

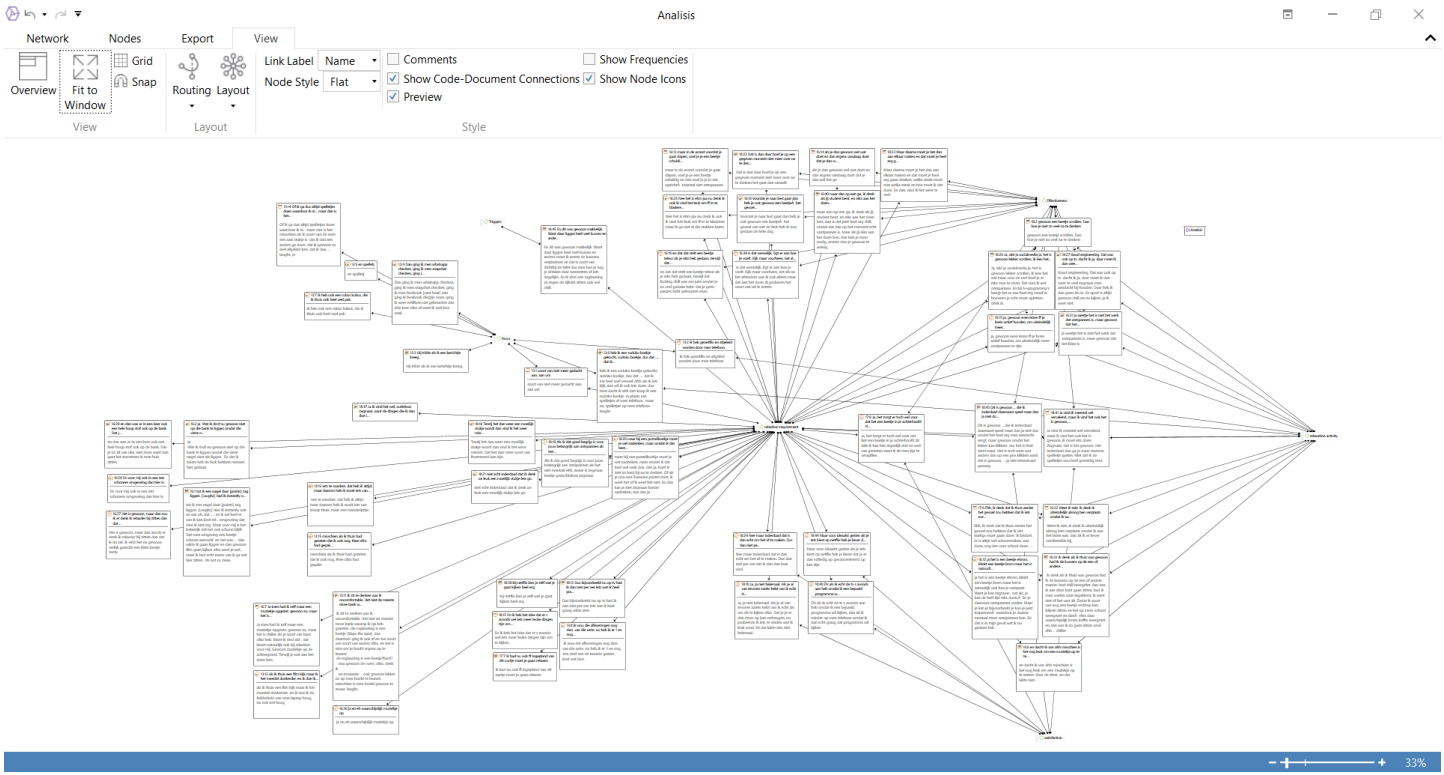


Figure 10 - Internal tool of ATLAS.to to analyse codes

In order to get a grip on the content, the quotes were clustered spontaneously and intuitively. Afterwards, they were rearranged several times until an understanding was formed. The first categorisation was related to mental and physical stimulation. It stood out that a lot or a little stimulation could be experienced as both positive and/or negative in relation to their relaxation. This created four categories (Figure 11), within these, the quotes were then rearranged to create an abstraction hierarchy (Figure 12)(Sanders & Stappers, 2016). This is done by asking why and how questions. While rearranging it was found that the levels of abstraction related to the activities they were talking about. So, the quotes were rearranged the last time based, categorized by their activities and layered by the level of abstraction.

Based on these quotes it was found that each activity was done to fulfil one or several needs which related to relaxation. These activities are visualised and explained in the results. Afterwards, a model was created which shows the relation between the needs.

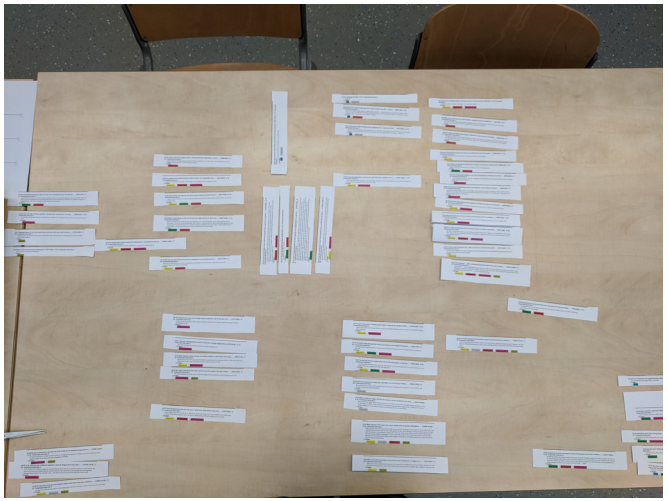


Figure 11 - Codes ordered in four categories

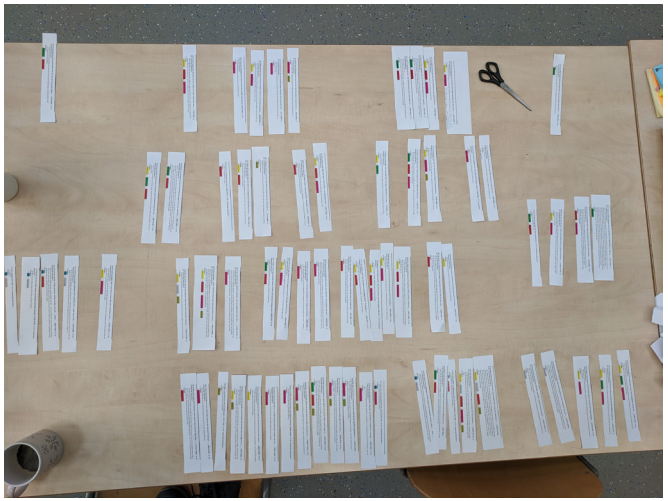


Figure 12 - Codes ordered by abstraction hierarchy

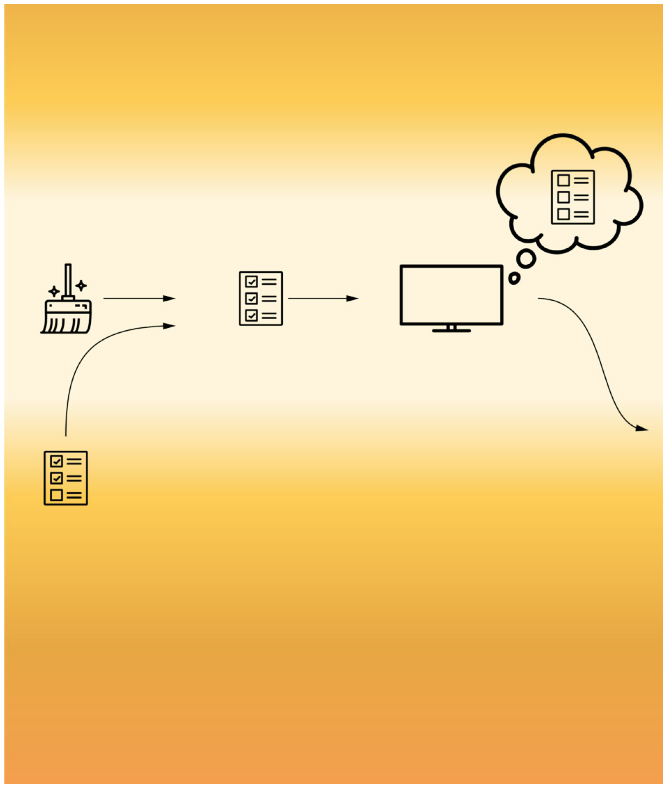


Figure 13 - Interview results 1, chores and to do's

Results

1)Depending on the effort required, doing chores and general to do's can be found relaxing. When the chores can be done with ease, such as doing the dishes the chores are sometimes described as relaxing. Other activities such as answering emails that require more effort are not in itself relaxing, but them being done gives them a sense of achievement which helps with being relaxed.

When people are relaxing, the things they still have to or don't have to do can influence the quality of the relaxations. If there are still some chores left to do, they are not able to fully relax.

P2: It is not the work that is relaxing but that it is finished.
P3: I think that at home I would sooner have the feeling that I have to do something useful. [...] it is in the back of my find; I cannot enjoy this as much because I am wasting my time.
P4: But with cleaning, you don't really have to think and I find that relaxing.

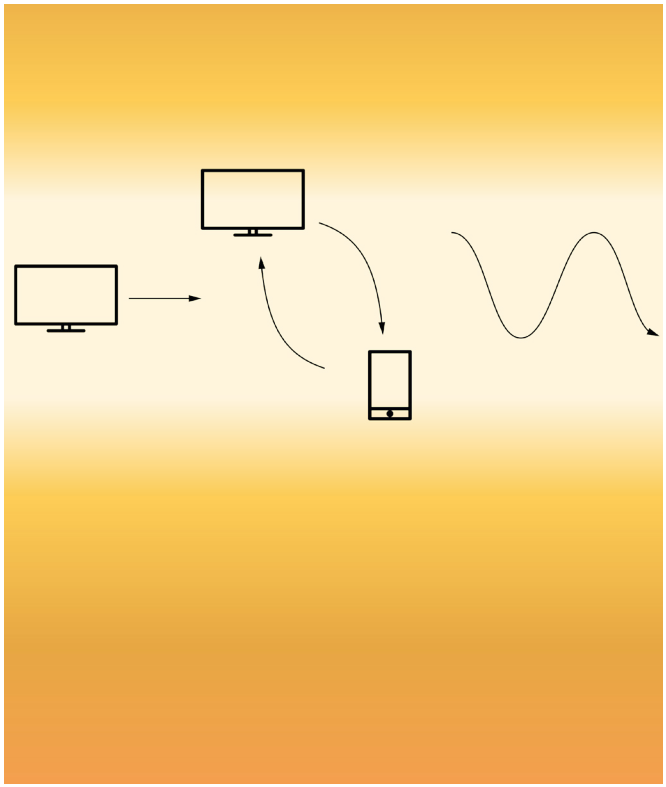


Figure 14 - Interview results 2, watching television and phone usage

2) When watching television or Netflix the effectiveness depends on the program they are watching. If it is something they wanted to watch beforehand it helps them to start relaxing because there is a form of anticipation. It also helps them stay relaxed because they enjoy this program and they have a sense of achievement when they have watched the program they wanted to watch.

If the program stimulates them a lot, it can go two ways. They either don't find it relaxing because it required too much effort. Or they find it relaxing because they learned something new or interesting which gave them fulfilment.

P1: I still wanted to see those episodes of that show. Now I have seen one and part of another, pretty nice.
P2: On Netflix, you have the brain explained and those kinds of those I find super nice to watch and then test in the real world.
P4: Good engineering was on tv, but I thought then I have to pay attention and I don't feel like doing that.
P4: If I know upfront that there are programs on tv that I want to watch I can look forward to them. But now I tried to find something I enjoy but that didn't quite work out.

However, during any program or show, there are moments where people use their phone at the same time. Sometimes caused by notifications other times caused by them being bored or feeling the need to do something with their hands. This caused them to fluctuate between the world of their phone and their show. Sometimes they even fully immerse into the world of their phone and then having to rewind back the part of the show they missed.

P1: or I go play games, but maybe there is then a boring part of the show and then I go do something else. Because I am so easily distracted.
P4: I don't know, I just want to have something in my hands.
P4: And I don't want to be on my phone then, but I do it anyway. Because, I sort of, have to do something.
P4: Yea usually I find it annoying, but I also have to do something. That's just it. And then indeed I go play stupid games. It's not like I find these games amazing.
P4: Because indeed I use my phone, while I am watching Netflix, and in the meantime, I miss a lot of what happens what I find really annoying because every time I go back and thing fuck what happened.

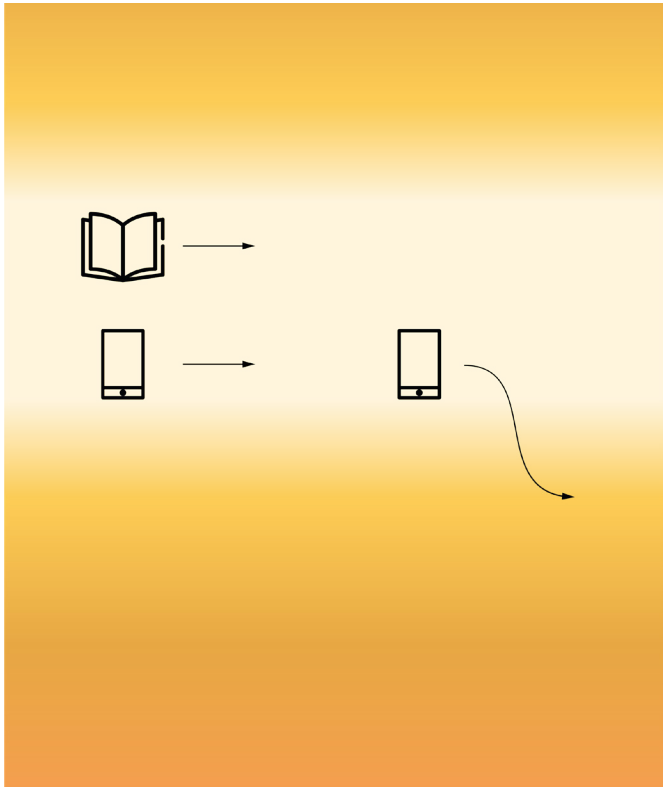


Figure 15 - Interview results 3, reading and phone usage

3) Being on their phone or reading are both found to be relaxing. However, the difference between them is that reading is found as fulfilling and being on their phone is not. If they did not do something fulfilling that day or that evening, they start to feel guilt which prevents them from relaxing.

P2: I thought I'd browse through this and then I'll look at the other one. But this turned out to be super nice.
P2: But then in the evening before you go to sleep, you feel a bit of guilt and in that way, it is not mentally relaxed.
P4: I find reading a book nice and it gives more fulfilment than watching something.
P4: But I find reading a book relaxing and fun to do.

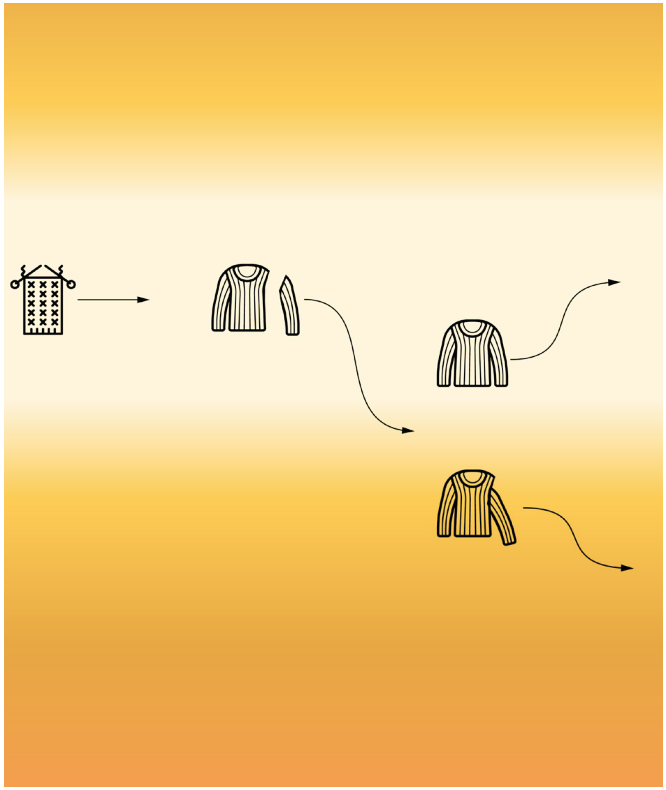


Figure 16 - Interview results 4, watching television and phone usage

4) Another activity that was mentioned as relaxing was knitting because it was something, she did not have to think too much about. However, if there was a part that was a bit harder then it was no longer relaxing to do and depending on the result it could become relaxing.

P4: For example, I find knitting or crochet also relaxing.
P4: After a certain amount of time you don't have to think about it anymore and it's effortless.
P4: Unless it's a difficult part, then I find it less.
P4: But that really depends on if I am happy with the result or not.

Insights

From these activities, it was found that each activity was done to fulfil one or several needs, that related to relaxation. To understand how these needs relate to each other and to relaxation a model is formed (Figure 17).

It was found that ideally people would go into their relaxation world and stay there. The top layer of the visual illustrated this. In order for people to get into and stay in their relaxation world, they have to be at ease, the second layer. Beneath being at ease lays needs which directly influence when they are at ease. The fourth layer is about the needs which contribute to the needs in the third layer. Here also lies the friction and difficulties people experience with regards to relaxation.

Relaxation activities are most effective when people can live inside the world of that activity. When they can fully focus on that activity and not be distracted by other needs. This means there is a three-step process. First, they have to feel like it's safe to enter the world they want to enter. Meaning they should have done the chores or homework they wanted to do or decided and accepted that they will do the work later. They also have to be comfortable, ergonomically speaking and mentally. Then when they are in the relaxation world, they should stay there for as long as they desired/intended. For this, it's important that they have the right amount of stimulation. Enough to keep them interested and not get bored/distracted but not too much that it can become exhausting. Having done their chores also helps because otherwise, they think, "Oh, I should still do them". Thirdly, after they have come out of the relaxation world it is important that they have a sense of fulfilment about the day or evening. This does not have to come from the relaxation activity, but it can. But if they do not have the feeling of fulfilment, they will feel guilt which then is no longer relaxing.

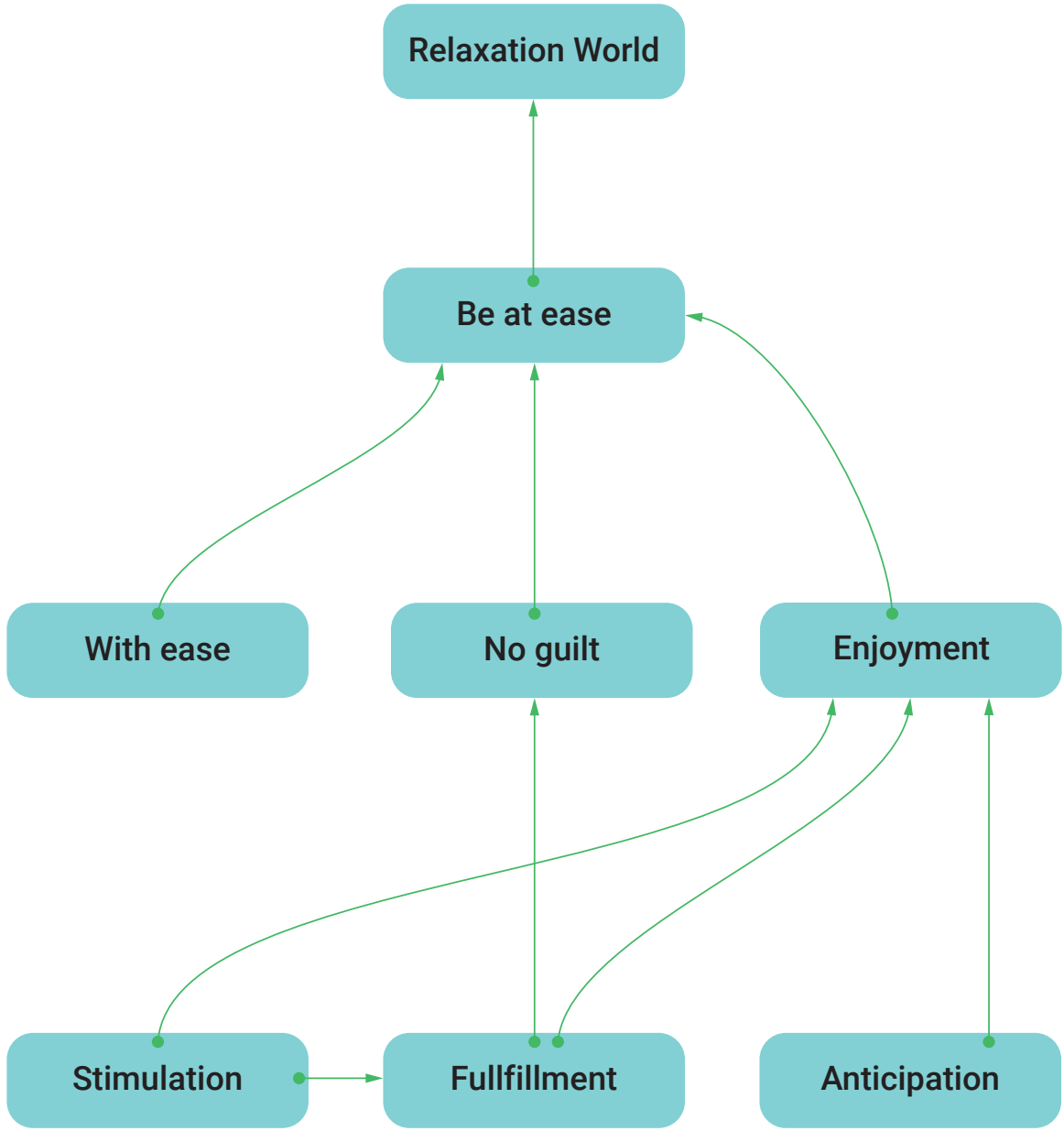


Figure 17 - Schematic overview of the interview results

2.4.2. Observation data

In order to gain insights from an hour of relaxation per participant, the sessions are visualized. To do this their behaviour is coded and put into chronological order. From there the visualisation is made and analysed to gain insight into their behaviour.

Method

First, the videos are imported into ATLAS.ti, within ATLAS.ti the videos are coded. The codes are created spontaneously based on what they were doing during the hour. This includes but is not limited to the device they were using to relax, their posture and the exploration of the room. This results in a list with codes and timestamps which is adjusted in Excel in order to be imported into RAWGraphs (Mauri, M., Elli, T., Caviglia, G., Uboldi, G., & Azzi, M, 2017). RAWGraphs is a free online data visualisation tool which works locally on your device. This tool can create bar charts from a time series input, which was then downloaded as a SVG file and imported to Illustrator. Within Illustrator the chart is adjusted and ordered according to codes that are similar. Then still frames of people's postures are added to the image to illustrate better the adjustments people made. The result can be seen in figure 18.

Results

In each figure, there are three timelines. The bottom one relates to their physical moments and their postures. A minor position adjustment is slight movements but keep a similar posture and support of their device. The middle row is related to the devices they used to consume content. The top row is related to other activities that stood out or did not fit in the other two rows.

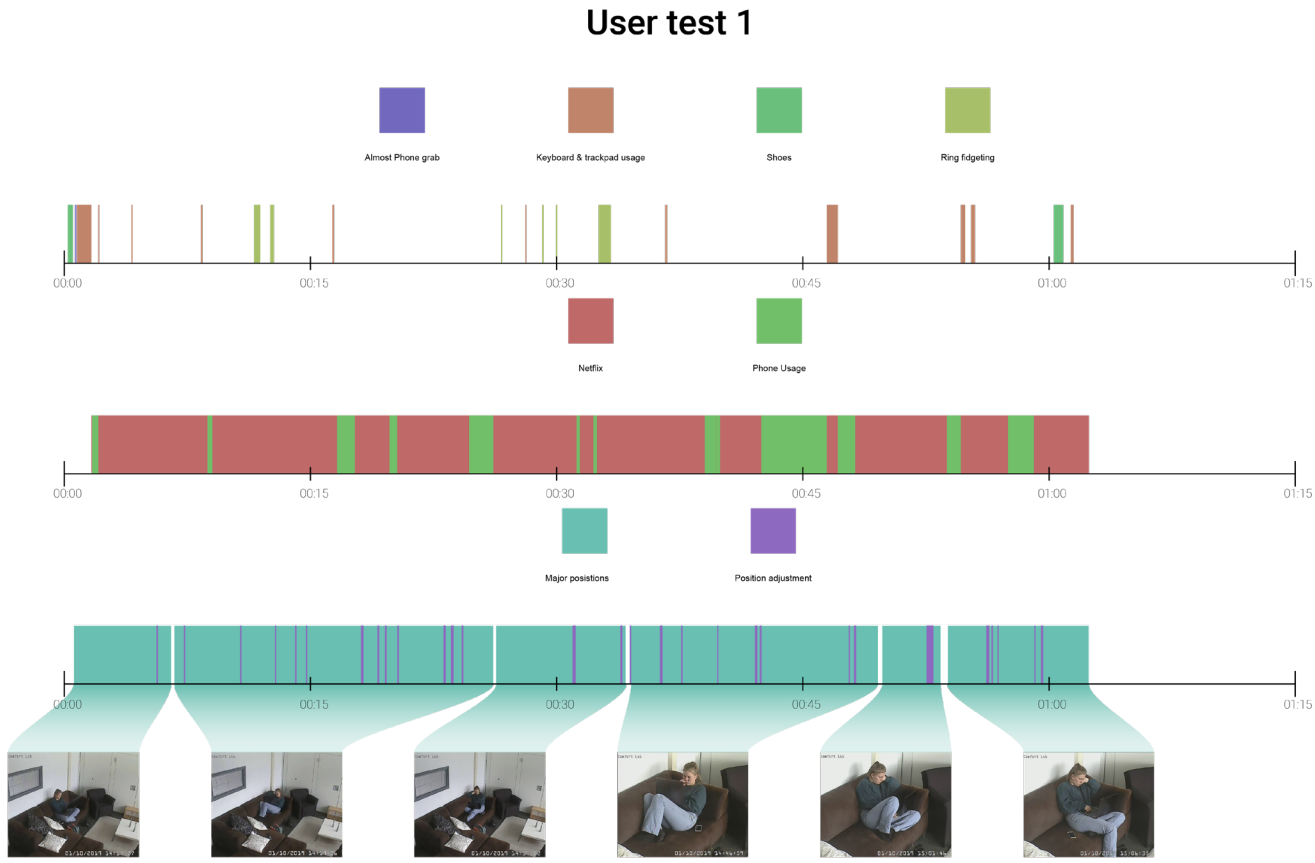


Figure 18 - Observation data results user test 1

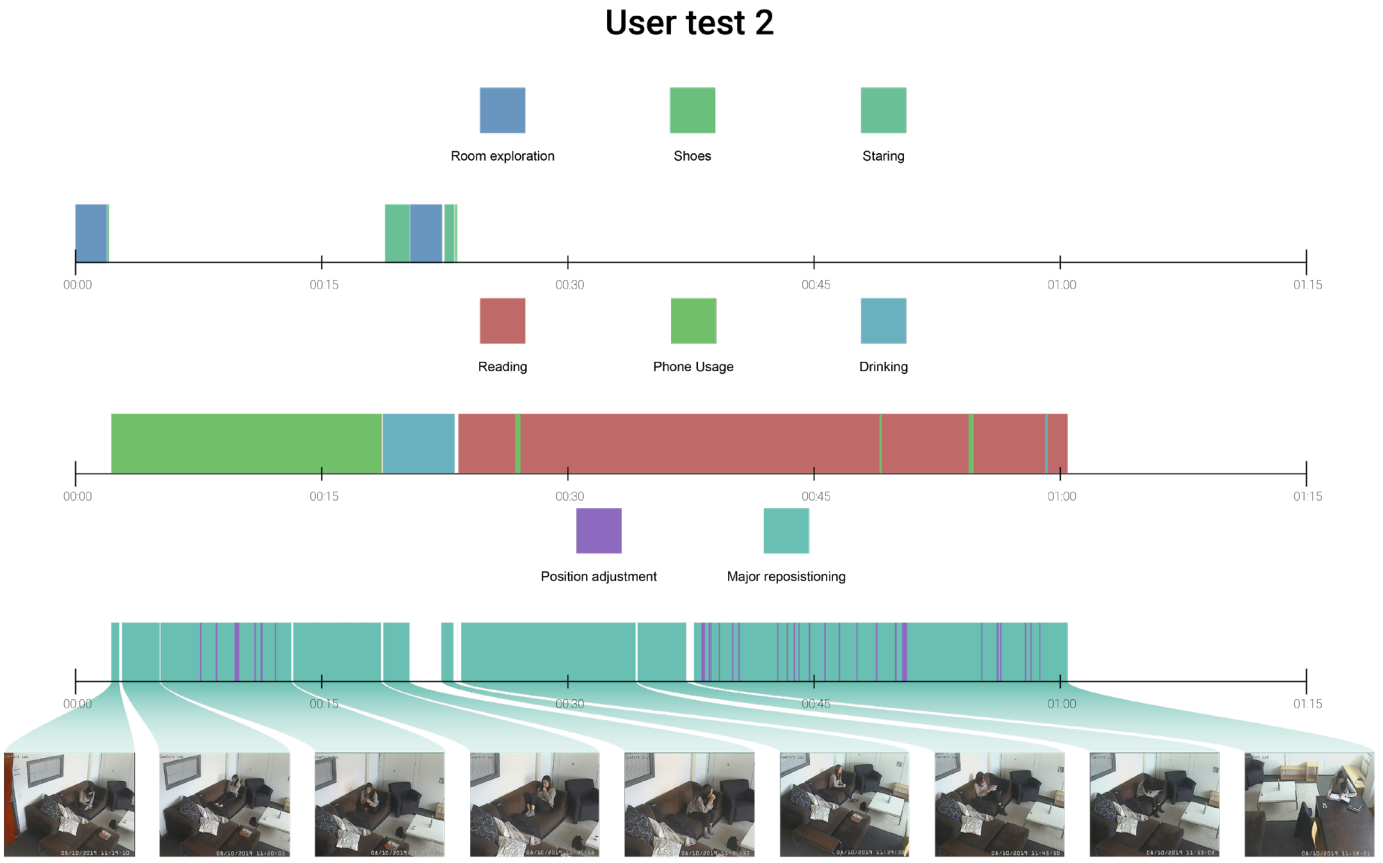


Figure 19 - Observation data results user test 2

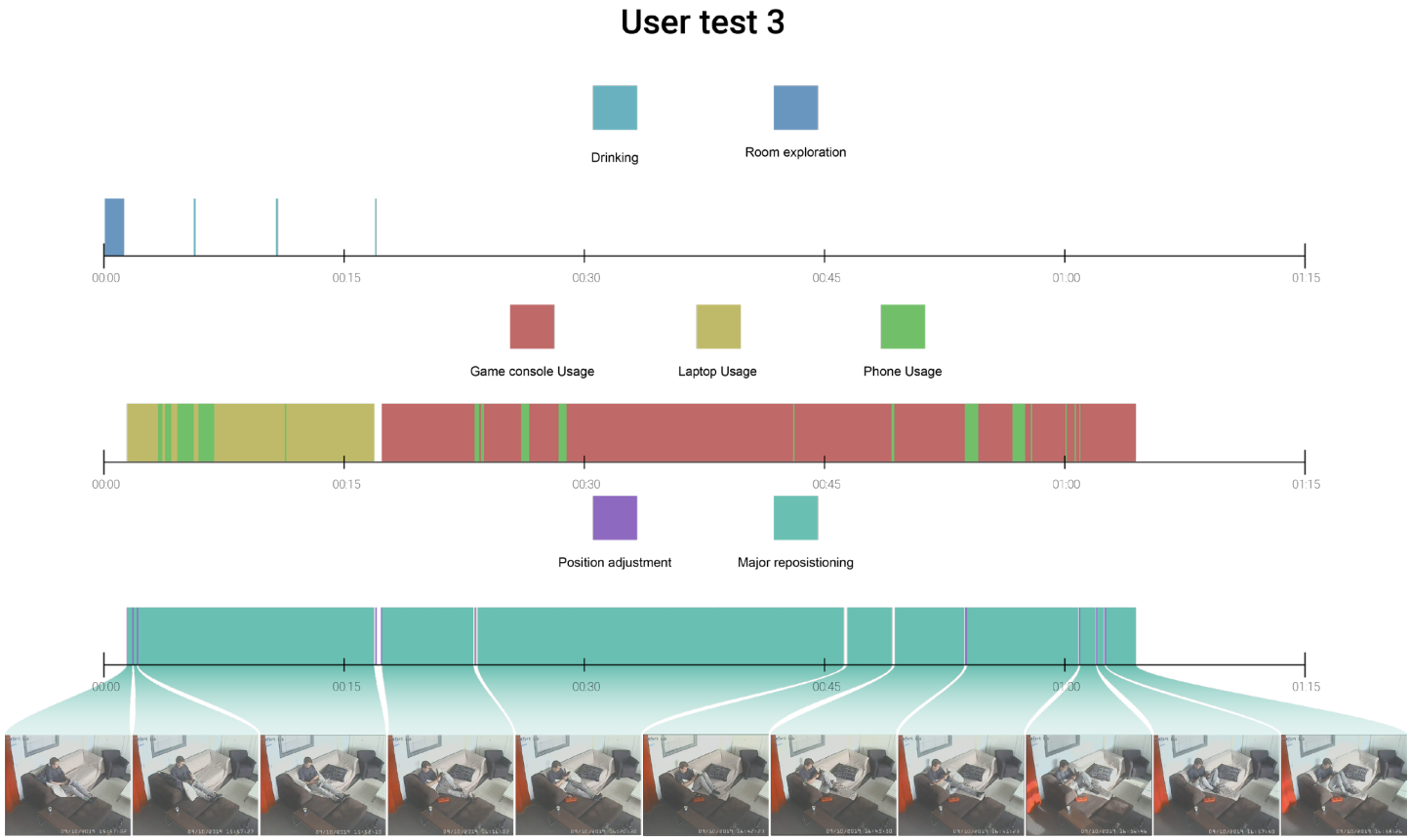


Figure 20 - Observation data results user test 3

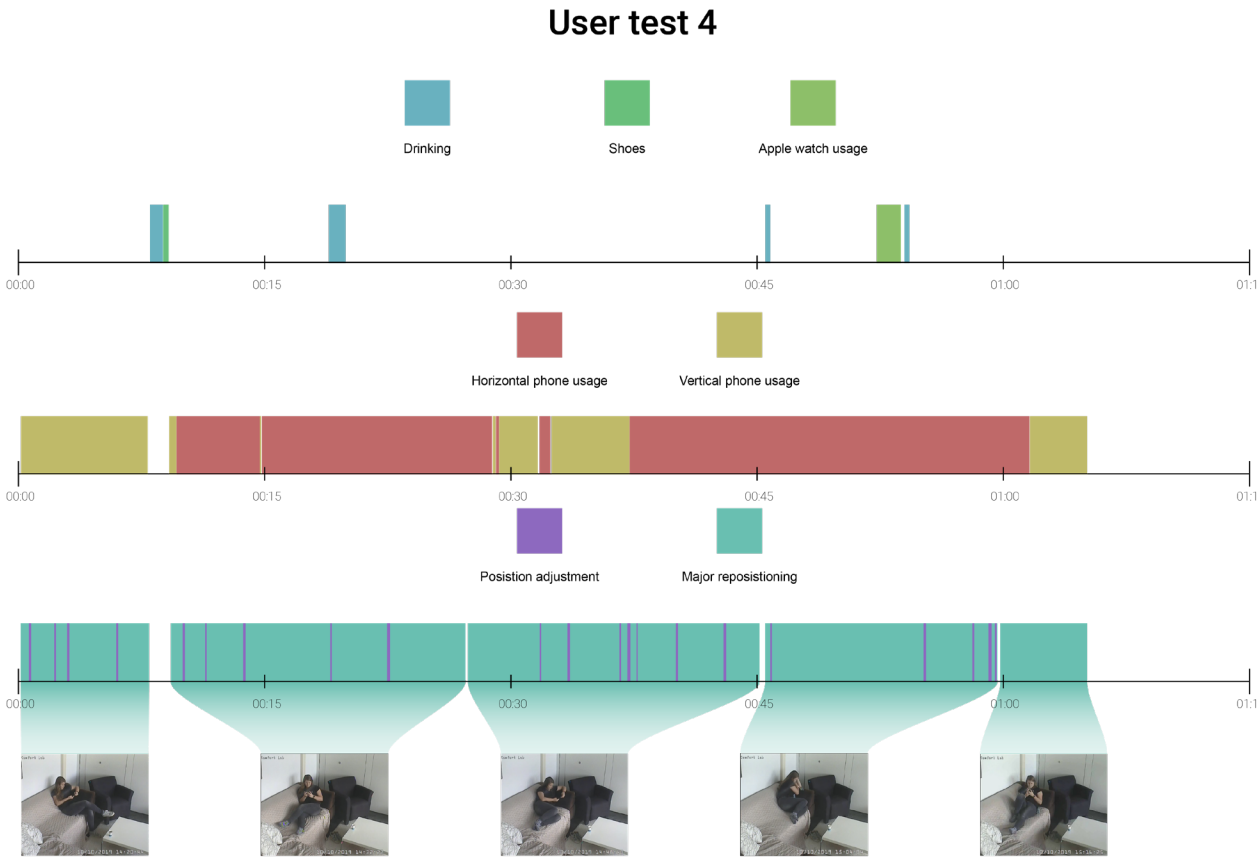


Figure 21 - Observation data results user test 4

Insights

From the visual, there are a few specific things that stand out. The first being that relaxation seems to revolve around the corner of the couch. Their postures are somewhere in between laying and sitting. Sometimes movement follows phone usage and the other way around. People adjusted their posture several times during the test. In most instances, there was a considerable amount of time in between each posture change.

2.4.3. Sensor data

With the force resistance sensors that were added, the goal is to get an understanding of what the sensory capabilities of them are. Specifically in relation to the behaviour of the user. Therefore, the sensor data is visualised in the same graph that is created for the observational data.

Method

The sensor data is first pulled from the server as a CSV file. This is imported into Excel and adjusted so that Illustrator could correctly create a graph with the same horizontal axis. From a total of 6 sensors, we placed only two had gathered data. Since they had a significant difference in the amount of force, they measured they have their own vertical axis.

Results

Within this graph (Figure 23), the rows are stacked on top of each other in order to see the links to the sensor data better. The green sensor was placed on the seating area of the couch and the red sensor was placed in the centre of the backrest (Figure 22).

Insights

Within the visual it can be seen that all the major position adjustments can be detected using an FSR. From the smaller adjustments, a few can be seen but to see all of them, the sensors have to be placed differently or another sensor needs to be used. During the fourth posture, it can be seen that no data was collected, a possible risk of using pressure sensors that only cover a small area. This was likely caused by the participant sitting next to the sensor. Finally, in the beginning, the red sensor measured a slow increase in pressure. This is presumably caused by slowly sitting more laid-back, which was described by another participant as something that happened to them. However, this was not detectable when watching the video carefully so it cannot be said for sure. This does indicate that the sensors could possibly detect more the human eye can see.

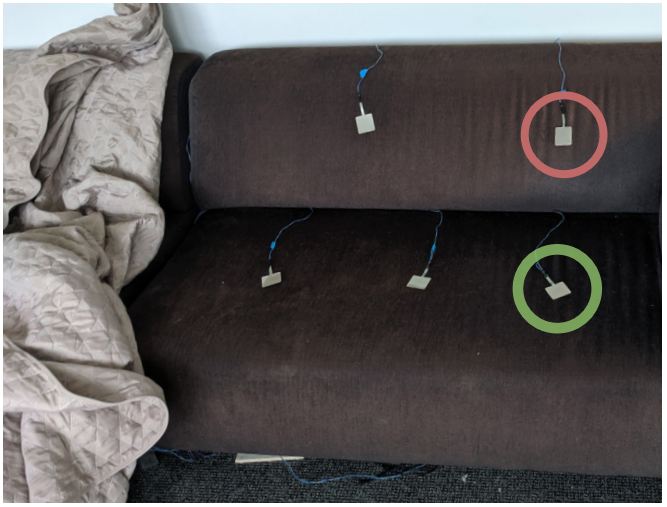


Figure 22 - Sensor placement on the couch

User test 4

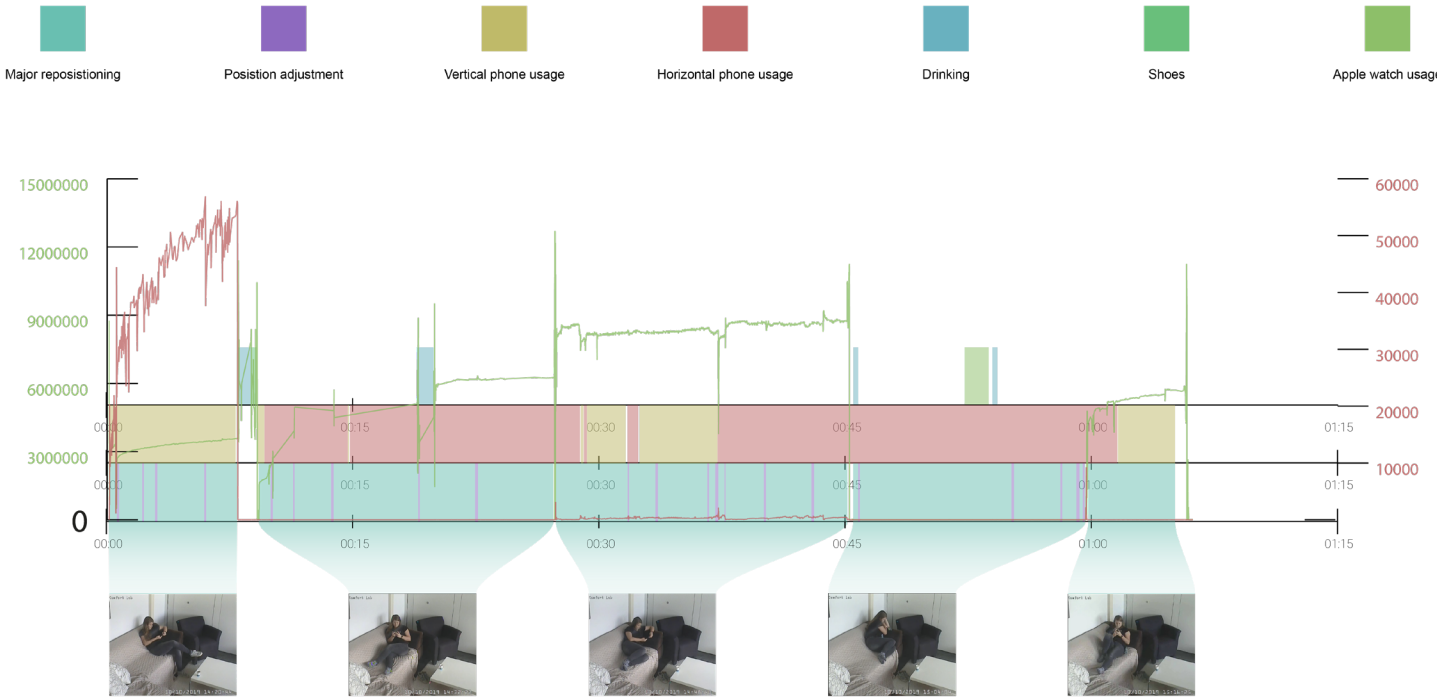


Figure 23 - Observation & machine data results user test 4

2.4.4. Conclusion

The couch was found as the object they used the most while relaxing for an hour in the comfort lab. More specifically they used the corner of the couch. They sat or lay on the couch because they wanted to be comfortable. While on the couch, they changed their posture several times in order to stay or become comfortable. While on the couch they engaged in activities on their phone, one a portable gaming console or with a book. These activities helped the user to enter their relaxation world. Doing to do's helped them to clear their mind. Other activities helped them enter the relaxation world because they had the right amount of engagement. How people feel about the activities they engaged with depended on how well the activity allowed them to enter the relaxation world. And thus on the factors shown in figure 17. It also depended on how long they engaged in these activities. This stood in relation to how long they intended or desired to engage in these activities and the other activities they did during their leisure time. For example, when somebody watches one episode of a tv show and wants to do something else afterwards. How they felt about that activity, depended on how much they enjoyed the episode and if they only watched one episode and were able to engage in the other intended activity afterwards.

With regards to the sensing capabilities of a hypothetical OwI, it was found that pressure could provide nuanced and detailed insights into how people behaved on the couch. However, these specific sensors were not the most ideal for a couch as their surface area and thus their coverage is relatively small. Thus when making the next step with regard to the sensing capabilities of an OwI, sensors detecting behaviour can be insightful. But 6 FSR's are not suited to cover the complete behaviour of a user on the couch.

2.5. Comparing results to psychology research

Within this chapter, three pieces of research are discussed. First two TED talks by Mihaly Csikszentmihalyi, a psychologist, about his research on flow theory. Then a paper by David Newman on leisure and subjective well-being. Finally, the book Thinking, fast & slow by Daniel Kahneman, and psychologist and economist. Then the findings from the observation & interview are put into the context of this research.

2.5.1. Flow theory

Flow theory comes from research into what makes a good, meaningful life. An element that contributes to this, is flow. Flow is a state in which people are so involved in an activity that nothing else seems to matter. Mihaly Csikszentmihalyi describes seven conditions that are there when a person is in flow.

"There's this focus that, once it becomes intense, leads to a sense of ecstasy, a sense of clarity: you know exactly what you want to do from one moment to the other; you get immediate feedback. You know that what you need to do is possible to do, even though difficult, and sense of time disappears, you forget yourself, you feel part of something larger."

(Csikszentmihalyi, 2004)

As can be seen in figure 24, relaxation is described as something different from flow. Therefore it is only briefly discussed and a more extended version can be found in Appendix 8.4.

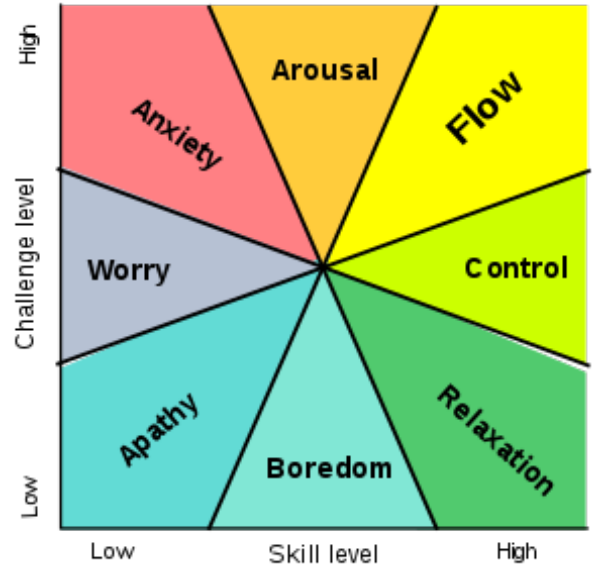


Figure 24 - Comparing skill level to challenge level (Csikszentmihalyi, 2020)

Implications

Despite it being different from relaxation, flow theory did help me interpret the results of the interviews. It put in context why there was this contradiction where on the one hand people desired stimulation and on the other hand things had to be done with ease. It also explained why the activities themselves were not always indicators of how they felt about their relaxation time. What was more relevant in predicting how they felt about the relaxation were how they felt about the activities.

2.5.2. Leisure and subjective well-being

The paper, leisure and subjective well-being: a model of psychological mechanisms as mediating factors (Newman et al., 2013), presents a framework (Figure 25) which shows through which psychological pathways leisure can be linked to subjective well being (SWB). It does this by making a quantitative summary of theories from 363 research papers that link leisure to SWB. The framework shows 5 physiological mechanisms which link leisure to SWB.

The first mechanism is Detachment-Recovery. Leisure can lead to detachment and detachment allows people to recover from work and non-work-related pressures. The type of activity that allows for recovery is not limited to low arousal activities (e.g. watching tv) but may also include more physically intent forms of leisure (e.g. running).

The second mechanism is Autonomy. The intrinsic motivation to do certain activities is an important factor in generating SWB from leisure. People are autonomously motivated when they engage in activities willingly, by their own choice.

The third mechanism is Mastery. Mastery is the act of honing one's skill to achieve a new level of success in a certain leisure activity. It is related to the concept of flow from Csikszentmihalyi explained in the previous chapter. Although flow is more common in work-related activities, mastery still promotes SWB by giving people a sense of accomplishment and providing flow experiences.

The fourth mechanism is Meaning. Meaning comes from activities that allow people to gain something important or valuable in life. Examples are running, quilting or volunteering. These activities reduce negative emotions while promoting positive emotions and life satisfaction.

The fifth mechanism is Affiliation. Affiliation is related to activities that are of a social nature, such as a team sport or going to a party. These activities allow people to build social relationships, encourage positive emotions, decrease loneliness and decrease sadness. With whom these activities are enjoyed may influence the types of benefits. Time with friends, for instance, causes immediate well-being while time with a spouse increase global well-being

Implications

The first mechanism, Detachment-Recovery is most similar to the behaviour people showed in the observation. Engaging in low arousal activities such as reading and watching tv. Autonomy is also present in the interviews where people explained that watching something, they wanted to watch increased their focus and enjoyment. As mentioned in the previous chapter mastery is something people do like to engage in during their leisure time but did not do

during the observation. Meaning and affiliation were also not present during the observation, but they were mentioned in the interviews as import factors.

For my context, relaxation in the living room, the detachment recovery is the most prominent factor within these five and the product should support that. Autonomy shows that it is important not to impose activities onto people but to allow them to spend their time how they want to. Mastery, meaning and affiliation were not present during the observation; however, people did mention them as important factors. Thus, it might be valuable to increase the quality of recovery and to help them stop engaging in low arousing activities after a while. Doing this would allow them to do activities that allow for detachment-recovery and activities that support the other factors in one evening.

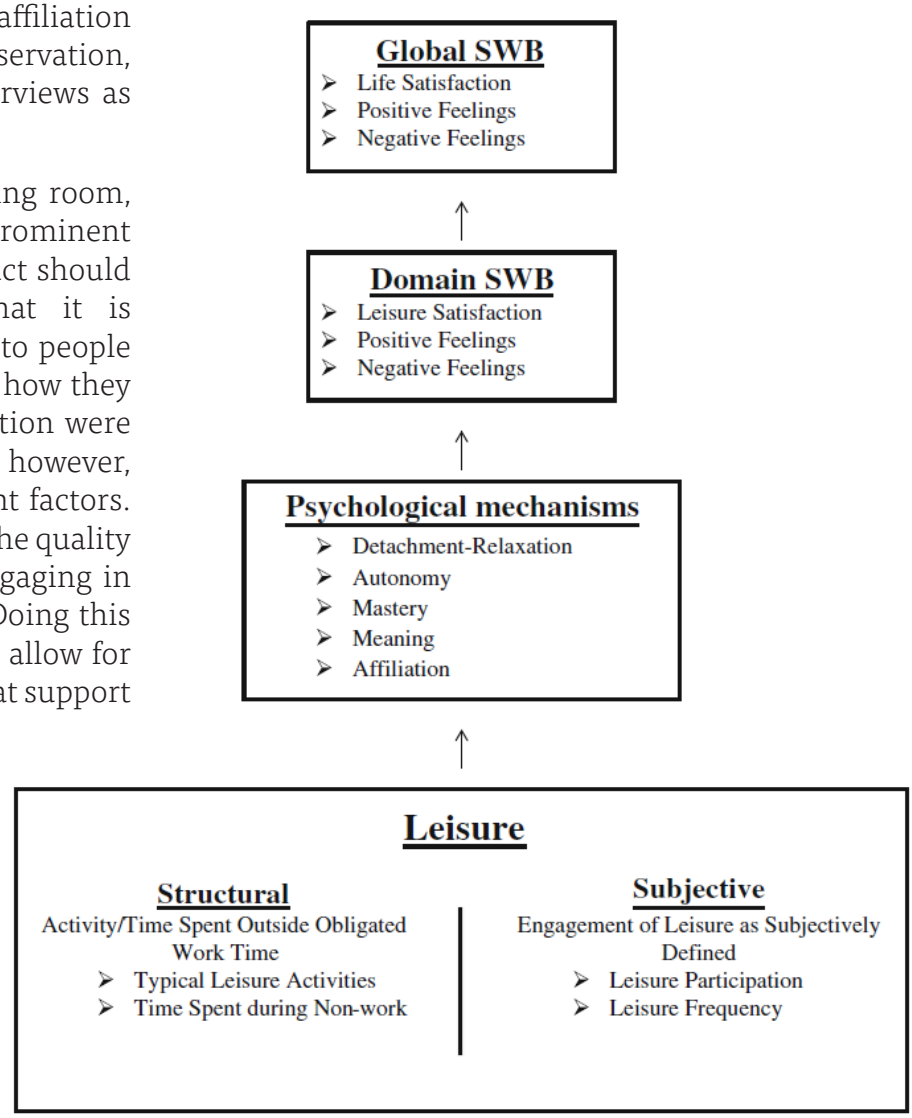


Figure 25 - Conceptual model linking leisure to subjective well-being (Newman et al., 2013)

2.5.3. Fast and slow

In his book, Thinking, fast and slow, Daniel Kahneman explains that we have two different systems of thinking. System 1 is fast instinctive and emotional. It costs less energy, but it is not always optimal. System 2 is slower, more deliberative and more logical.

Implications

Based on the interviews it was found that at home people usually act using system 1. For example, when watching a tv show they may end up watching four episodes while they only intended to watch one. That is because people are tired and watching another episode is the easiest option. The product may help them by activating system 2 at different points to, for instance, force them to make a conscious decision about how long they want to spend watching tv. This could help prevent the feeling of guilt mentioned in the interviews and help them to engage in activities that support the other psychological mechanisms mentioned in leisure and subjective wellbeing.

2.6. Co-creation

As mentioned in the approach, a user-centred approach is taken. This was done not only through the observation and interviews but also through a co-creation session. The goal of the session is to go from the abstract problems and opportunities that are found in the previous chapters towards a concrete situation and possible solutions.

2.6.1. Method

To ensure a productive session a fellow student who did the elective creative facilitation was approached. Together with him, we created a plan for the whole session, figure 26 & 27.

The session was held with four participants, one IDE master student, one IDE master graduate, and two communication and multimedia design (CMD) students. They were chosen because they are within the target group and have experience with the creative process. This was to increase the speed and the depth we could go in this session.

The session itself consisted of four parts. In the first part, participants were made familiar with the context and the problems and opportunities found. Within the second part, the goal was to look at a specific scenario in which the most relevant problems and opportunities would arise. In the third part, the scenario was enacted and changes to the enactment were made to go from the current situation to the desired situation. Before the final part, OwI's were introduced and explained to the participants and they were asked to design an OwI that could achieve the desired situation.

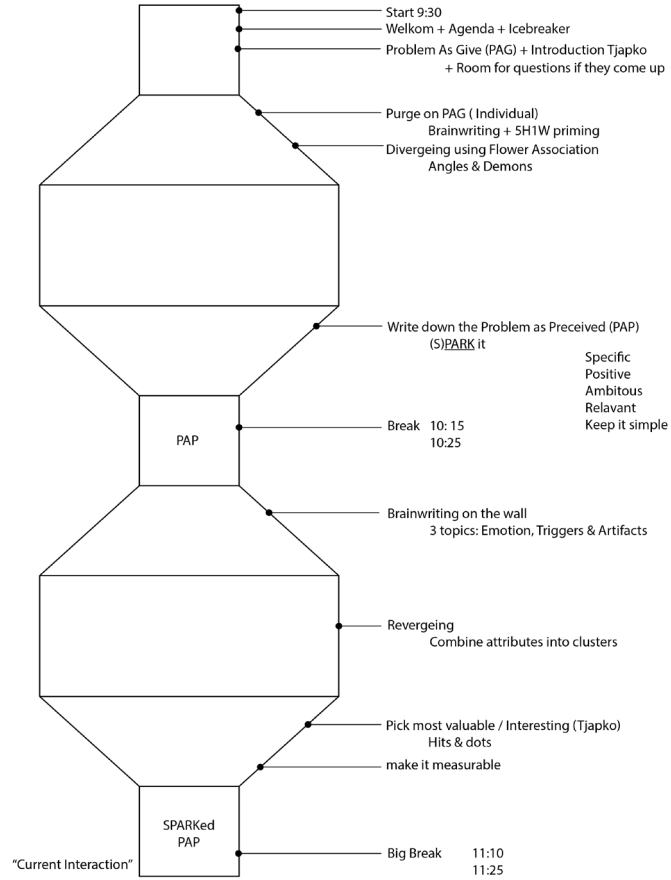


Figure 26 - Session plan part 1

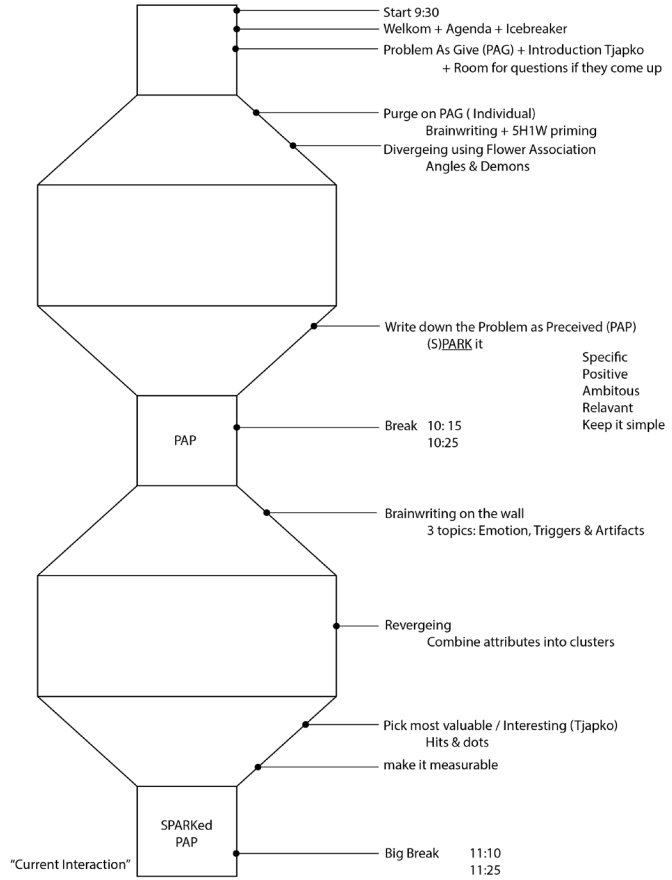


Figure 27 - Session plan part 2

Figure 28 - Picture of the co-creation session

2.6.2. Result

In this co-creation session, the following moment was found: the first moment people have free time (time for leisure) after a day at work or school. This moment is usually the moment they come home, after they have eaten or done the dishes. At this moment they have the desire to sit on the couch and recover for a moment. This moment is spent watching tv, being on their phone or playing a video game. They are not always happy with the activity itself and/or the length they engage in this activity. They also have a variety of other activities they want to engage in during the evening such as exercise, personal development or a social gathering.

For this situation, two solutions were found within the session. The first being a phone stand that activated the lights and home entertainment system of the room. The second being a pillow that would crave your attention and wants you to cuddle with the pillow. Both were designed with the mindset of also decreasing phone usage because the co-creators saw this as an important element.

However, as mentioned in the previous phase autonomy is an important part of leisure to contribute to SWB. Taking away the option to use your phone would contradict this part. That is why the solution was not further used within this project. However, it did help with specifying the moment my product should intervene and it added a desired interaction with the product.

The moment of intervention should be one of the first moments of people's leisure time. That is the moment they sit down on the couch, are tired and have a desire to recover and detach. The co-creation also confirmed the importance of the user taking control of how long they recover-detach as they mentioned they have a desire to engage in multiple activities next to recovering on the couch. In one of the solutions, they also showed a trade-off mechanism where the users needed to put the phone in the stand in order for the music to activate. This allowed the object to negotiate with the user. This mechanism was added to the list of requirements.

Figure 29 - Brainstorm results of co-creation 1

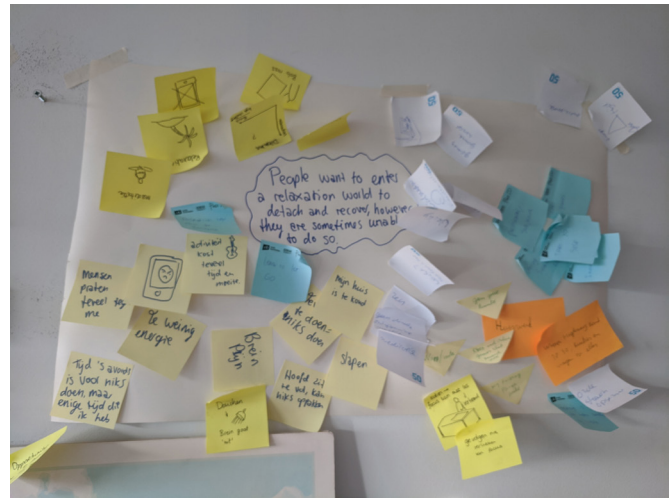


Figure 30 - Brainstorm results of co-creation 2

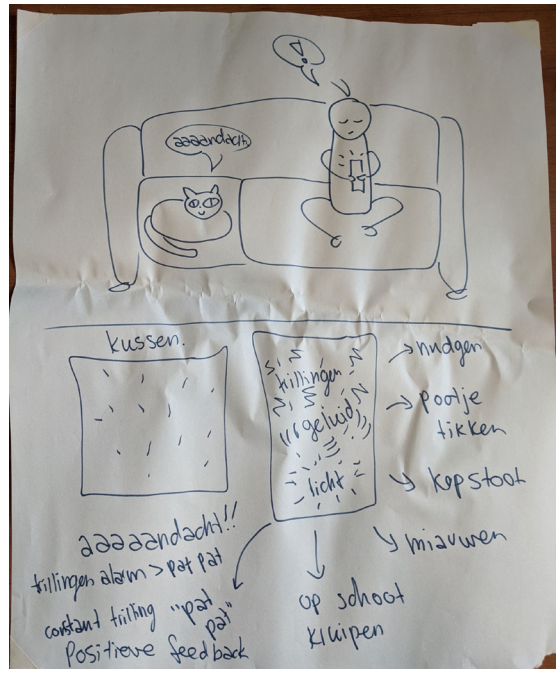


Figure 31 - Drawing of concept which was conceived during the co-creation

2.7. Conclusions on having explored relaxation in the context of the living room

Based on the findings in this phase the following design goal is created:

"I want to increase people's subjective well-being during leisure after work by improving the quality of recovery-detachment and enforcing them to take control of how long they recover-detach."

From the co-creation session, it was found that the first moment of leisure after work was the most promising moment to intervene. The overall goal is to improve people's SWB, which happens through five psychological mechanisms. During this moment recovery-detachment was the most prominent in the user test and is, therefore, part of the design goal.

Enforcing them to take control of how long they recover-detach, aims to help the user in two ways. Firstly, it was found important that they could immerse themselves into the relaxation world. Making the start of the recovery-detachment deliberate could help users commit to recovering for that moment. By making it limited it should take away some of the worries they have during recovery. Secondly, making the start deliberate and by limiting the time they recover, system 2 of Daniel Kahneman should be activated. Through this users can make a conscious decision on if they want to engage in other activity during their leisure and relate that to how long they want to recover-detach. Engaging in other activities is something user expressed they wanted and other activities could trigger other psychological mechanisms such as mastery.

To achieve the design goal the following list of requirements was made:

- The object should be used while recovering on the couch
- The user must set a time for how long they want to recover
- After the time is done the object should communicate to the user that the time is done
- The user should be able to use the object while in multiple different postures
- The pillow should not distract the user from the activity they are doing.
- The user should be able to engage in whatever activity they wish to, giving them autonomy during the recovery.
- During the recovery, the object should provide the users with an active form of comfort which allows it to negotiate about setting the time.

2.7.1. Reflection on the use of data for this phase

Behavioural data helped me understand what people do in the living room.

Most insights during the phase came from subjective data gathered during the interviews. It helped in building a thorough understanding of what activities people engaged in and how they felt about the activities they engaged in during relaxation in the comfort lab and leisure at home. This was of great value when forming a design goal which was relevant to the user in this context.

Behavioural data show how people acted and behaved during relaxation in the comfort lab. While this did not lead to direct insights with regards to the design goal, it did give me a starting point for designing an OwI. Namely that the object should be used on the couch. It also revealed to me, that people regularly changed their posture during relaxation.

The machine data showed that there was potential for tracking how the people moved and behaved on the couch. While this did not provide additional or new insights next to the behavioural data, it did show similar results. Which indicates the possibility of the OwI being able to detect and utilize the way people move on the couch. It also indicated that machine data could provide with a more nuanced image than the behavioural data could.

3. Phase II - Concept development:

Towards developing a smart pillow as an intervention

In this phase, the development of the concept is discussed. First, the aim and approach are explained. Then an object with intent is chosen based on the findings of the previous phase. This is done by forming the intent, sketching the desired scenario and finally choosing a relevant object. Afterwards, the object is given form and shape through prototyping.

3.1. Aim

The aim of this chapter is to present the process of arriving at the concept of a smart pillow as an intervention to improve the quality of their recovery on the couch. Based on the design goal made in the previous phase, an intent is formed and a pillow is chosen as a meaningful object in achieving the design goal. An embodiment of the pillow has been crafted to explore the overall look and feel of the pillow and to allow for user tests to further understand how people intuitively use and experience it, and to speculate about its functionality and behaviours.

3.2. Approach

To design an object with intent the first step that is taken is to determine the intent. This is done first because I view the object as a means to achieve the intent and through that the design goal. Afterwards, a scenario is sketched to give an overview of the context in which the object will be embedded.

The next step is to pick an object that will be designed into an object with intent. In designing the object with intent it is important to realise that objects with intent are hybrid character artifacts (Rozendaal et al., 2019). This means people can frame the object as a tool, an agent or a combination of these. In this phase, the focus lays on designing the OwI as a tool, which means it aims to achieve its intent through its physical attributes. Afterwards, a prototype is created to further determine a first look and feel of the pillow. Within this prototype, care is put into developing a pillow that is comfortable and can accommodate multiple postures.

3.3. Concept development

Within this chapter, an object with intent is created. First, the intent is formed and explained. Then a scenario is drawn, explaining how this object could achieve its intent. An object is then chosen based on the intent, the scenario, and the findings of the previous phase.

3.3.1. Intent

The intent of the object is made in alignment with the design goal:

"The object wants people to take a conscious moment to recover after work"

The recovery is based on the moment people described in the co-creation session, the psychological mechanism and the result of the observation and interview. The conscious moment should cause people to be made aware that they are going to recover, for how long they are going to recover and that their recovery time is over. This ensures that at multiple points during the interaction system 2 of Kahneman is activated. This is done, in order to allow users to also engage in other leisure activities they might desire that also support the other psychological mechanisms. The activity they are doing or should be doing is deliberately left out of the intent. The reason for this is that the activity can have a different effect depending on the person and their day. Another reason is to allow them to feel a sense of autonomy.

3.3.2. Scenario

Based on the intent, a scenario (Figure 32) is formed to explore how an object could achieve the intent.

1. The object should detect the presence of the person in the room or on the couch.
2. The object should invite the person to use the object.
3. Based on the input of the user, a timer should be set.
4. The object should support the relaxation of the person.
5. When the time is over the object should stimulate the person to leave the couch and stop recovering.

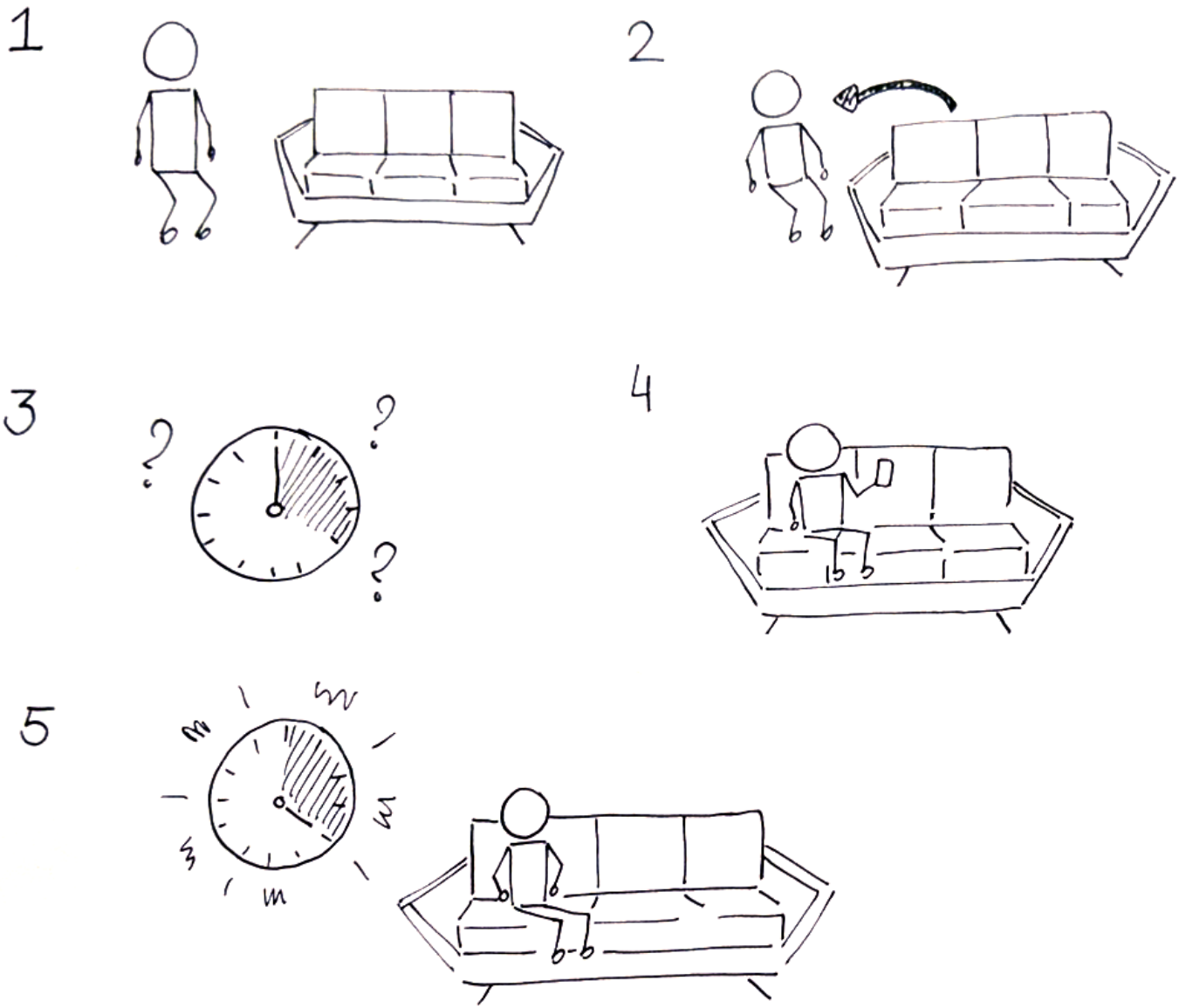


Figure 32 - Envisioned scenario

3.3.3. Object

To design the object the type of object first has to be chosen. This is done by exploring existing products that fit into the context and by looking at the results of the observations.

Exploring Objects

From the observations, it is apparent that people spent most of their time recovery on the couch. As can be seen if figure 18, 19, 20 & 21 all four people used the corner of the couch.

Thus, the object should be an object that fits in the context of the corner of the couch. This could be a pillow, the couch itself, a blanket or a small table for on the corner. With that knowledge, different kind of existing products were explored online and, in IKEA Delft, (figure 33).

A couch and a pillow were the two options with the most potential because they allowed the user to be comfortable. Ergonomic comfort was deemed important because it would be easier for them to immerse themselves into their activity and not be distracted by discomfort. Additionally, giving the object influence on the comfort of the user would give interesting possibilities of communicating. From these two the pillow was chosen as the object to design because it would have a larger reach. People would only have to buy an add-on for their living room instead of having to buy an entire couch.

Figure 33 - Overview of object explorations

3.4. Design & Prototype

Within this chapter, the object: a pillow, is given shape and form. This is done by exploring 3d shapes, sketches and iterative prototyping. First, the inside shape and material are discussed, then the outer look is created.

3.4.1. Shape

The main goal of the design of the shape is to provide comfort to the user. From the observation, it was apparent that the postures of people differ greatly and changed over time (Figure 35). In order to support this behaviour, the pillow would need to provide support for a wide variety of postures. To do so a variety of different postures and possible support for these postures were explored.

From there an ambiguous 3D shape was created (Figure 34) that could support most of the postures explored.

Figure 34 - Ambiguous 3D shape

Figure 35 - Overview of postures

3.4.2. Prototype

The shape was achieved by using soft foam from a baby mattress. This material was chosen because it was relatively cheap, easily available and had the softness I was looking for. This baby mattress was then cut into three equal pieces and stacked on top of each other (Figure 36) to gain the outer volume of the design.

Figure 36 - Outer volume of the design

From there a template was made for the side of the pillow to allow for cutting and testing the exact shape. During this process, the exact shape was yet to be decided so three templates were created (Figure 37).

Figure 37 - Outer shape of the design

Because the first one was the biggest, it was cut out first (Figure 38). By using that shape it was found that it was a bit too big. Thus, the pillow was cut down into the third shape (Figure 39).

Figure 38 - Large shape of the pillow

Figure 39 - Final shape of the pillow

3.4.3. Case

In order to give the prototype a finished feel and be able to test it a pillowcase was created. This was done by cutting out three pieces of fabric. Two for the sides and one long one going around the pillow. On the long piece of Velcro was added to allow removal of the pillow and washing of the case. The sides were then sewn together with the long pieces creating the final prototype.

Figure 40 - Encasing the pillow

3.5. Conclusions on having developed a concept of a pillow to help people relax

In this chapter, an object with intent and a prototype of this object has been created. This happened through an iterative process that builds on the findings from the previous phase. The OwI came to be by starting with picking a fitting intent, followed by creating a scenario and finally an object was selected. This was further developed and given form through creating a prototype. From this process came the pillow that can be seen in figure 41 & 42.

This pillow had the following intent:

"The object wants people to take a conscious moment to recover after work"

By giving the object shape in a physical prototype it can be utilised in the next phase. Firstly to validate if the pillow will be used as envisioned and to explore how else people experience the pillow. Secondly to inform and inspire the next step in the development, the actuation and behaviour of the pillow.

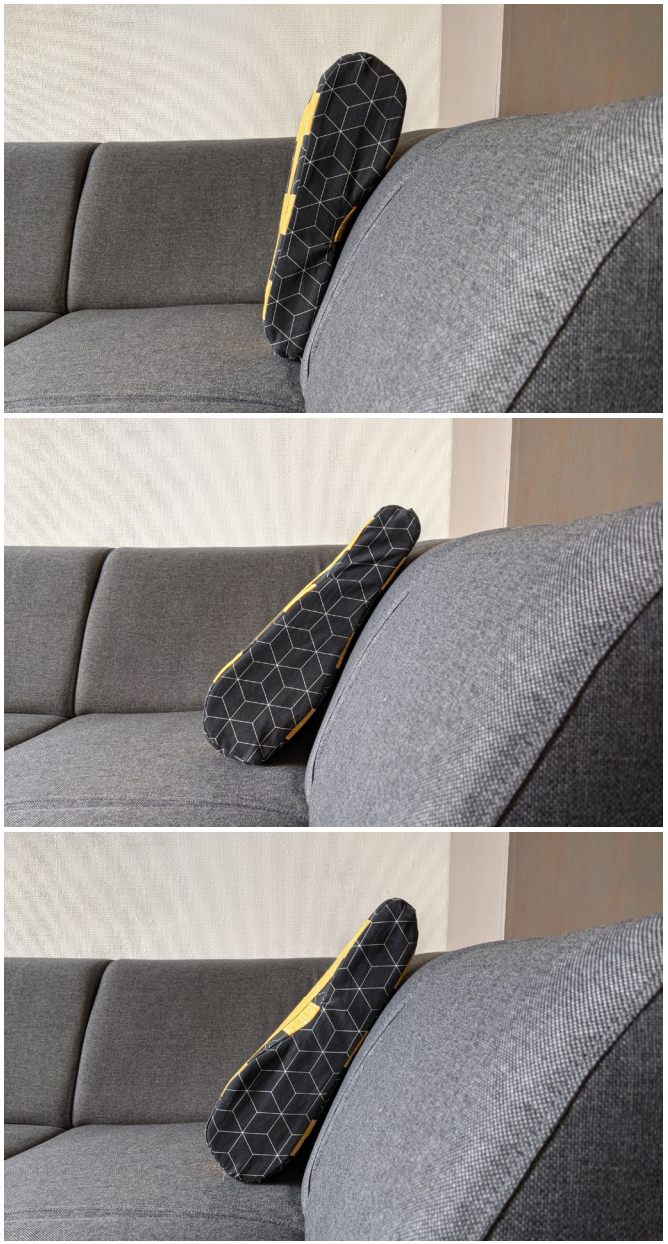


Figure 41 - Prototype against the side of the couch

Figure 42 - Picture of the prototype on a couch

4. Phase III - Perspective discovery:

The perspective of the user and of the Object with Intent

4.1. Aim

The aim of this phase is to enable the further development of the concept. The next step in the development is to improve the use of the pillow as a tool and to turn the object into an agent by designing its behaviour. To enable the next step, this phase aims to build an understanding of the perspective of the user and the perspective of the object. The perspective of the user is on how they view the pillow as a tool and on what kind of behaviour they desire from the pillow as an agent. The perspective of the object is on what the object can sense from the world around it, it's sensory intelligence.

The view of the pillow as a tool will enable iterating on the physical design of the pillow. Through this iteration, it should improve the use of the pillow as a tool. The combination of both perspectives will enable the design of the behaviour of the pillow. Through this, the pillow will become an agent.

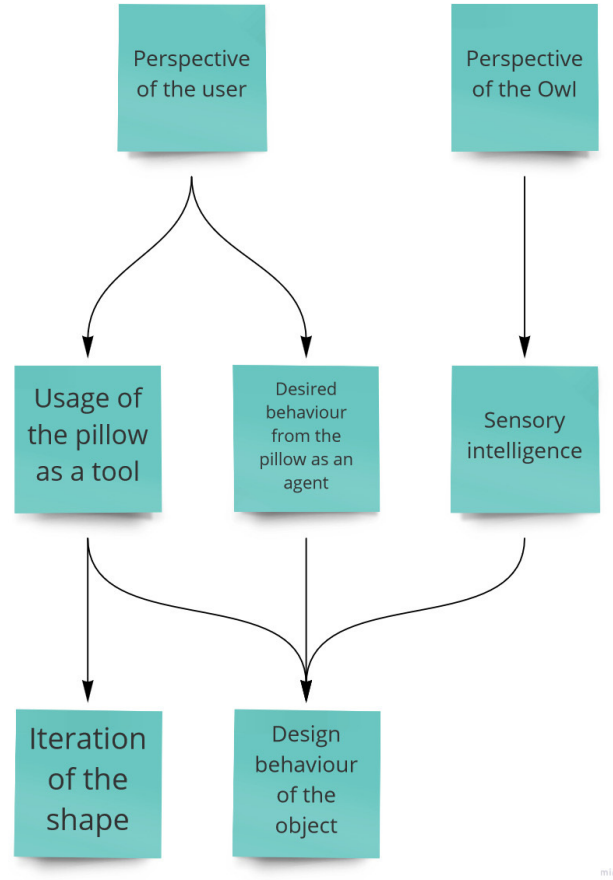


Figure 43 - Overview of the aim of phase III

4.2. Approach

To achieve both perspectives a data-enabled (J. van Kollenburg & S. Bogers ,2019) approach is taken. This is done by using a sensor-equipped prototype in a session with users. The data from this session is then processed and analysed. Afterwards, conclusions are drawn.

The first step in this process is to create a sensor-equipped prototype. This is done by making an assessment of what kind of sensing abilities could provide the object with relevant information to achieve its intent. Afterwards, these sensors are implemented into the prototype created in the previous phase.

The session with users consists of three parts. First, the users are asked to use the sensor-equipped prototype. Afterwards, they are interviewed about the usage of the pillow as a tool for recovery. Finally, the users are asked to co-create with me about the desired behaviour from the pillow as an agent which helps them recover. For this co-creation part, a live visualisation is made to help the participants in understanding the perspective of the object.

Afterwards, the tools and method used to process the data form session are explained. Then the analysis en insights for the usage of the pillow, the desired behaviour and the sensory intelligence are shown.

4.2.1. Data-enabled prototype

Before being able to execute the session with the users, a sensor-equipped prototype has to be made. This is done by making an assessment of what kind of sense capabilities are desired for the object. Then these are implemented into the prototype that was created in the previous phase.

4.2.2. Session with users

The sessions will be split up into three parts, based on theory from the convivial toolbox (Sanders & Stappers, 2016) (Figure 44). The first part, usage, will be a representation of the present (1). The second part will be an interview where users are asked to reflect and compare the present to their past (2). During the third part, the participants will be co-creating with the designer and going from the past (3) to designing for the future (4). During the last part, users have access to a visualisation of the data that the object gathers. Throughout the session machine and behaviour data is gathered.

The three parts all serve their individual purpose to achieve the design of the behaviour and are analysed accordingly. The interview is analysed to validate and improve the current shape, feel and texture of the pillow in relation to it achieving its intent. The co-creation is analysed to find what kinds of behaviour in terms of physical response people want. It also gives an indication of when the pillow should react to implicit or explicit behaviour of the user. The observation

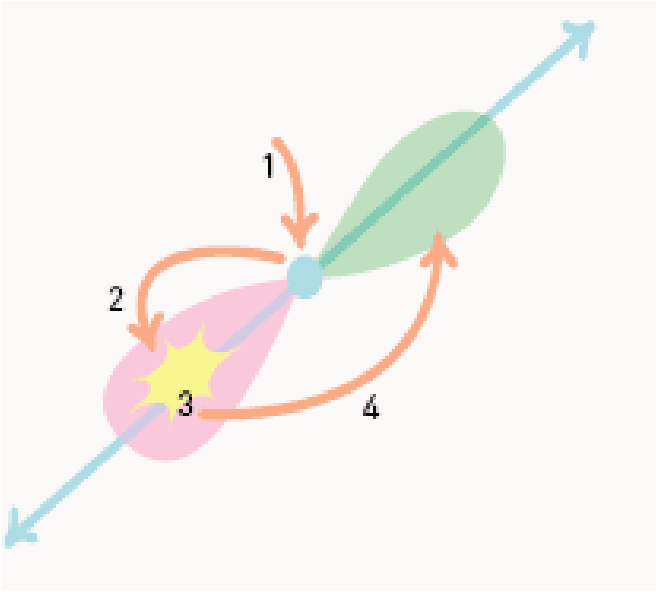


Figure 44 - Present, past & future (Sanders & Stappers, 2016)

is analysed to find specific moments in machine and behaviour data that require a response from the object.

To analyse the observation the machine data will be processed into a video showing a 3d visualisation of the object and its sensors over time. This video is then analysed in itself without the video of the observation. The reason for this is that the object will also only have the machine data available, thus it is important to find things in the data. The videos of the observations are also analysed individually. Afterwards, the videos are brought together, compared and analysed.

4.3. Data-enabled prototype

Within this chapter, an assessment is made of what kind of sensing abilities the object could have to achieve its intent. Then the implementation of these sensors is discussed by explaining the hardware and software.

4.3.1. Sensors

The goal of the sensors is to enable the object to detect the right cues to which it can respond with behaviour. However, it is not known what the right cues are or how the object will respond. What is known is that it is a pillow that will be used on the couch to recover. During the recovery, people will sit and lay in different postures and the pillow will provide the user with comfort. As a starting point in providing the pillow with sensing capabilities, the goal was set to find how the pillow is being used. To measure how people use the pillow, three parameters were chosen. The orientation of the pillow, the deformation of the pillow and the temperature inside of the pillow.

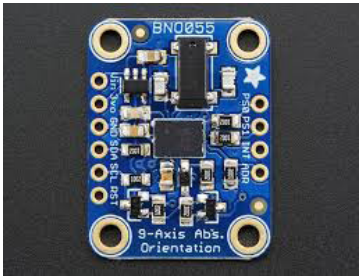


Figure 45 - BNO055

The orientation was measured through the IMU BNO055 (Figure 45). This sensor uses three sensors and complex algorithms to be able to calculate its orientation. The three sensors it uses are an accelerometer, gyroscope and a magnetometer.

The temperature was measured through the DHT22 (Figure 46), a temperature and humidity sensor.

Figure 46 - DHT22

To measure the deformation a custom sensor was created. This was done by using Velostat (Figure 47), an packaging material. This is a polymeric foil impregnated with carbon black, making it a conductive material. The conductivity of the material changes when it flexes, making it ideal to measure the deformation.

Figure 47 - Velostat

From the sheet of Velostat sheet, five strips were cut out and sandwiched between strips of aluminium foil. They were attached together using non-conductive tape and placed in the centred of the foam inside the pillow. On both sides of the material, a strip of aluminium foil was placed using non-conductive tape (Figure 48).

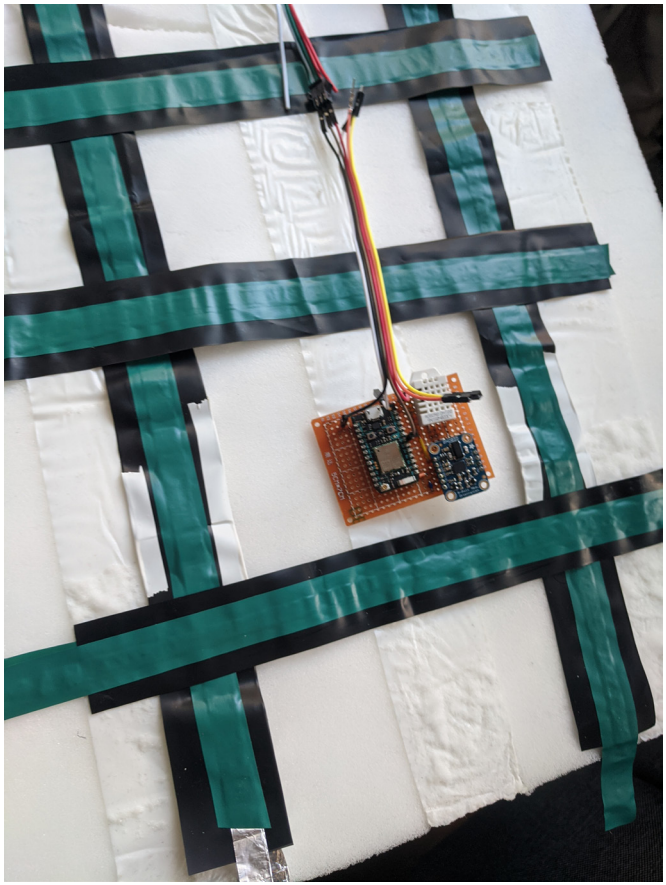


Figure 48 - Pressure sensors inside the prototype

Then all the wires and sensors were soldered to a board to make a compact and durable package that could be placed inside the pillow. All the wires were then connected and taped, and the foam was put back together.

To send data gathered by the sensor to the server, the same method as in the previous test was used. This was by sending the data from the board to the particle server and then from the particle server to the DCD Hub.

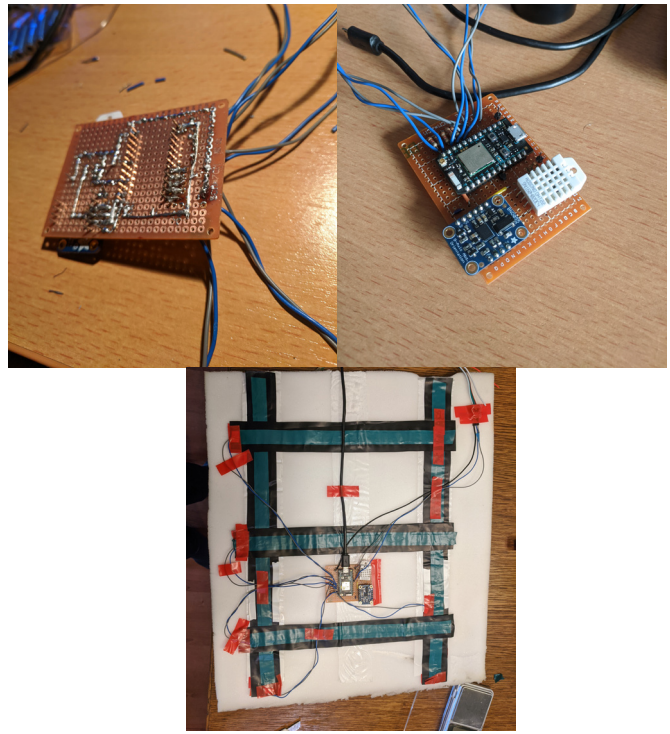


Figure 49 - Wiring of the prototype

4.4. Session with users

In this chapter, the co-creation session is discussed. First, an introduction is given, and the research questions are discussed. Then the method and the data-enabled prototype are explained. Afterwards, the results are analysed, and conclusions are drawn.

4.4.1. Introduction

As mentioned in 4.2.2. this consist of three parts, product usage, an interview and a co-creation. For the usage, participants will be asked to recover for half an hour using the concept. During the interview, they will be asked questions regarding their experience with the pillow and their daily lives at home with respect to relaxation and recovery. During the third part, the co-creation the participants are asked to think about how the concept can help them in the future.

The session will take place in the comfort lab with a similar set up as the previous test. There are two main differences. Firstly the pillows present in the previous test will be removed and replaced with the concept. Secondly this time there will be a tv present for them to use.

4.4.2. Research questions

For each part of the session, there are different research question.

Usage

1. How do people use the pillow?
    a. What kind of postures are comfortable with the pillow?

Interview

1. What does their current recovery moment look like?
    a. How would the pillow fit into that moment?

Co-creation

1. What kind of feedback do people want from the pillow at what moment?
2. How do people want to be encouraged to take a moment to recover?
3. How can the pillow encourage/enforce an active sitting position at the end?
4. How long should the recovery moment be?
    a. Is it similar every day or does it vary?
        i. If it varies how can the time be set?

4.4.3. Hypothesis

Usage

The pillow was designed to be placed behind and next to people, it should be comfortable when sitting upright and when laying down. However, the expectation is that there will be more postures in which the pillow will be used.

Interview

Based on the previous research the expectation is that these recovery moments currently are longer than the participants would like and that they have trouble with activating themselves. These moments will be spent mostly on the couch while watching tv, on their phone or playing a video game.

Co-creation

The expectation is that people desire the most feedback at the beginning and end of a recovery moment. At the beginning to invite them and at the end to help them stop relaxing and re-energize. During the recovery the expectation is they desire minimal input from the pillow.

4.4.4. Participants and procedure

For this research, there were four participants. Three of them were Industrial design students, one studies Communication and Multimedia design. Three were male, one was female. They were aged between 22 and 26.

Each test will start by giving the participants a short introduction of the experiment and the product. After the introduction, people will be asked to sign a consent form regarding the study and collection and storage of data. Afterwards, they will spend half an hour in the comfort lab with the goal for them to take that moment to recover. Then there will be a semi-structured interview about their experience, the product and their home experience. This will flow into having a co-creation session where they will be asked to think about how the pillow should help them during recovery. During this, my role will be mainly to help them think about the possibilities and to give them examples of behaviour. While brainstorming, a live visualization of the data the pillow gathers will be used in order to stimulate thinking about what input should lead to what output. The complete procedure can be found in appendix 8.5.

4.4.5. Data-enabled session

During the session with the users, all three types of data were gathered. Figure 50 gives an overview of what data was gathered from which part of the study and what goal of this phase it informed.

During the co-creation users are asked to think about what behaviour they desire from the pillow. However, for the pillow to be able to execute this behaviour, it needs to know to what cues it should respond with that behaviour. In order to stimulate the participants to not only think about the behaviour but also about the cues, a live visualization of some of the sensors is made.

For the visualization of data gathered by the pillow Processing("Processing.org", n.d.) was used. Processing is an open-source graphical library and an integrated development environment(IDE), making it a fitting tool to create a visualisation from data. The code written for processing retrieves data from the past 10 seconds from the server. It visualized the flex sensors into 5 individual graphs and the data from the temperature sensor is displayed in the text.

Due to the limitation of the particle the refresh rate for this visualisation was approximately once every 1.5 seconds. An attempt was made to reduce this refresh rate, by sending the data directly to the DCD hub using MQTT. However, this turned out to be very difficult or impossible with a particle photon. Due to time constraints, the 1.5-second refresh rate stayed.

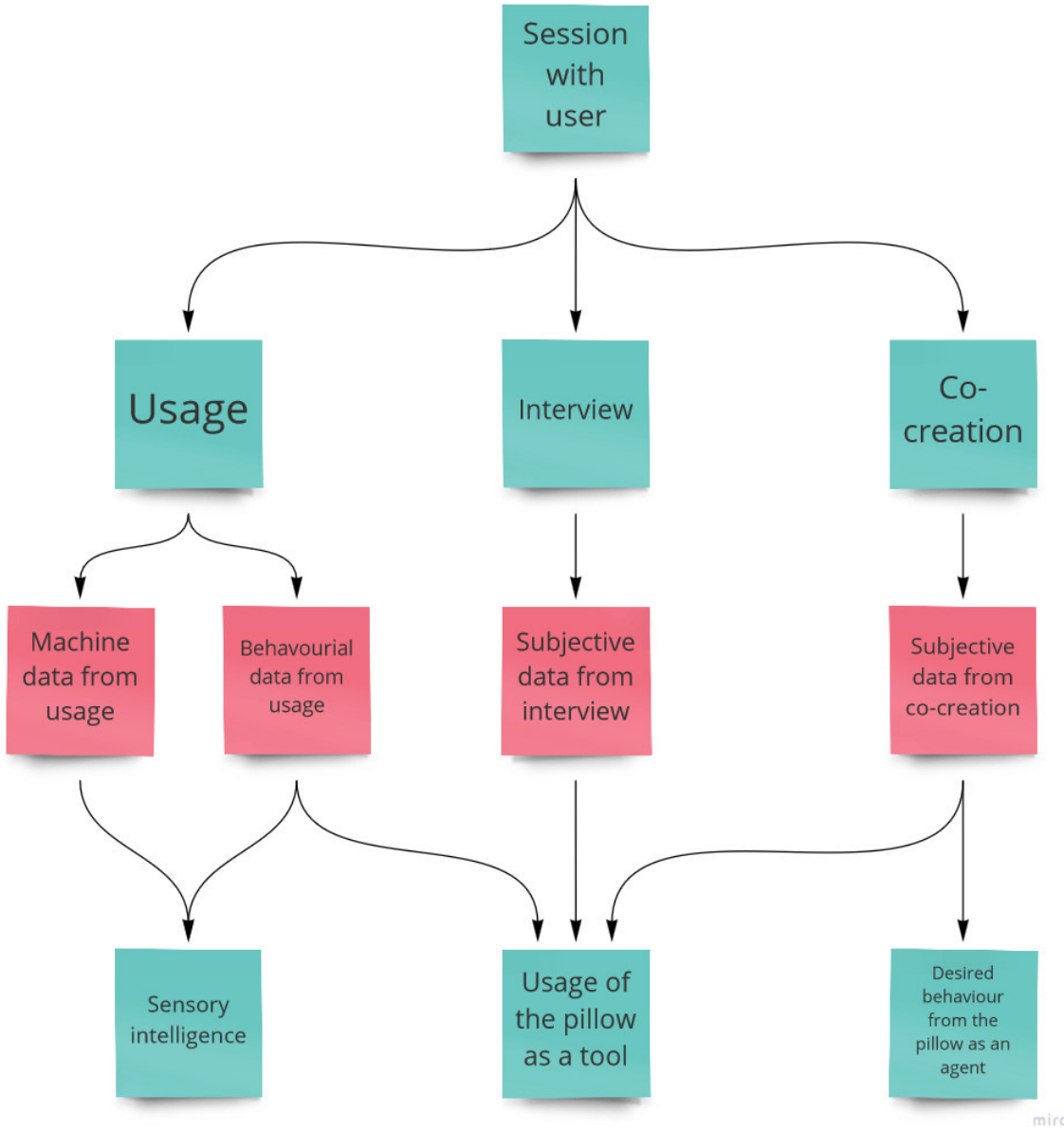


Figure 50 - Data flow phase III

4.5. Data processing & analysis

Within this chapter, an explanation is given on how each data type is handled. For each data type, the tools and methods used to process and analyse the data are explained. For the machine data, a visualisation is made which includes a 3d representation of the object. For the behavioural data, similar visualisations to the first phase are created. The subjective was processed in a more pragmatic way through note-taking.

4.5.1. Machine data

The machine data was generated during the usage part of the test. The data comes from the sensors placed inside the pillow. The data generated during the test was sent to the DCD hub. For each sensor, the data can be pulled from the server. When the data is pulled from the server it is still in its raw form. The data a big list, where each entry consists of a timestamp and values from the sensor (Figure 51). The list of values that one sensor gathered during one test of 30 minutes can have up to 6000 entries. This list is not only incredibly long but also hard to read and uninspiring.

```
1580304162309,-0.401367,-0.431213,-0.59021,-0.551941
1580304162614,-0.401367,-0.431213,-0.59021,-0.551941
1580304162999,-0.401367,-0.431213,-0.59021,-0.551941
1580304163004,-0.401367,-0.431213,-0.59021,-0.551941
1580304163308,-0.401367,-0.431213,-0.59021,-0.551941
1580304164103,-0.401367,-0.431213,-0.59021,-0.551941
1580304164410,-0.401367,-0.431213,-0.59021,-0.551941
```

Figure 51 - Raw data from BNO055

As a first step, the data from the pressure and temperature sensors were imported into Excel and graphs were created (Figure 52 &53).

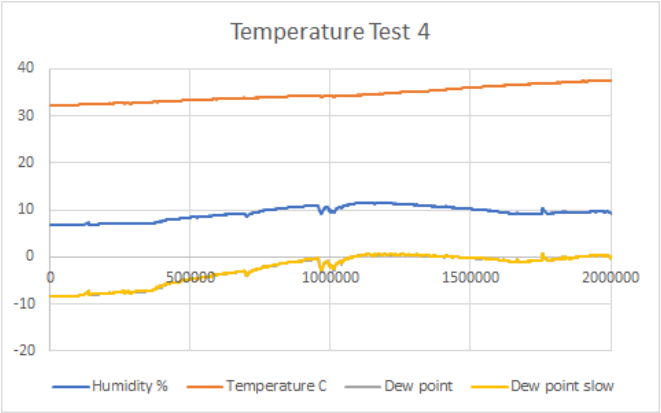


Figure 52 - Temperature data visualised in Excel

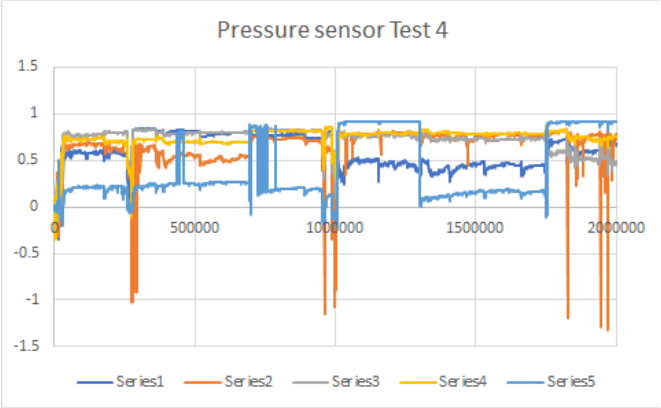


Figure 53 - Pressure data visualised in Excel

While the graph of the temperature shows a relatively clear picture, the graph of the pressure is harder to read. To improve the visualisation of pressure and include the orientation sensor I asked myself three questions that I thought could help me understand the sensory intelligence of the object.

- What can it sense in a specific moment?
- How does that evolve over time?
- How does that relate to the world around the pillow?

To answer those questions I decided that the visualisation should be an animation of the data. By making an animation which shows the data in real-time, it could be linked to the video of the observation and through that the world around the pillow. It would also show what the object could sense at any moment by going to the desired timestamp. By simply watching the animation I could understand how the data would evolve over time.

Figure 54 shows a snapshot of the animation that was created. The animation consists of three parts. 1) A 3D representation of the object and the data. 2) A complete timeline of the data generated by the pressure sensors. 3) A 10-second zoomed-in view of the data generated by the pressure sensors that shows a detailed view of the data.

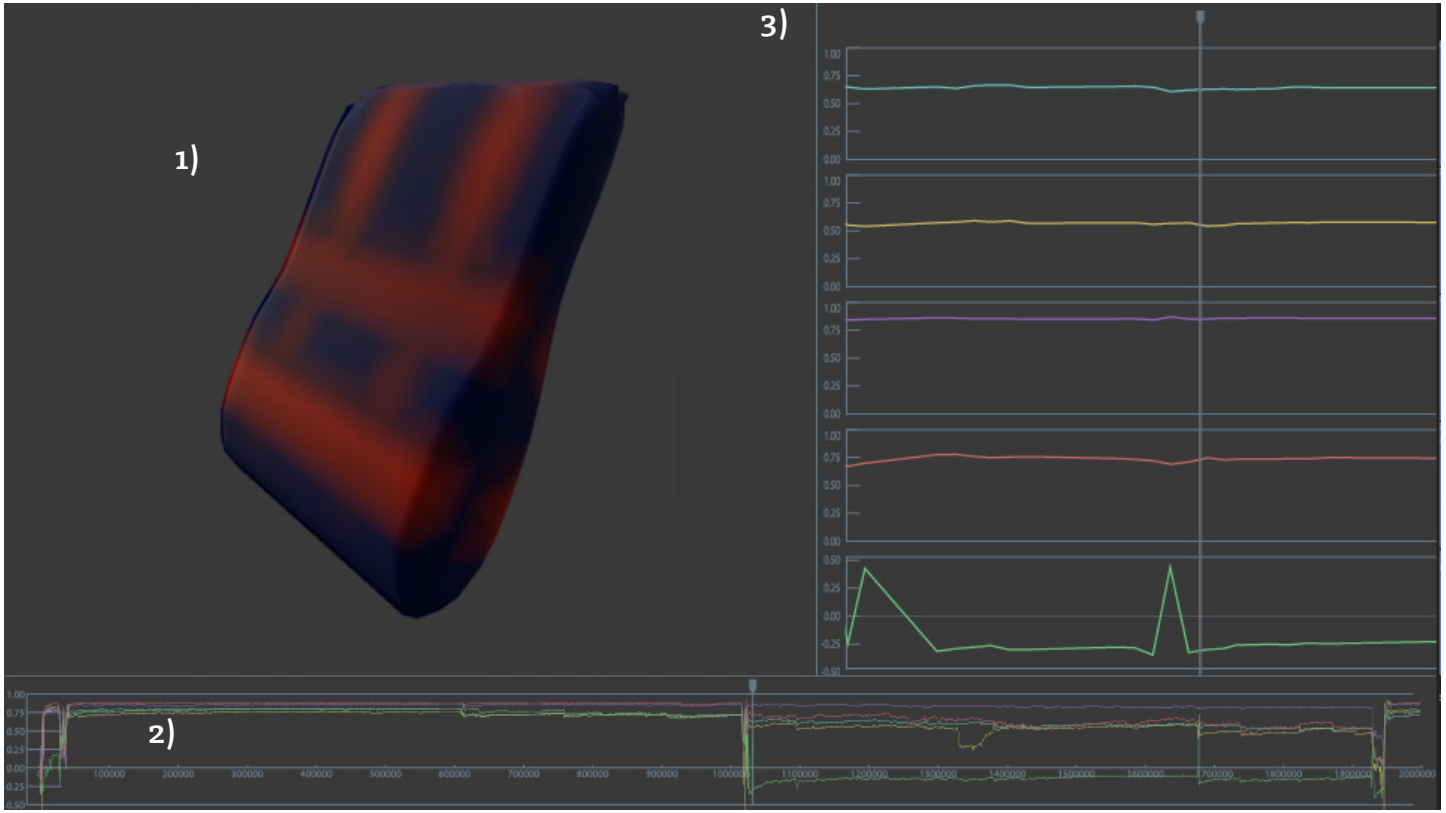


Figure 54 - Snapshot of the animation of sensor data

3D representation

In order to create a 3D representation of the object and the data Blender (Blender, 2020) was chosen. Blender is a free and open-source 3D creation suite. Within Blender, a 3d model was created which represents the pillow. The video of the observation was also added as a reference (Figure 55).

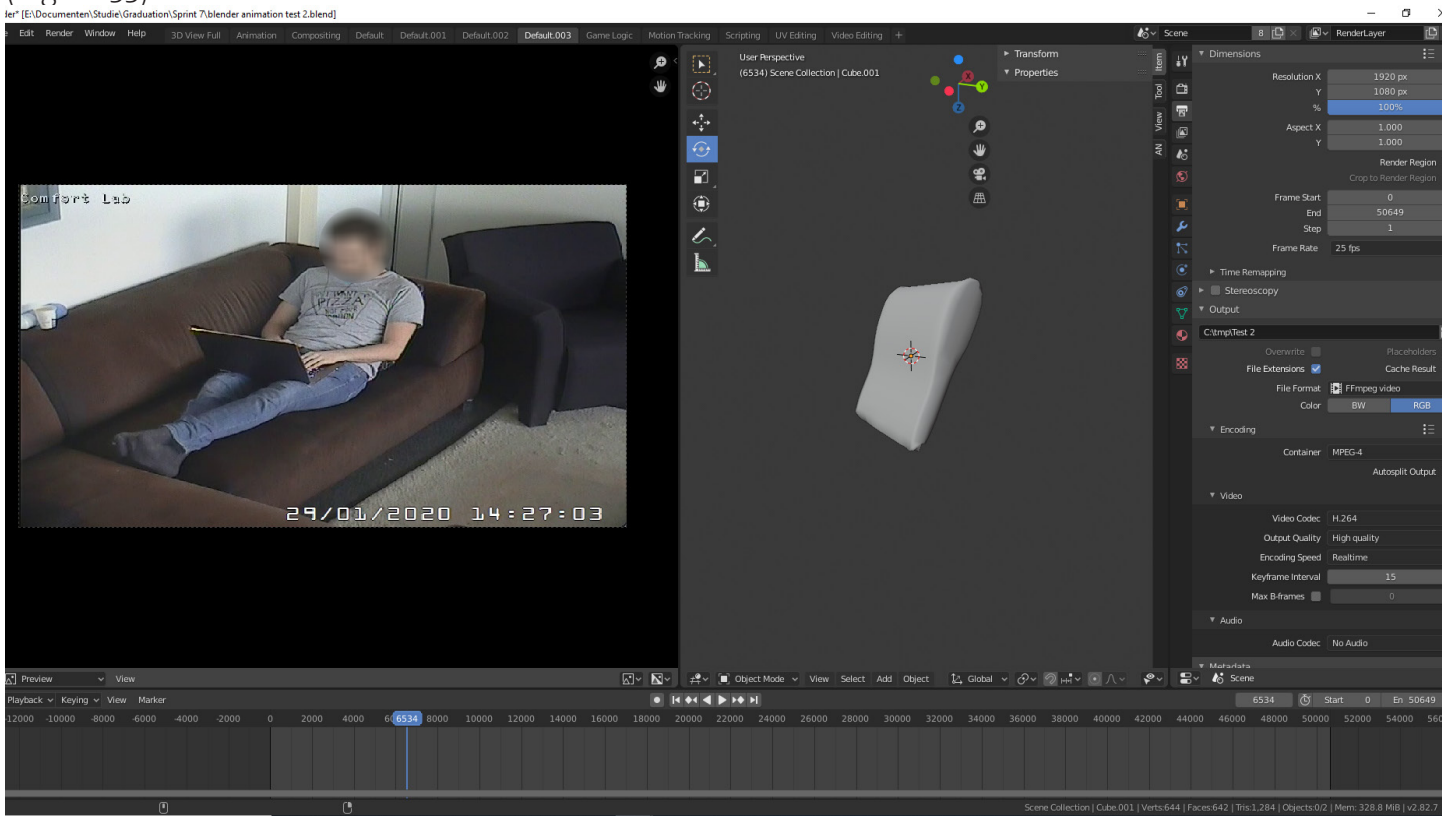


Figure 55 - 3D model and video footage in Blender

To apply the data to the 3d object, Animation Nodes (Lucke, 2020) was added to Blender. Animation nodes is a visual-based scripting system for motion graphics in Blender. For each test, the CSV files of the pressure data and the orientation data were pulled from the DCD hub and imported into Animation Nodes. These files were parsed into objects animation nodes could work with, figure 56.

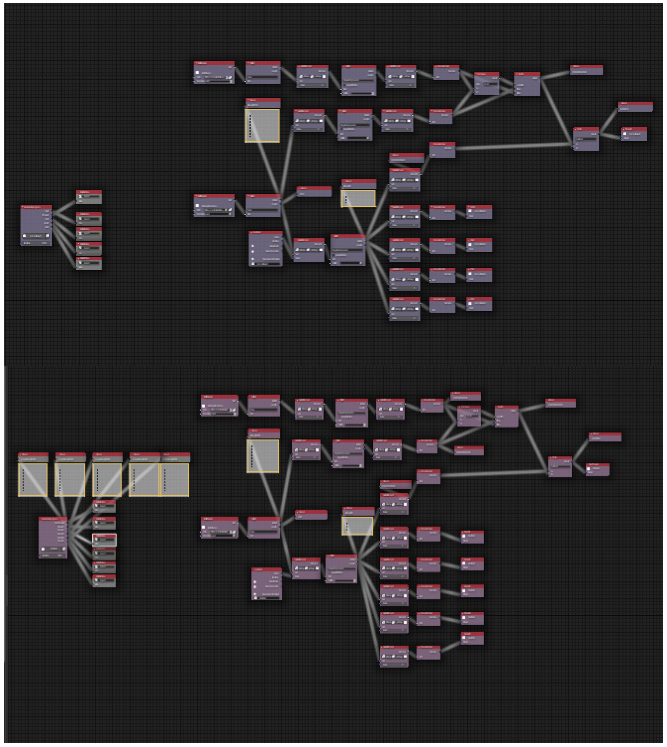


Figure 56 - Proccesing CSV data in animation nodes

From there the data could be used to animate the orientation of the object and visualise the pressure on the pillow (Figure 57 & 58). To visualise the pressure on the pillow, the values of each of the pressure sensor was normalized between 0 and 1. This was necessary because the pressure sensors were custom created and the range for each was vastly different. Thus, when there was no pressure each sensor displayed another value. By normalizing these values, the visual displayed the relative change in pressure, which worked fine for this visual. The pressure sensors are displayed by placing red strokes on the pillow, and the more red and intense they are, the higher the pressure is.

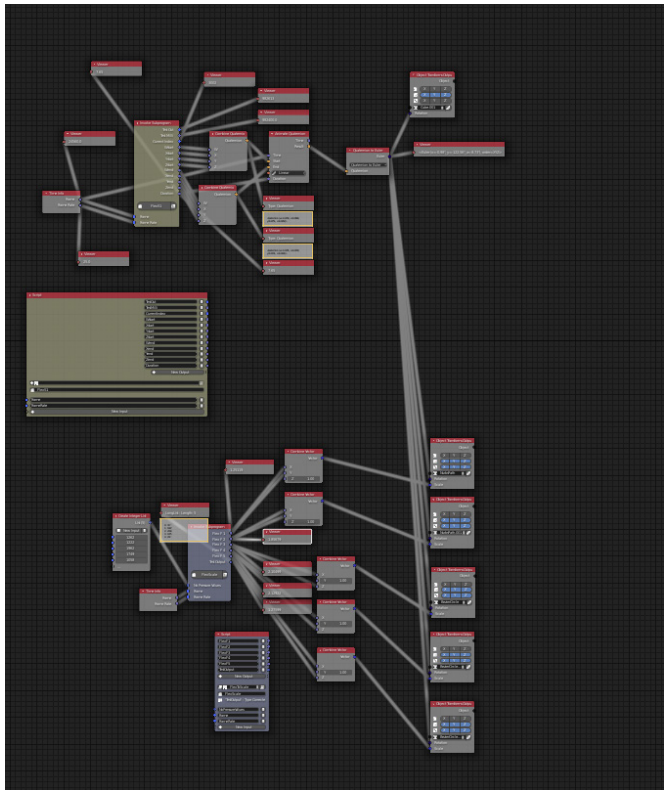


Figure 57 - Animating the pullow in animation nodes

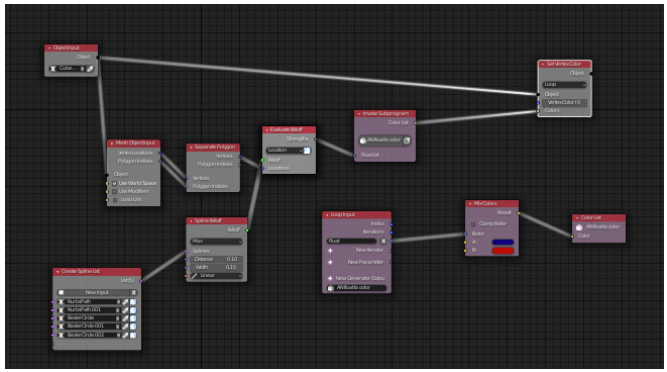


Figure 58 - Visualising the pillow in animation nodes

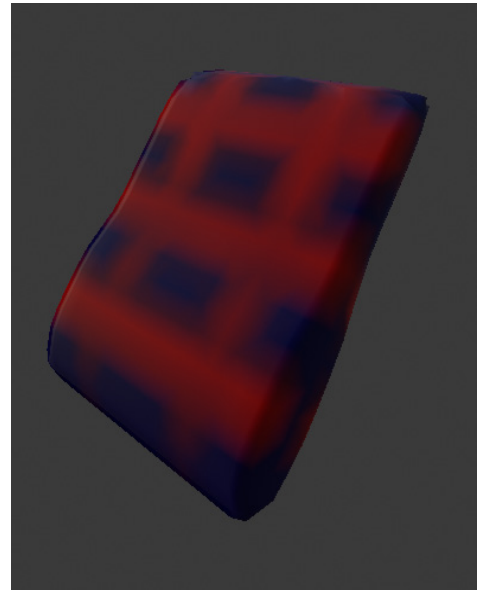


Figure 59 - Pillow being fully pressured

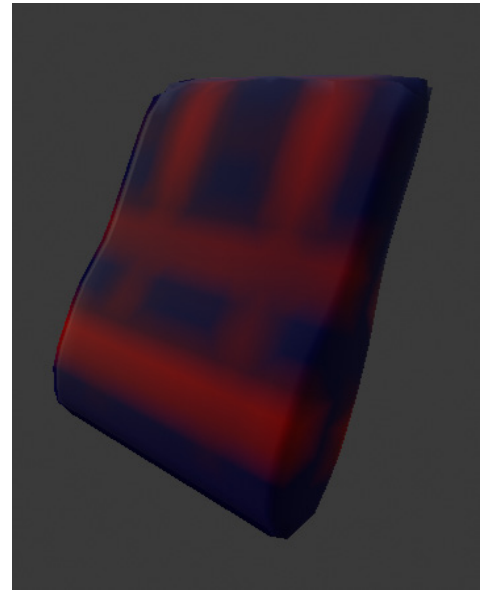


Figure 60 - Pillow being partially pressured

At this point, Blender was able to show a 3d representation of the object with its orientation and the pressure sensors. However, this animation ran incredibly slow and even after quite a bit of optimisation it still ran at around 10 frames per second, which is a third of what the desired speed is. Therefore it was decided to export this animation into a video and create the rest of the visualisation in another program.

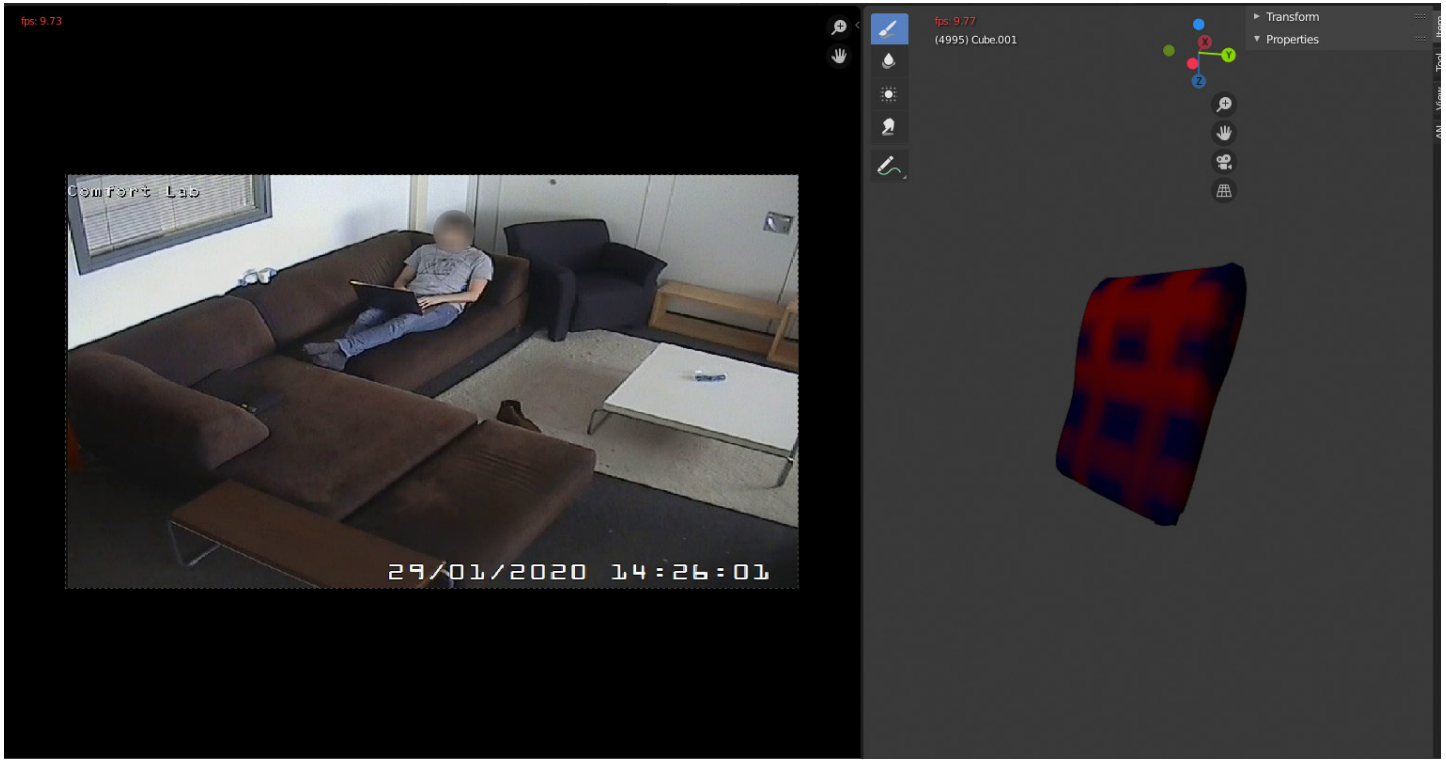


Figure 61 - Blender running below 10 fps

Pressure sensor graphs

To create a complete timeline of one test the CSV files that were pulled from the server were imported into Excel. In Excel, the values were normalized again. From there the values were copied to Illustrator and within Illustrator, the timeline was created (Figure 62).

The process for creating the detailed view was similar, only where the aspect ratio completely different because only 10 seconds at the time were visible.

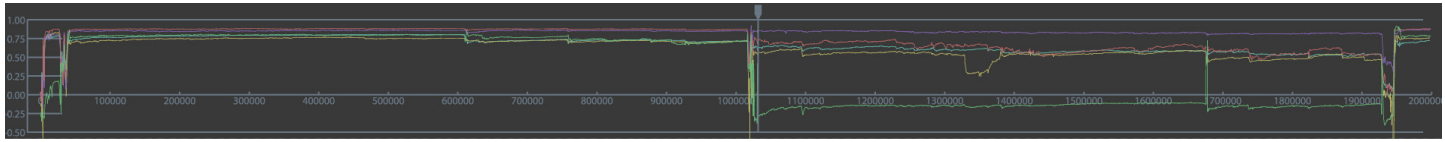


Figure 62 - Complete timeline of the pressure data

Creating the animation

In order to create one animation with the 3d representation, the complete timeline and the detailed view, After Effects was used. Within After Effects the different elements were imported and animated. An indicator was placed and animated on the complete timeline to show where in time the animation was. The detailed view was animated and synchronized with the 3d representation of the pillow.

Next to an animation of the machine data, an additional animation is created where the video of the observation is added. This was also done in After Effects by importing the video and rearranging the elements.

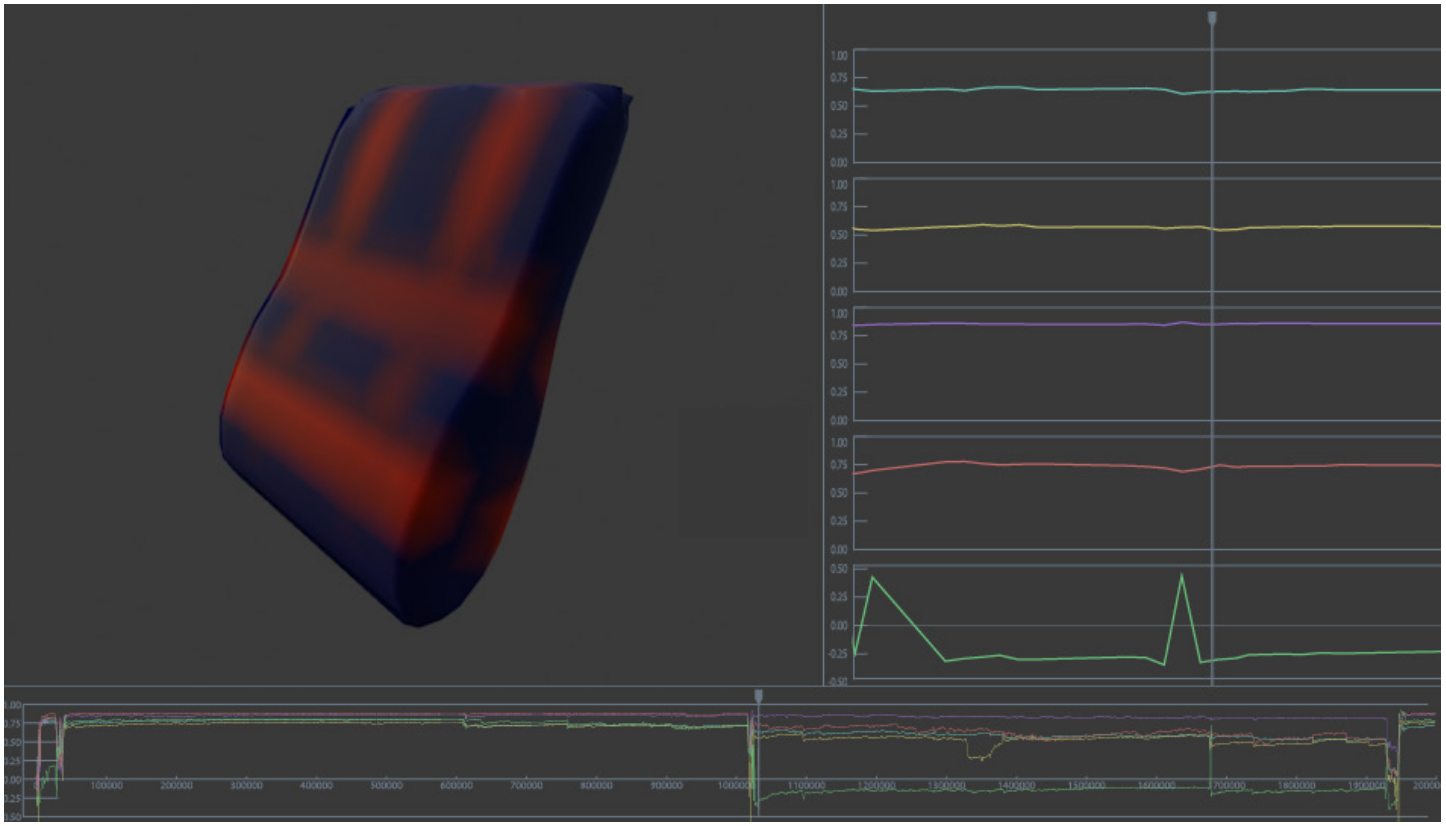


Figure 63 - Animation with of a 3D represenation, the complete timeline and a detailed view

Analysis

In order to analyse the visuals created, they were exported into .mp4 formats. These were then imported into ATLAS.ti. Within ATLAS.ti the videos were coded, these codes were of a descriptive nature where the pressure and the rotation were described. The process of coding the video and the codes themselves were equally valuable for gaining insights.

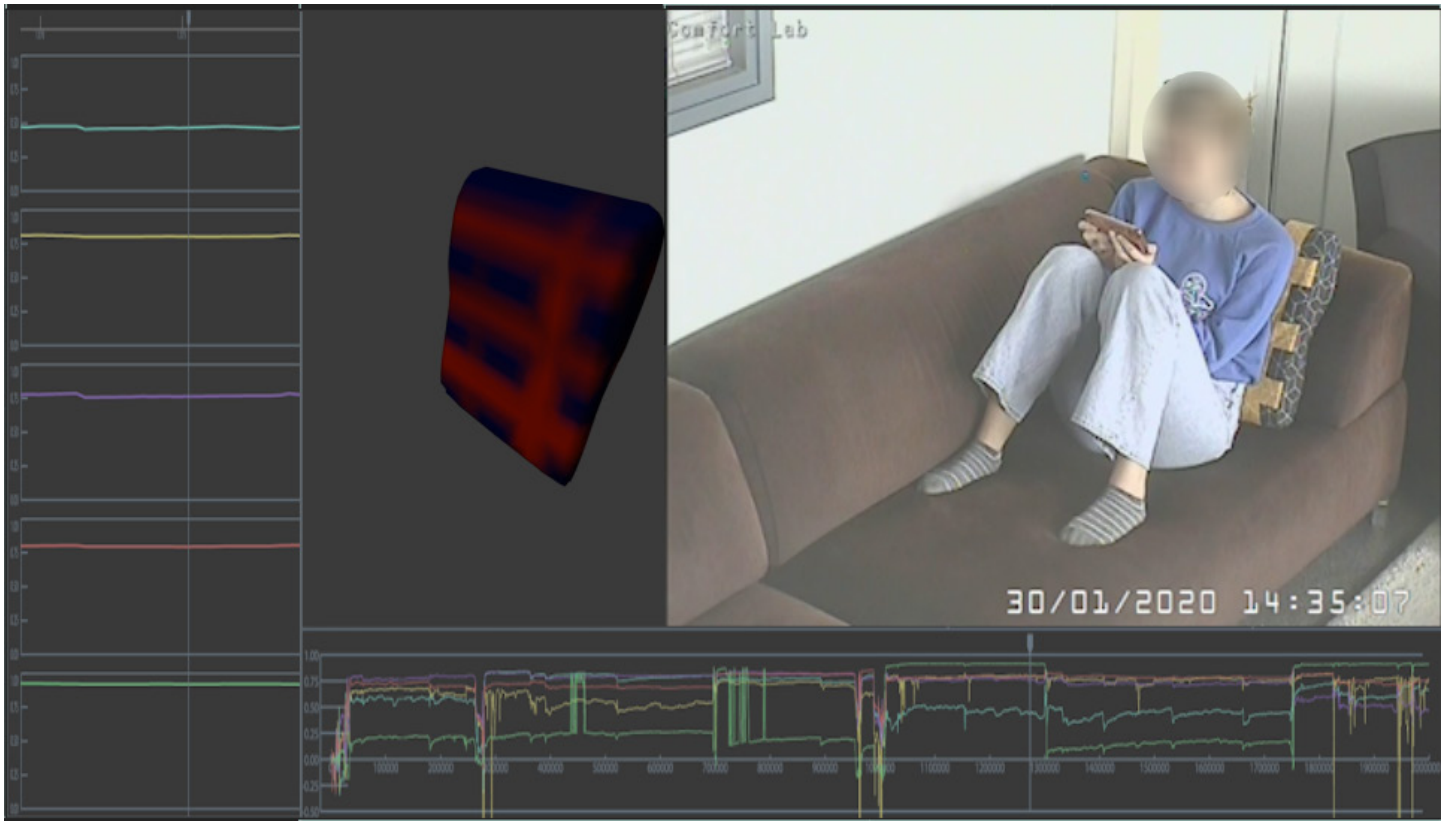


Figure 64 - Animation with of a 3D represenation, the complete timeline, a detailed view and the corresponding video

4.5.2. Behavioural data

The behavioural data of this test was generated during the usage part. This data are videos that recorded the usage of the pillow. To analyse this data ATLAS.ti was used again. Within atlas, each video was coded. These codes were descriptions of the behaviour of the participants and the usage of the pillow. They described the posture, big and small change in posture and the orientation of the pillow.

In order to gain further insights into this data, these codes were visualised. This visualization is a timeline of the codes created in Illustrator. To get the codes into Illustrator, they were first exported to Excel. Here the names of the codes were split to get a timestamp for each code. Then the Excel was imported into RAWGraphs. RAWGraphs generated a time series chart which was exported as SVG. This SVG was then imported into Illustrator and adjusted into the timeline that can be seen in figure 65 &66.

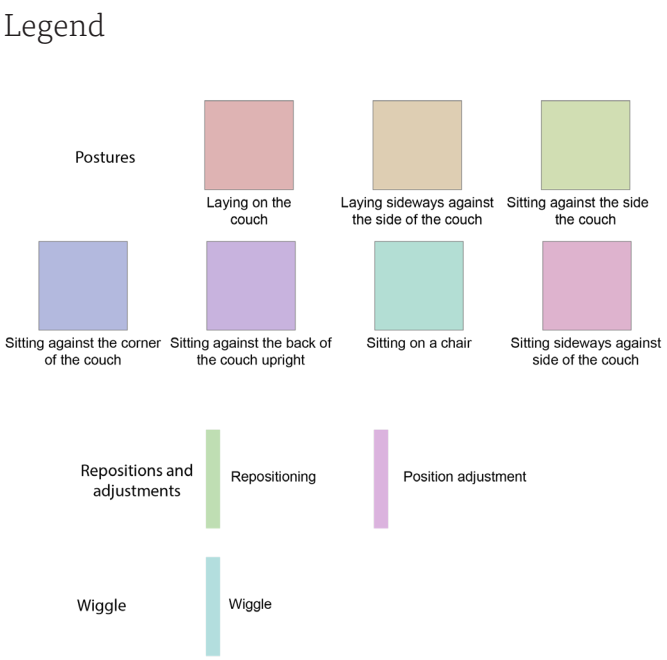
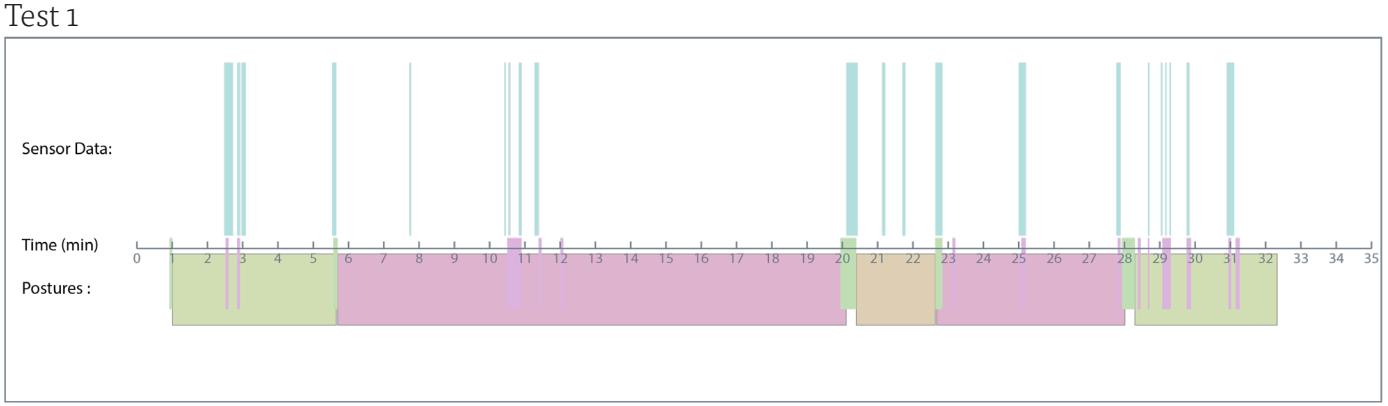
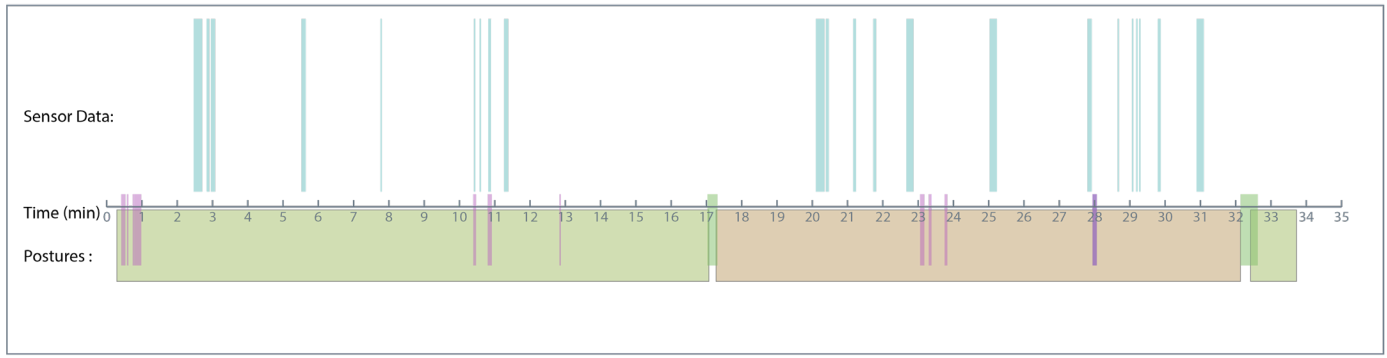


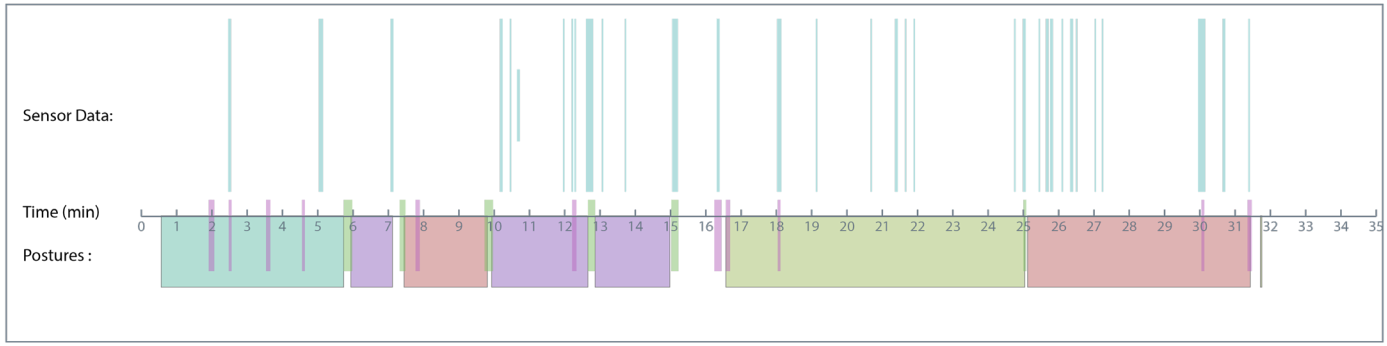
Figure 65 - Graphs showing posture codes from the videos and the wiggle code from the animations



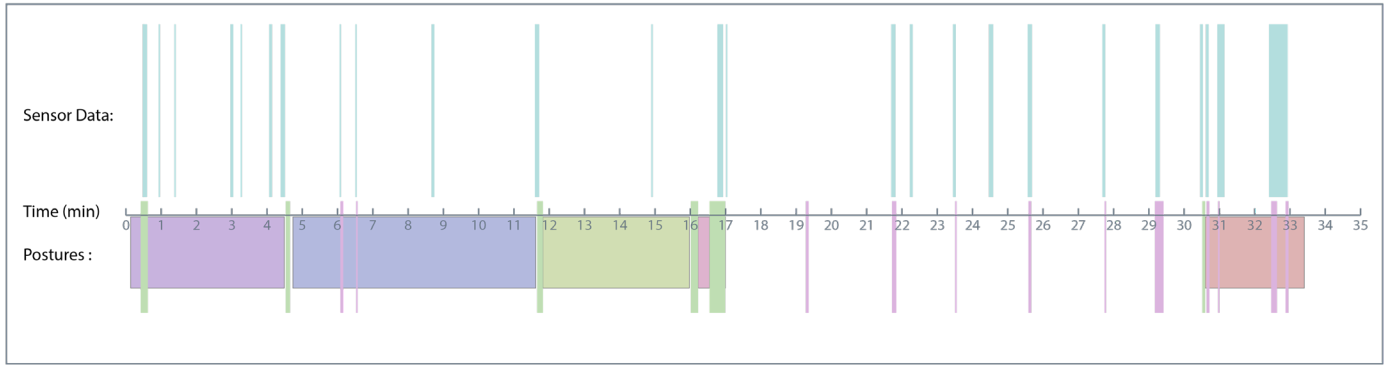
Test 2



Test 3



Test 4



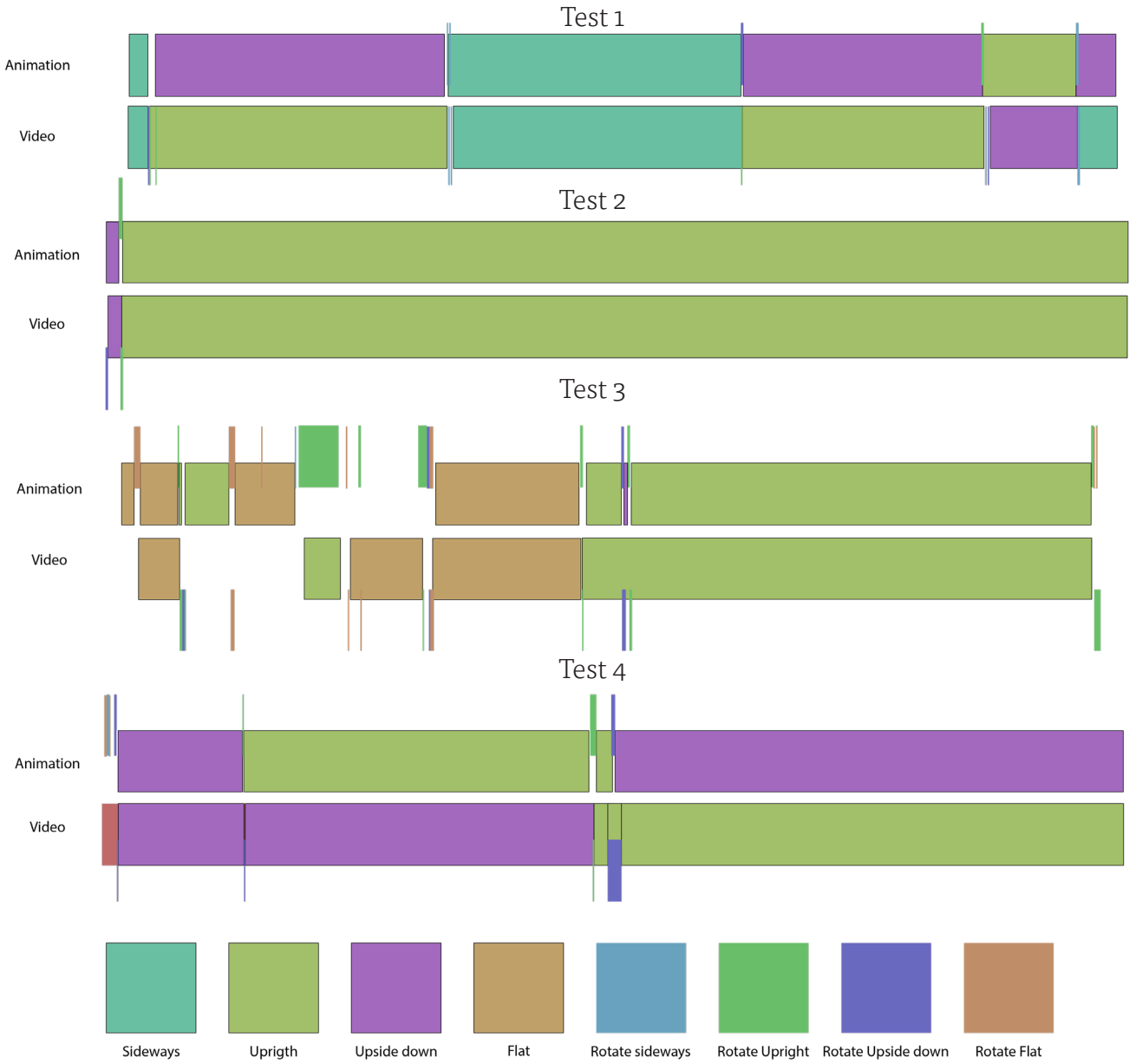


Figure 66 - Graphs comparing the pillow positioning and movement codes between the animation and video

4.5.3. Subjective data

The subjective data was generated during the interview and co-creation. It consists of an audio recording of both the interview and co-creation; notes made during the recording; sketches and notes made together with the participants during the co-creation. For each goal, the audio was carefully listened back to and notes were made of anything that was deemed relevant. Based on the notes made during the test, the notes made while listening back and notes and sketches from the co-creations, conclusions were drawn for each goal.

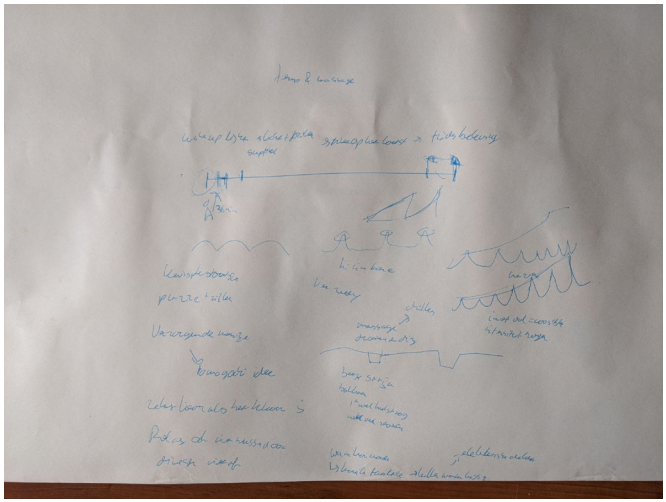
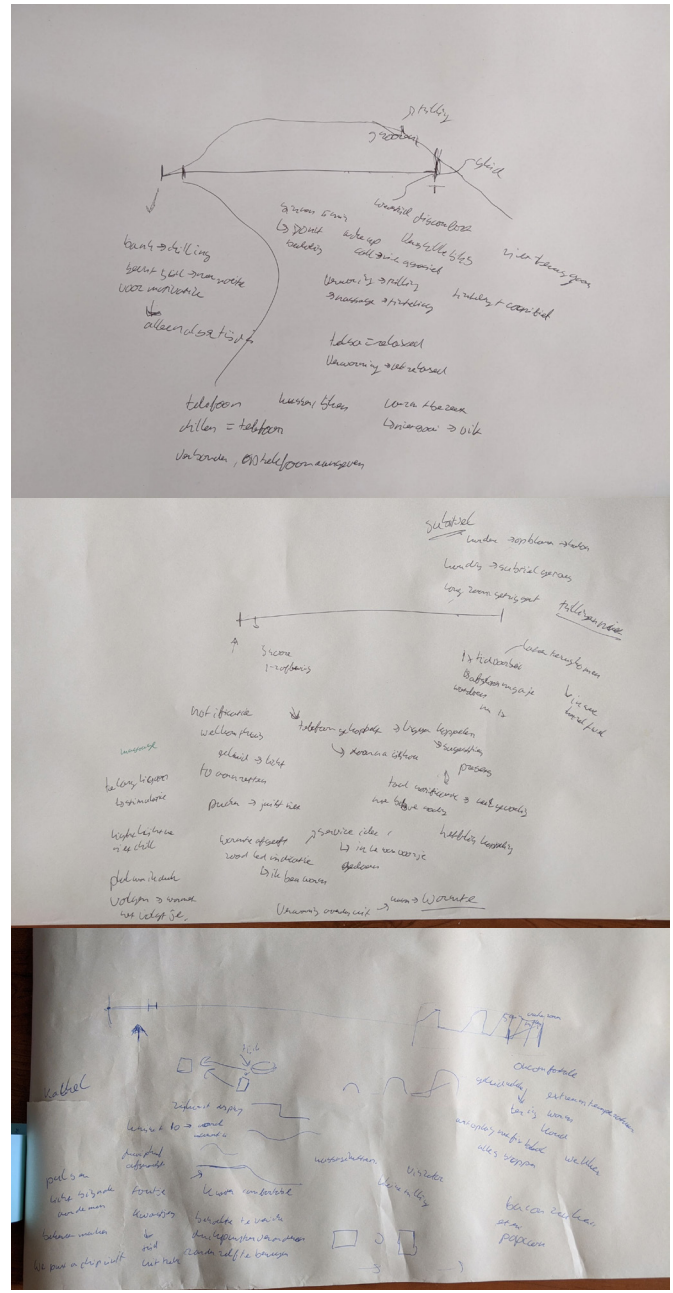


Figure 67 - Sketches and notes made during co-creation



4.6. Results

In this chapter, the results of the analysis are presented. First, the usage of the pillow as a tool is discussed. Then, the desired behaviour from the pillow as an agent is discussed. Finally, the sensory intelligence of the object is shown.

4.6.1. Usage of the pillow as a tool

In phase II, the OwI was designed and a physical prototype was created. The shape and material that were chosen had two primary goals. Firstly the pillow should provide comfort to the user. Secondly, the pillow should support a wide variety of postures that people use on a couch. These goals were validated based on the observation and interview with the participants. The participants were also asked to reflect on how the pillow would fit into their daily lives.

Comfort

From the interview, it was found that all participants liked the shape of the product. Their reasons were that it was supportive in multiple postures and that it made the couch more comfortable. However they would like the pillow to be a bit softer, one participant proposed a two-layer system as mattresses use.

Variety of posture

From the observation, it was found that people used the pillow a wide variety of different posture (Figure 65). They also mentioned the support in multiple postures as one of the features that made the pillow more comfortable.

Fit into their daily lives

When asked how the pillow would fit into their daily lives they said they would like to use a pillow like this at home. One even mentioned that it would create new comfortable options of sitting on their couch. However, they did point out a possible improvement before they would use it. Namely that the prototype did not yet look enough like a pillow one would use on the couch, a throw pillow. The pillow should fit better on the couch and should communicate through its shape and look like it is supposed to be used on the couch.

4.6.2. Desired interaction with the pillow

During the co-creation session participants were invited to think along with the next steps of the development of the object. We, the participants and the researcher, looked at how the user would want to interact with the pillow and what kind of behaviour was desired from the pillow.We specifically looked at three moments during the interaction. First, at how the time should be set for the recovery. Second, at how the pillow could provide them with active comfort during recovery. Third, at the end of the recovery and with that the continuation of their evening

Setting the time

When asked how they would want to set the time for their recovery they mentioned using their phone or a smart speaker such as Google Home. They proposed it could even have presets, for example, the length of their favourite show on Netflix. However, I challenged them to think about a solution in which it would be integrated into the OwI. From the brainstorm afterwards, the most promising proposal was to integrate it by adding tassels to the pillow. The tassels could then be pulled and the length they were pulled would determine the length of the recovery.

Providing active comfort

When asked how the object could actively provide them with extra comfort they unanimously mentioned they wanted the pillow to provide them with warmth. They also imagined it would be nice if it could give them a massage.

Stopping

When asked to think about how they would want the end of the recovery to be they said they wanted to be notified when their time is almost over. This reminder should be subtle with a consistent interval so that they could mentally prepare that they have to stop recovering. When it was actually time to stop recovering they thought the pillow should communicate that to them by making the usage of the pillow uncomfortable. The moment it was time to stop had to be clear, yet also private in case they were surrounded by roommates. If the pillow was able to force them off the couch, they wanted the pillow to have a cooldown timer. This would mean that if a user would come back to the pillow within a few minutes it would immediately start providing discomfort again.

4.6.3. Sensory intelligence of the pillow

The data gathered by the sensors on the pillow provided a detailed image of what the pillow could see. So detailed that it would take a long time to investigate all the machine data. For example, the sensors of the pillow might be able to detect the breather rhythm of its users. However, to investigate and validate this would take time, which is not worth it if this pillow does not end up using this.

Therefore, the analysis of the sensory intelligence happened through an iterative process where the design of the behaviour of the pillow was the driving factor. Within this process, I intuitively switched between the sensory intelligence, the desired behaviour and the requirements from phase 1, to iteratively improve the design. Each step the behaviour of the pillow became more specific. In this process, the sensory intelligence inspired new behaviour and added specific cues to behaviour. The results from analysing sensory intelligence that explicitly led to inspiration and cues are presented.

Slouching

As can be seen in figure 68, one participant slowly started to slouch near the end of the half-hour of recovery. This inspired a further look into the data so see if this was detectable because it could give the pillow a new behaviour. As can be seen in the first image, the pressure is on the upper side of the pillow while in the other pictures it is on the lower side. While the moments they adjust their position between the later three pictures can be seen in the data, the positions themselves are not clearly distinctive. Therefore with the current sensors slouching is not clearly detectable.

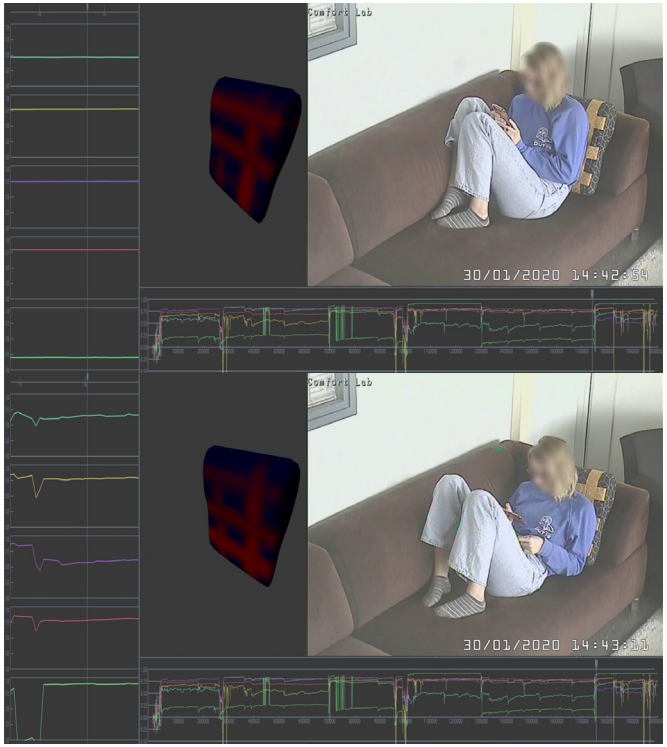
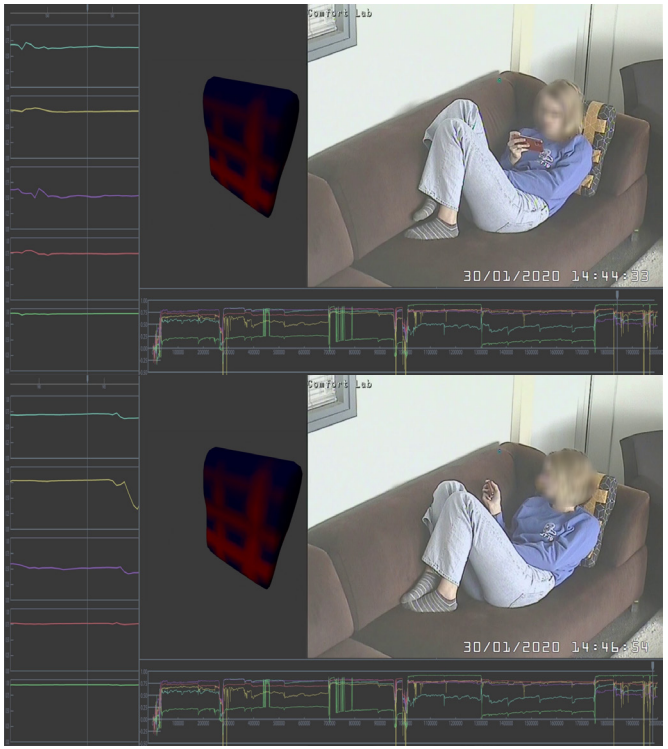


Figure 68 - Participant slouching near the end of the session



Only using part of the pillow

In the animation and the video, it can be seen that at different points throughout the usage of the pillow, the participants did not use the full surface of the pillow that was available to them.

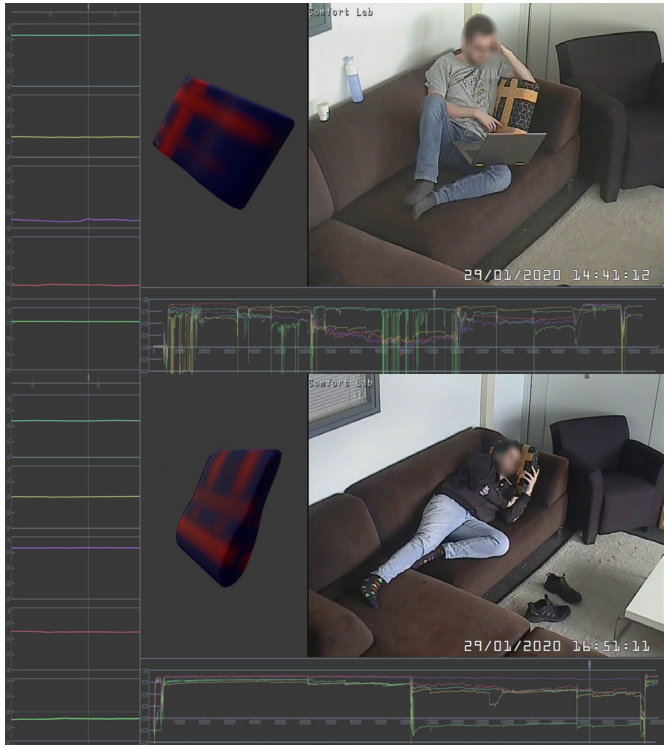
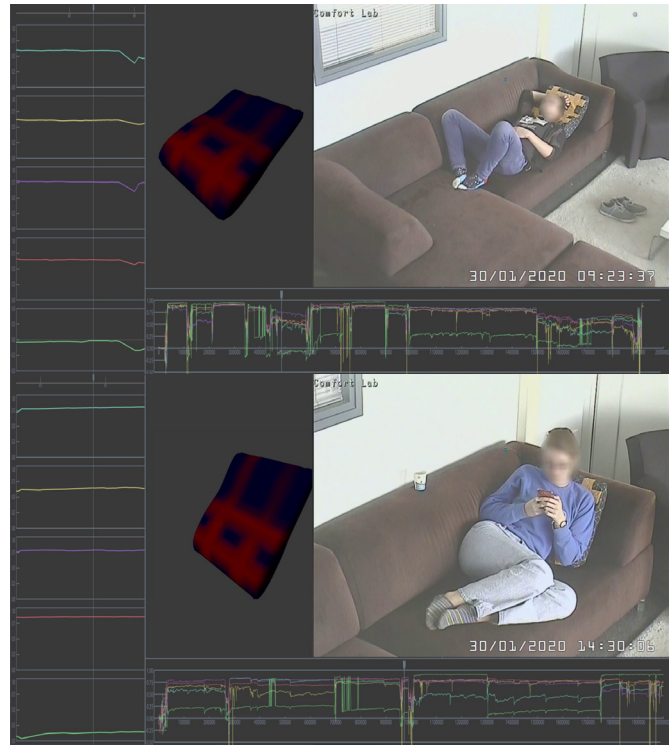


Figure 69 - Participants using part of the pillow



One participant was also hugging the pillow

Figure 70 - Participant hugging the pillow

Changing posture

The process of changing posture can be described as iterative and explorative. Participants were not always immediately satisfied with how they were sitting when they changed their posture and/or the orientation of the pillow. They try out one or multiple combinations before they settle down in a position they stick with.

4.7. Conclusions on Perspective discovery

Within this chapter, an understanding has been gained on the perspective of the user and the OwI. To achieve this, a data-enabled prototype was created. This was used in a session with users. In this session, they used the object, were interviewed about the object and engaged in a co-creation about further development. Afterwards, the tools and approaches used to process, visualize and analyse the data have been described extensively. From the results of the analysis, the following conclusions are drawn:

The use of the pillow as a tool was found to be effective. People found it comfortable and were able to use it in a wide variety of postures. For one participant it even created additional comfortable options that were not possible with traditional soft pillows. The effectiveness of the pillow as a tool can also be improved by making the pillow a bit softer. People also desired that the form-giving of the pillow would be more like that of a throw pillow, allowing it to fit better inside a living room.

Co-creating with the users about the desired behaviours lead to useful insights. A tassel was found as an opportunity for setting the time to recover through interacting with the pillow, as a pillow. During recovery, people desired the pillow to provide them with warmth. Before the recovery is over people would like to be notified

and warned. When the recovery is over they want the pillow to be clear in this and to become uncomfortable. Afterwards, they want the pillow to not be usable for a while.

The sensory intelligence of the object provided a detailed image of what the pillow was able to sense of the world around it. Through this insights were gained about people slouching near the end of their recovery. People also did not always fully utilise the complete surface of the pillow Finally changing their posture was an iterative and explorative process where they were looking for a new comfortable posture. The data from the temperature sensors did not lead to any insights during this analysis. However, it might have influenced people during the co-creation when they saw the data in the live visualisation.

These conclusions and the visuals created in the phase provide handles that will enable the next design step. These handles will improve the use of the pillow as a tool and design the behaviour of the object that will allow it to become an agent.

4.7.1. Reflection on the use of data for this phase

During the user test machine data, behavioural data and subjective data were gathered. From these, subjective and behavioural data provided me with the clearest insights and results. While working with machine data was found difficult and time-intensive and the visual created of the machine data did not provide clear insights. The reason for this is that I wanted to be inspired by the data but did not know how it would do this and what questions I had to ask. The machine data, however, did spark a back and forth between the behavioural and machine data. When something happened in one of the data types, I checked if this was also visible in the other data type. This then let to new questions of the first data type. Through this process, I did find that the behavioural data and the machine data enriched each other.

5. Phase IV - Concept design:

Sketching the smart pillow as a final design proposal

In this phase the conclusions of the previous phase are implemented into the design and a final design is proposed. Then, a storyboard is shown explaining the usage and behaviour of the pillow. Afterwards, the electronics of the object are presented.

5.1. Aim

The aim of this phase is to design a concept proposal of the pillow as an OwI to help people recover. This means to iterate on the design of the object as a tool from phase two and to design the behaviour of the object to allow it to become an agent.

5.2. Approach

The first step in this is to design the OwI. First, the use of a tool is redesigned. Then the behaviour of the pillow is designed. Afterwards, the actuators of the pillow are chosen and the sensors are iterated upon. Based on the design of the pillow and the behaviour of the object a storyboard is created to show the full range of the use and behaviour of the pillow in its context. Afterwards, the electronics in the pillow are discussed. Finally, conclusions are drawn and a reflection is made on the use of data.

5.3. Design

Figure 74 shows the final design of the object with intent. In this chapter different aspects of the design are highlighted, starting with the redesign of the shape and the materials. Then the desired behaviour of the object is discussed.

5.3.1. Redesign

As shown in figure 71 the defining organic shape of the pillow remains the same. It was found in this user test that the shape was comfortable and supportive in multiple different postures. However, participants felt like the pillow did not fit on a couch in a visual manner. They wanted it to look more like a throw pillow (Figure 72). A throw pillow consists of two pieces of fabric, usually square, sewn together and filled with polyester fibre. Therefore roundings were added to the sides of the pillow and the outer fabric is made out of two pieces of fabric.

Additionally, while people liked the organic shape of the object and the support the foam provided them, some felt like it was a bit too hard and they wanted to sink a bit more into the pillow. To adjust to their wishes and help it become more like a throw pillow, polyester fibre was added. This was done by reducing the size of the foam and filling the leftover spots with polyester fibre (Figure 73).

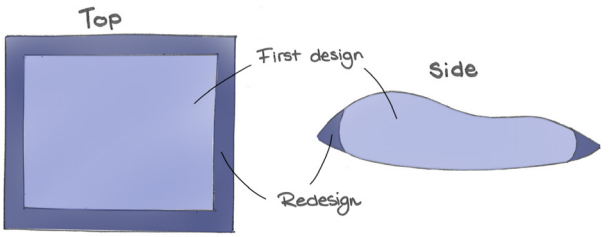


Figure 71 - Top and side view of the pillow

Figure 72 - Example of throw pillows

Figure 73 - Addition of polyester fibre

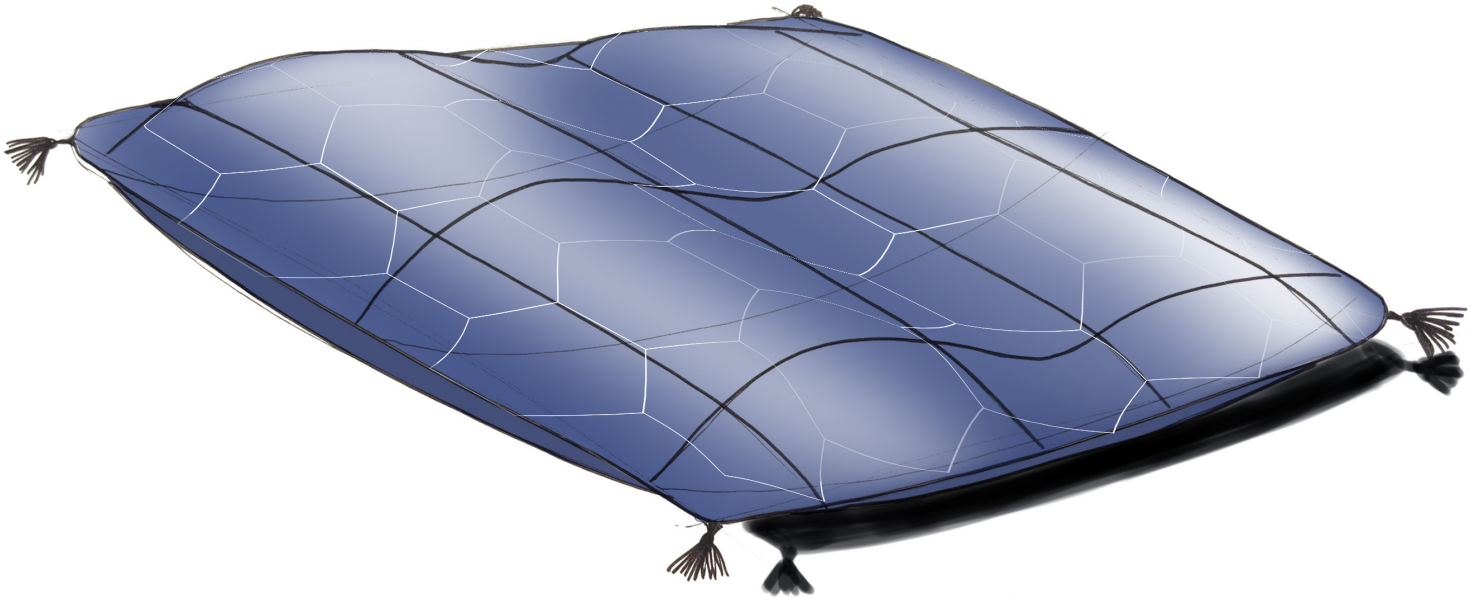


Figure 74 - Redesign of the pillow

5.3.2. Behaviour

The prototype of the pillow aimed to achieve its intent by being a comfortable, flexible and supportive tool for the user. In this chapter, the goal is to design an OwI intent that can be framed as a hybrid character artefact by designing its behaviour and through that giving it agency. The behaviour of the object revolves around two topics, the time spent recovering and the comfort during recovery.

The time spent on the couch was one of the main things people expressed dissatisfaction in the first user test. In the second user test, it was confirmed that the desired time varied per person and could vary per day. In the first user test, it was also found that when a user committed to relaxing for a certain amount of time they found it easier to stay in their relaxation world. Therefore the pillow should force the user to set a time for how long they wish to relax, remind them when their time is almost over and enforce the time limit when the time is over.

To make this clear for the user it was decided that the pillow would only allow the user to use it when they actually set a timer using the pillow. To ensure the pillow would still be used the pillow is given tools that provide the user with active comfort. These tools would provide additional comfort to the user and give the object a strong bargaining position. If a user wants to use this comfortable pillow, they need to set the timer.

During the co-creation users were asked to think about what the pillow could actively do for them to increase their comfort. From this users seemed to unanimously want the pillow to provide them with warmth. Additional inspiration came from the analysis of the interview and the video and animation of the user observation. During the interview, people pointed out that they wanted to sink further in the pillow. In the video, some people nestled themselves into the pillow. In the animation, it can be seen that people sometimes lean against a small part of the pillow. Combining these insights it was decided that the pillow should actively encapsulate and hug the user during recovery.

Finally, it was found that a user slouched near the end of the user test and when the test was over they were almost laying on the couch. I hypothesize that it would be easier and more pleasant for the user to stop recovering and get off the couch when they are already in an active sitting position instead of laying down. Therefore the pillow should encourage an active sitting position near the end of the recovery time.

To summarise, the pillow will actively try and achieve its intent by enforcing the user to set a time for their recovery. Providing active comfort during the recovery in the form of heat and hugs. Reminding the user when the time is almost over and encouraging active sitting posture near the end. And finally, forcing the user not to use the pillow anymore when the time is actually over.

5.3.3. Actuators

In order for the pillow to become active and act as described above, it needs to be equipped with actuators. These actuators are a way for the object to communicate with the user and to provide them with comfort and discomfort. For this, two actuators were chosen, the first one provides warmth to the user, the second one can change the outer shape of the pillow. Below a quick overview is given of both and they are explained more in-depth in the electronics chapter.

For providing warmth to the user a conductive fabric is proposed. The fabric warms up evenly when a current is applied to it. In the image below shows how the fabric heats up by laying a layer of cotton that is treated with heat-reactive paint on top of it.

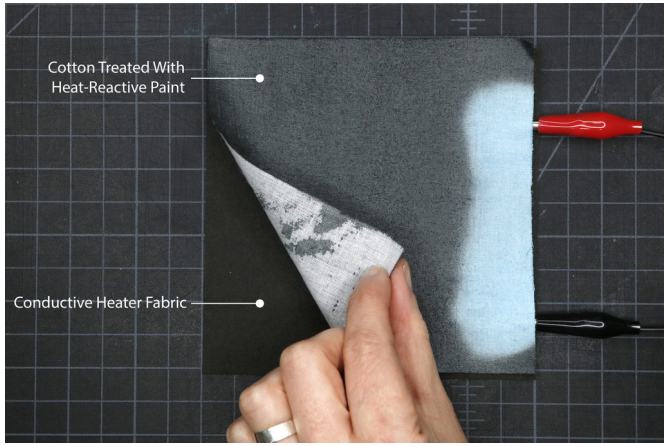


Figure 75 - Image showing the heat distribution

The goal of this fabric is solely to provide the user with extra comfort.

For changing the outer shape of the pillow, a pneumatic system is proposed. In this system, air pockets will be placed inside of the pillow in between the foam and the polyester fibre (Figure 77). These air pockets can be targeted individually and will gain volume like a small balloon. Through this, the object can change its outer shape as shown in figure 76.

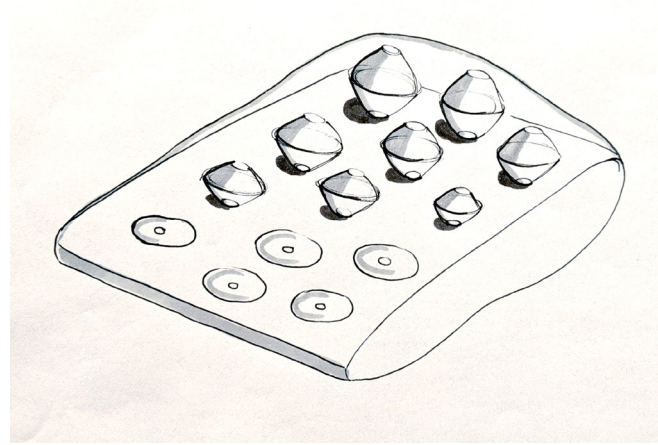


Figure 76 - Airpockets changing the outer shape

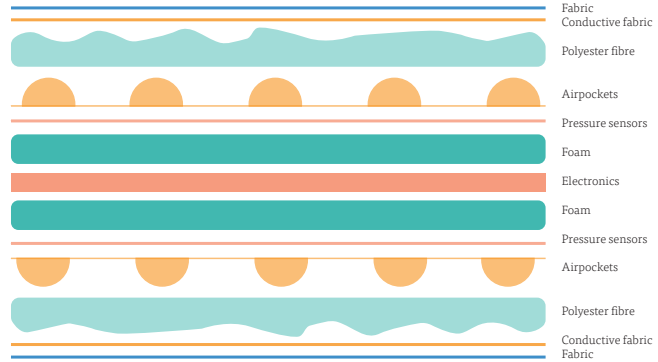


Figure 77 - Layup of the pillow

These pockets allow the object to form itself to how the user is sitting and through this, it can hug the user. These pockets also provide a way for the pillow to communicate with the user. When the user did not set a time yet or should be stopping their recovering, the pillow can show its displeasure by creating discomfort. This happens by blowing up all air pockets at the same time and then realising all the air. It can do this several times with an increase of intensity. It can also communicate to the user that they should sit upright when they start to slouch near the end of the recovery. In figure 78 it is shown how the pillow does this. The blue area is the pressure the user applies to the pillow, the grey area is the activation area of the air pockets.

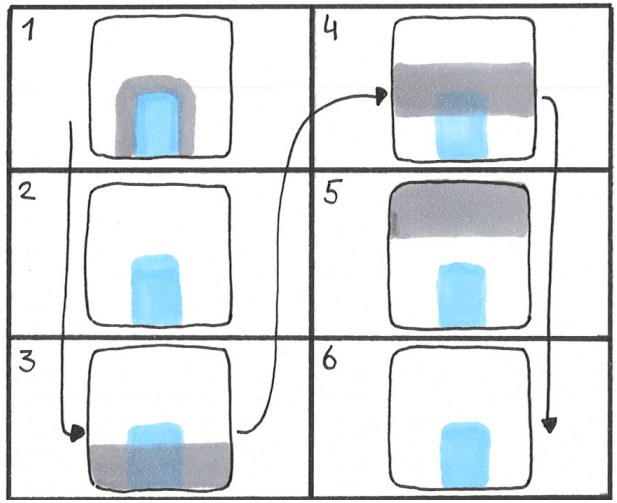


Figure 78 - Upwards movement of the airpockets

It starts by releasing the encapsulation of the user. Then it makes an upwards movement to push the user up.

Finally, it reminds the user their time is almost over by giving short bursts of pressure through its air pockets. These start out softly and small and become a bit bigger until the time is over. This should distract the user minimally of what they are doing, thus the exact intensity needs to be designed and tested experimentally.

5.3.4. Sensors

As with the actuators, the sensors are explained in more detail in the electronics. Both the pressure and orientation sensor are kept and iterated upon. In this section, the addition of a new sensor and the removal of the temperature sensor is discussed.

As mentioned in the behaviour chapter, the user needs to communicate to the pillow how long they wish to recover for. For this interaction, it was desired that the pillow itself would remain a pillow in its look and feel. Thus, adding a touchscreen or buttons are undesired solutions. The desired solution was found in the co-creation part of the second test. By adding pullable tassels to the pillow, it not only increases the look of a throw pillow, but also adds a way of interaction with a pillow that will likely not feel out of place. The tassel would be attached to a retractable cord and how far the user would pull the tassel would determine the length of the recovery.

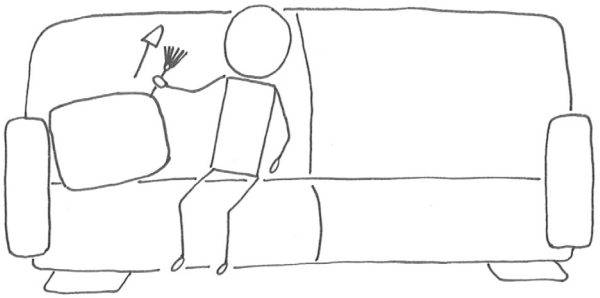
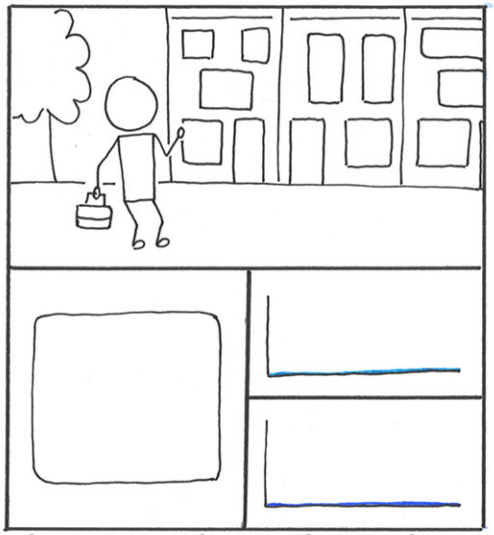


Figure 79 - Tassel being pulled to set the time

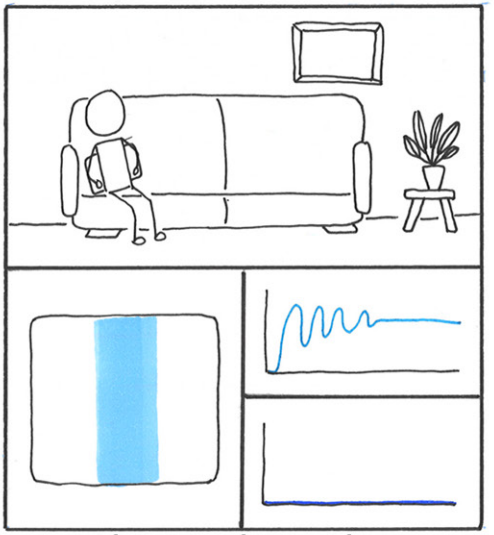
The temperature sensor did not provide any insights nor is it required for the designed behaviour of the object. Therefore it is removed from the design.

5.4. Storyboard

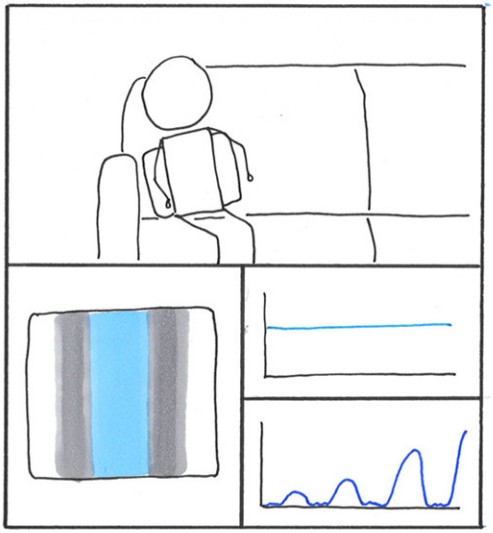
In this chapter, the storyboard is shown. The storyboard is created to make a complete overview of the usage and behaviour of the pillow. The scenario itself is not the desired scenario, but a scenario that shows the complete range of behaviour of the object.



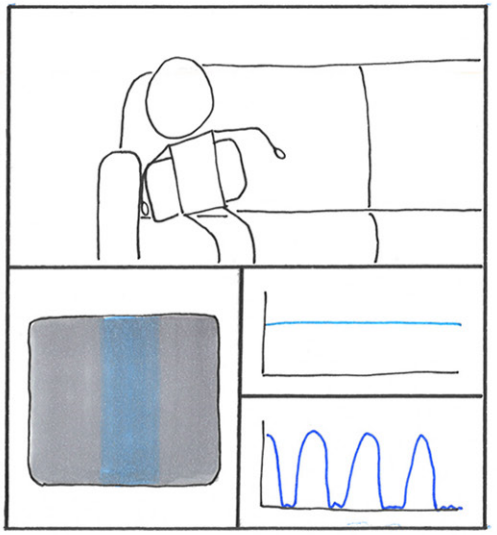
Thom arrives home after work.



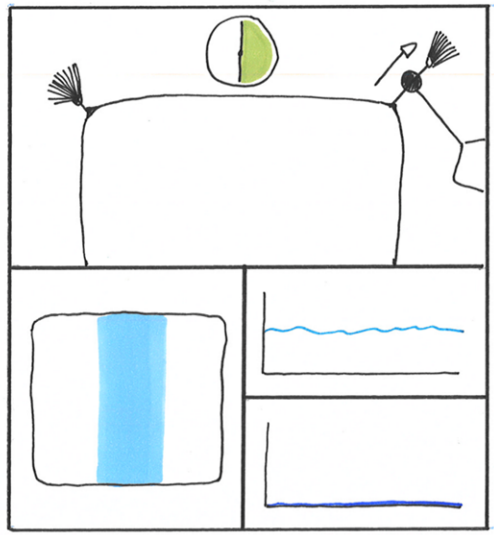
He sits down on the couch.
The pillow detects his presence.



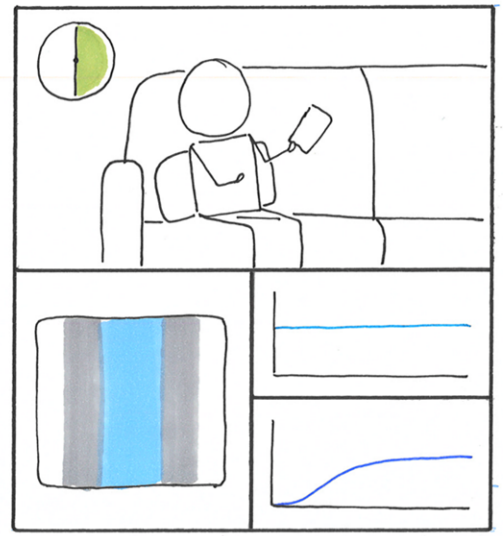
The pillow starts giving him increasingly harder pushes.



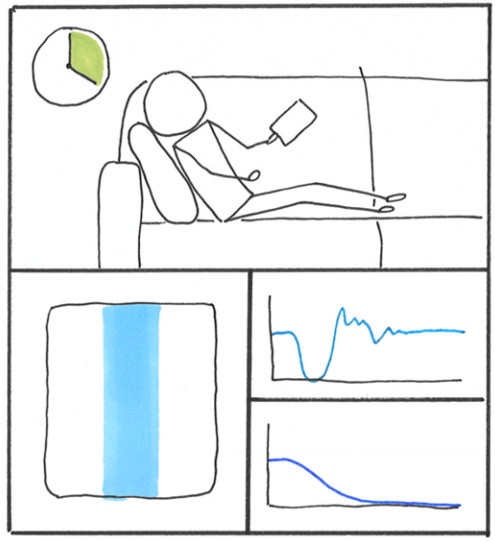
Without a response from Thom, the pillow keeps being annoying.



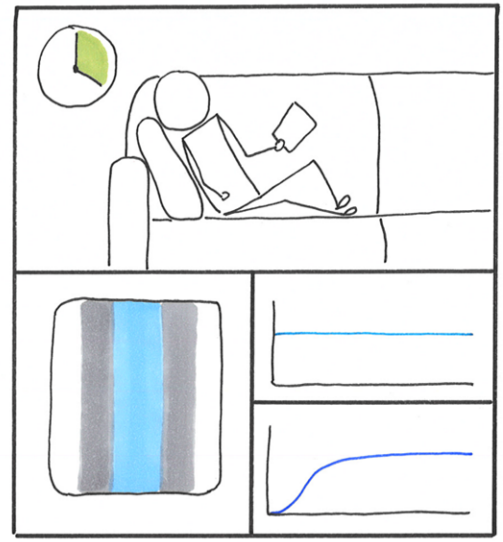
Thom finally reacts and sets the time for how long he wishes to recover.



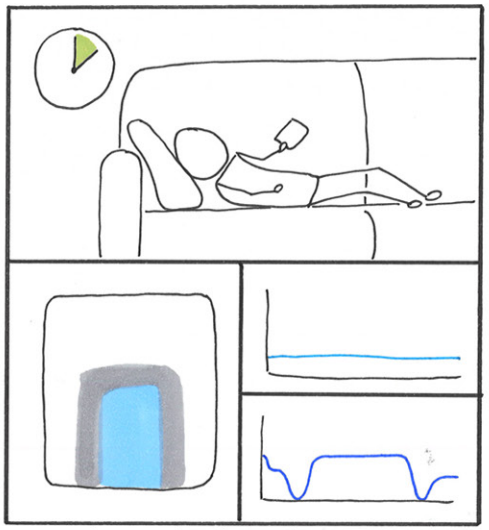
The pillow starts hugging Thom and providing him with warmth.



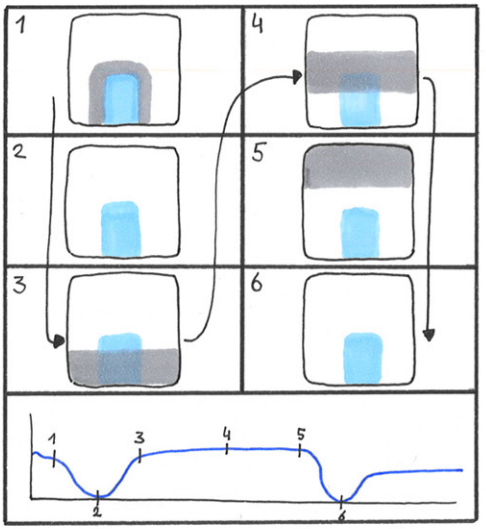
Thom repositions, the pillow stops hugging him while he does so.



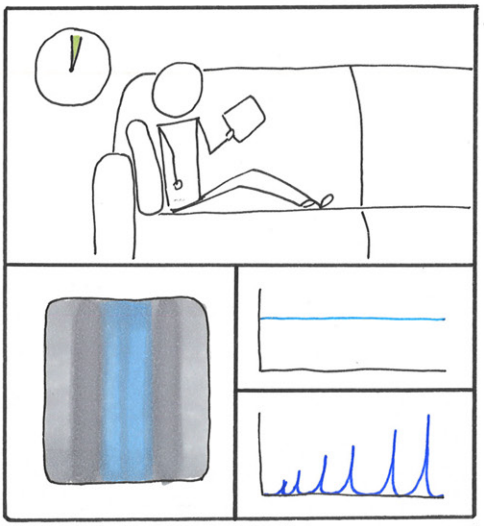
When Thom has settled down, the pillow starts hugging him again.



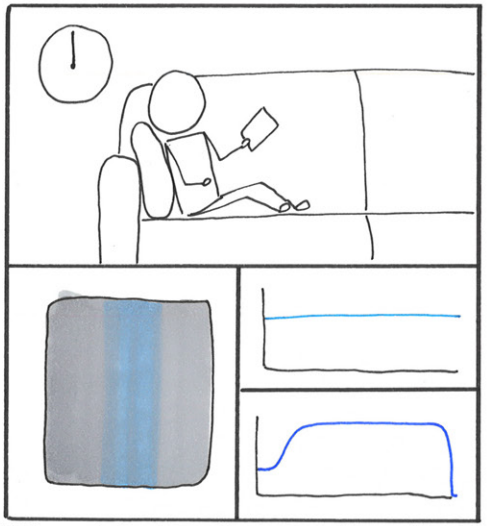
Near the end, Thom has started to slough. The pillow notices this.



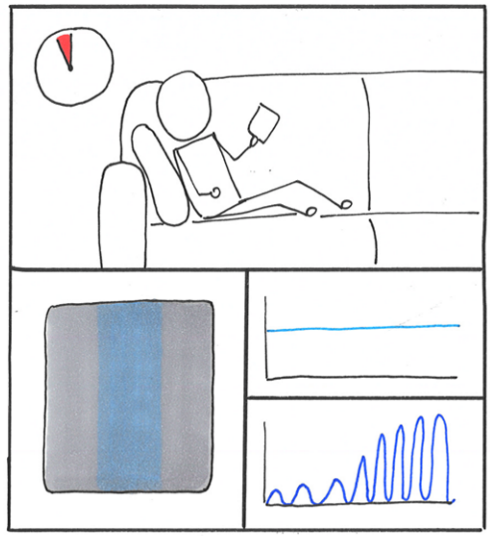
The pillow responses by making an upward motion with the airpockets.



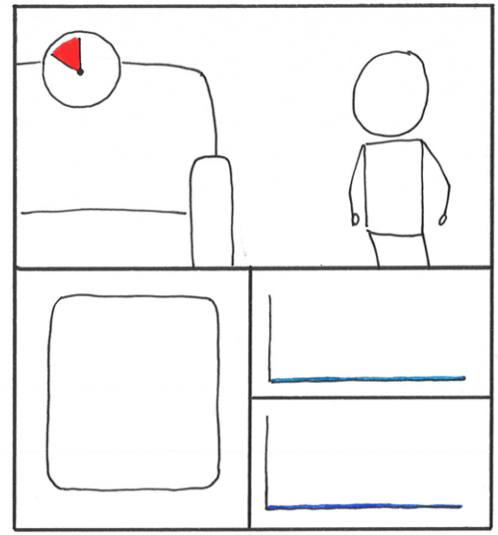
When his time is almost over, the pillow regularly reminds him of this.



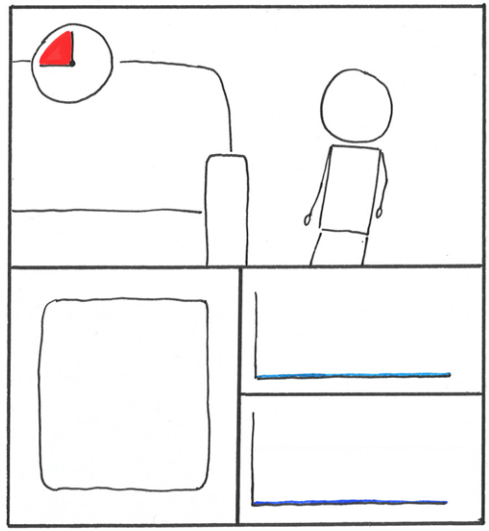
When his time is over, the pillow firmly pushes him.



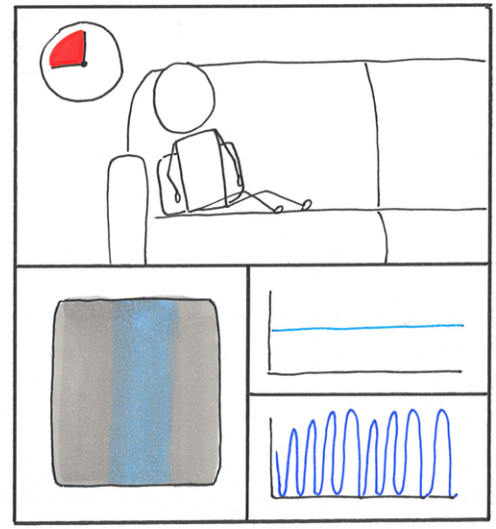
Thom stays seated, the pillow becomes increasingly annoying.



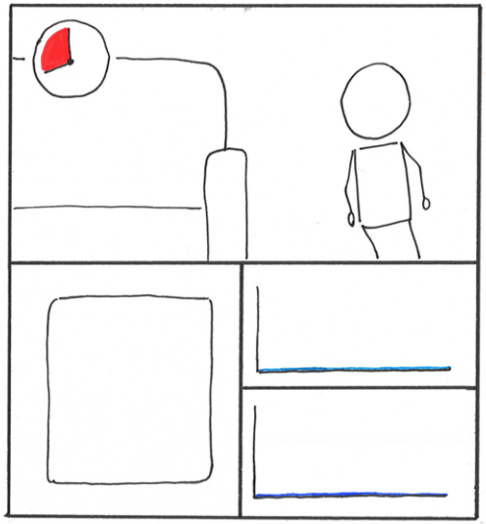
Thom finally gets up and moves away.



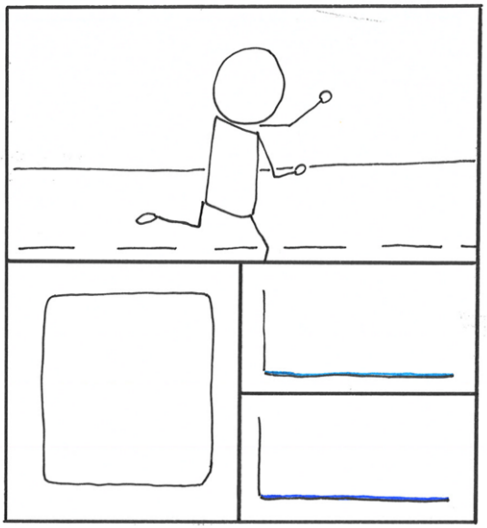
Shortly after, Thom comes back to the couch.



Thom sits back down, but the pillow does not accept this.



Thom decides to get off the couch again.



Afterwards, he goes for a run like he wanted to.

5.5. Electronics

Within this chapter, the sensors and actuators of the pillow are discussed. The sensors are the medium through which the pillow can observe the world around it, they are the pillows senses. These senses are the bases on which the object acts and interacts with the world around it. The goal of the pressure sensors and orientation sensor is to detect the posture of the user and how the pillow is being used. This information is used to decide when the pillow should turn on and which air pockets and heating elements need to be activated. The goal of the string potentiometer is to allow the user to communicate how long they wishes to recover.

Based on the data gathered by the sensors, the object can react to cues found in this data through actuators. The cues can be explicit and implicit actions from the user. To respond to these cues two actuators were added. The first being an actuator that provides warmth for the user. The second is an actuator that can adjust the shape and soft-/hardness of the product. These two together should provide the user with active comfort and help with communicating with the user. How and when these actuators would be activated can be seen in the storyboard in the previous chapter.

5.5.1. Pressure Sensors

As mentioned above the pressure sensors are there to detect the posture and usages of the person using the pillow. This is done by measuring how the pressure is distributed over the surface of the pillow and how much pressure is being applied. To measure this, the pillow needs to detect the pressure at multiple locations on the pillow.

Current design

In the current prototype of the pillow, custom sensors were made for this purpose. This was done using Velostat, aluminium foil, wires, pull up resistors and microcontroller. Velostat is a packaging material that is impregnated with carbon black. This makes it a conductive material. Originally it is used as a packaging material for electronics that are susceptible to damage from electrostatic discharge. However, when the material is bent or pressure is applied the resistance changes.

The sensor itself was created by making a sandwich of aluminium foil, Velostat and aluminium foil. To both strips of aluminium foil, a wire is connected. A current is then sent through the one wire and the second wire was attached to the ground and an analogue port on the Arduino. Using the function analogRead from Arduino data was gathered.

Five of these sensors were created and distributed on the pillow as shown in figure 80. The goal was to evenly spread them over the pillow and get the full picture of the pressure and the distribution.

After using these sensors in the test there were a few drawbacks to using the sensors like this. The first drawback is that they were placed in the centre of the pillow, this gives a general overview of the flex of the pillow. However, this does not communicate from which side what pressure comes. Thus, what pressure comes from the person and what comes from the couch. The second drawback is that the sensor only communicates the pressure and because they are quite long it is hard to determine where on the sensor the pressure is applied. While this could be estimated by looking at the sensors that are perpendicular to the sensor, it is still inaccurate. The last drawback is the number of sensors. They give a general overview, but it is missing detail and nuances. Having more sensors would give a more nuanced detailed image of the pressure and its distributions that the pillow is experiencing. This would be useful because through this the pillow could, for example, better detect if a person is slouching.

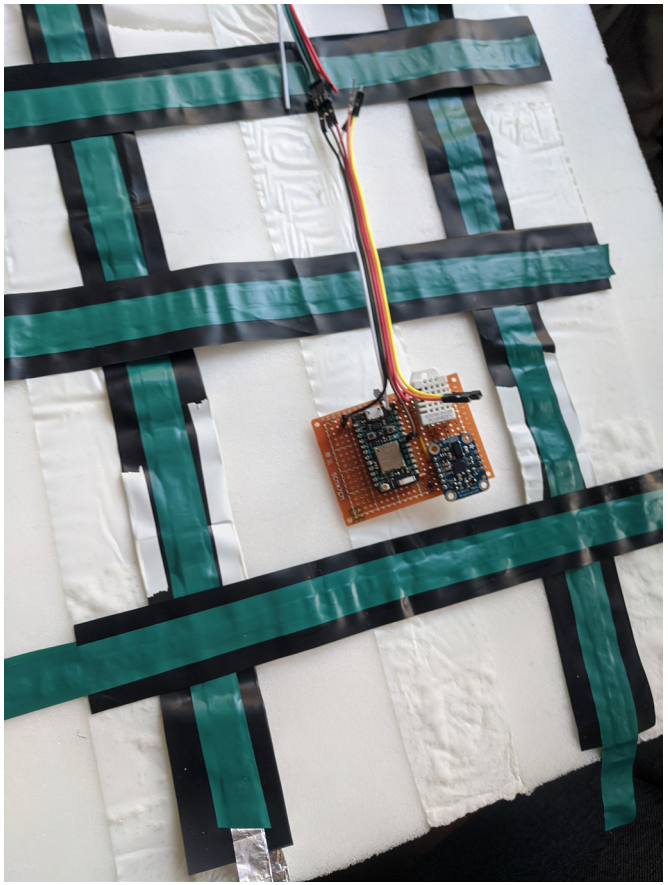


Figure 80 - Original implementation of Velostat

Redesign

To address the drawbacks of the previous design the following redesign is proposed. The redesign is based on the same principle of having a sandwich with a layer of conductive material that changes resistance sandwiched between conductive materials. However, some improvements are made to address the drawbacks

Firstly, the materials, Velostat was found to be an effective material to measure the difference in resistance and is therefore still used. The aluminium foil was a fine material to make a quick prototype, however for further prototypes a better, more consistent material is proposed such as a conductive wire or copper tape.

Secondly, instead of using 5 single sensors, it will be changed to a grid. This means a raster of Velostat will be made. Then on one side of the Velostat, all the horizontal lines get a line of copper tape. On the other side, the vertical lines get a line of copper tape. Then a signal is the microcontroller loops through the horizontal lines and sends a signal. Then the microcontroller reads the values of the vertical lines. This way a more accurate image of the pressure distribution is created

Thirdly the sensors moved from the centre of the pillow to the front and back of the pillow. They will be attached to the outer layer. This allows the pillow to distinguish signals from the front and back and be able to determine on which side the user is.

Lastly, the number of sensors, or better put, the number of vertices the sensor creates. The goal of increasing the amount of vertices is to get a more detailed view of the pressure on the pillow. This allows the pillow to better distinguish between postures and to better determine which actuators to activate. As a first step, a grid of 7 by 5 lines, and thus 35 vertices is proposed.

As mentioned above Velostat is used to determine the pressure and thus get a picture of the usages of the pillow. This material was chosen because of its flexibility and ability to change resistance based upon pressure. However, it may also be interesting to look at Eeonyx Stretchy Variable Resistance Sensor Fabric - LTT-SLPA-20K ("Eeonyx Stretchy Variable Resistance Sensor Fabric", 2020) when continuing with this project. This is a piece of fabric instead of a plastic, which would be better suited in a pillow. The main difference is that the resistance of this material changes based upon how much it stretches instead of the amount of pressure it receives. It would need to be tested to see how well that would perform in determining the usage of the pillow.

5.5.2. Orientation Sensor

In the prototype, the orientation sensor bno055 was used to determine the orientation and rotation of the pillow. It was placed in the lower half of the pillow, see figure 81.

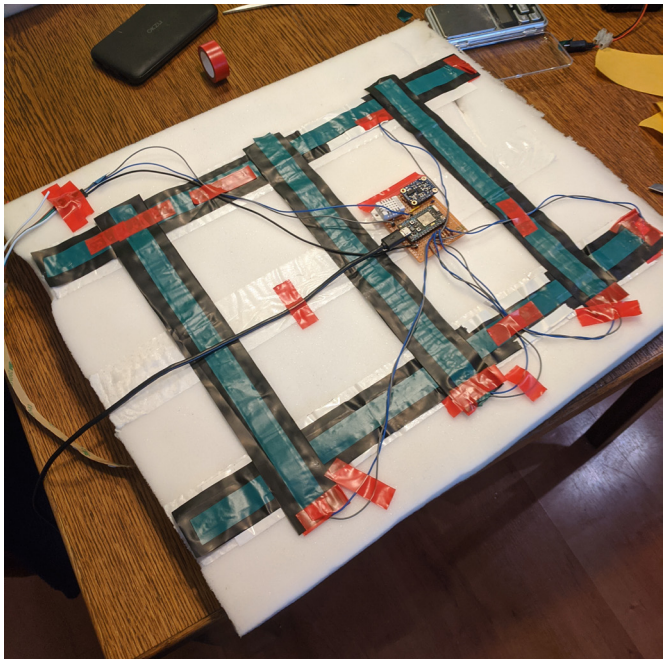


Figure 81 - Placement of BNO055

The sensor in itself seemed to be working properly and provided with the data required. However, the placement of the sensor inside the pillow could lead to an inaccurate representation of how the pillow is oriented. As can be seen in figure 82, the orientation of the pillow in the 3d representation is different from the orientation in the video. This is caused by the fact that the orientation sensor is placed in the thicker part of the pillow and in the video the pillow is bent.

Figure 82 - Placement of BNO055

Because the pillow had a tendency to bend around the centre of the object (Figure 83), placing the orientation sensor in the centre would also not give the complete picture. Therefore, to give a good overview of the orientation of the pillow and to help determine the deformation of the pillow, it was decided to add an orientation sensor and place this in the thinner section of the pillow.

Figure 83 - Bending of prototype

5.5.3. String potentiometer

As part of the desired interaction, the user would need to set a time limit for how long he/she wishes to recover. When designing this interaction, it was a requirement that the pillow itself would remain a pillow in its look and feel. Thus, adding a touchscreen or buttons are undesired solutions. The solution that was found was pulling the tassels of the pillow. The tassel would be attached to a retractable cord and how far the user would pull the tassel would determine the length of the recovery.

The length the tassel can be pulled is 36 cm. Every 2 cm the tassel is pulled, 5 minutes is added to the total length of the recovery. This makes the maximum length one and a half hours. In order to measure this length and ensure it retracts a string potentiometer is used.

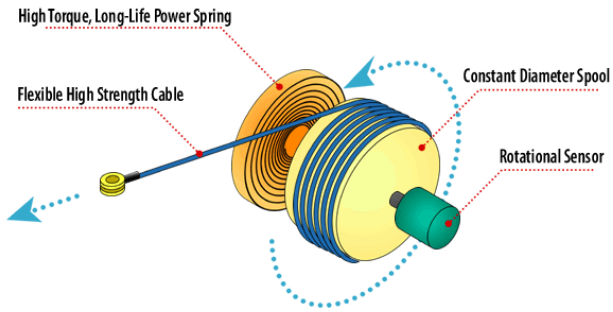


Figure 84 - String potentiometer

In order to communicate to the user how far the string has been pulled markers are added to the string. Additionally, tactile feedback is added. This is done by adding a freewheel mechanism as seen in the picture below. This can rotate in both ways but provides a tactile feeling with every 2 cm.

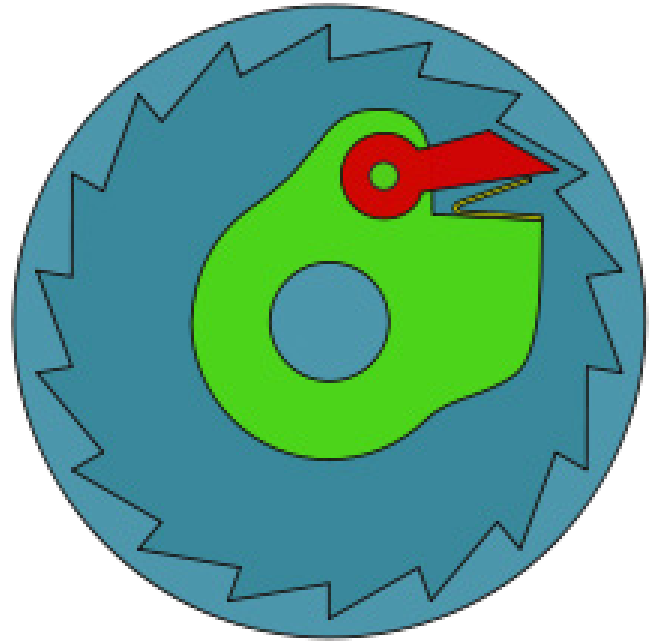


Figure 85 - Freewheel mechanism

5.5.4. Heat pad

In order to provide warmth to the user, one could look at traditional heating blankets. Heating blankets use insulated wire, heating elements, or carbon fibre elements in between two layers of fabric. Then, by applying a current to the elements inside the blanket the elements heat up. However, for this product, a different solution is proposed.

EeonTex High-Conductivity Heater Fabric - NW170-PI-20 is, as the name suggests, a conductive fabric. By attaching a positive and negative point to different points of the fabric a current runs through the fabric from the positive to the negative. The result is shown in figure 86 & 87, where heat-responsive paint is used to demonstrate the working. As can be seen in the image, this material spreads the heat more evenly, in contrast to the single lines that get hot in a heating blanket.

By attaching wires to multiple points on the fabric, complete coverage of the material can be created and controlled. Thus, the pillow can determine what parts of the pillow are used and can warm those parts.

Although the material looks promising and interesting, more research and tests are required to further develop this product. The two main things to look at are the safety and the power . The safety has two main concerns, the first being that it can not get too hot to prevent people from burning themselves. The second has to do with the voltages that are running through the product. How much is it and how easily can it be exposed by, for instance, a tear. The power required for the EeonTex High-Conductivity Heater Fabric - NW170-PI-20 seems reasonable at first glance. However, as an industrial designer, my knowledge with regards to electrical engineering and thermodynamics is limited. For this design, it is important that the product stays portable and thus it cannot rely on wall power but needs to have a battery. The amount of power it requires depends on the temperature difference, how fast it needs to achieve that difference and how long it needs to maintain the temperature. Ideally, it would provide a constant heat, but the actual temperature it needs to be and how fast it needs to be at that temperature needs to be determined experimentally using user tests.

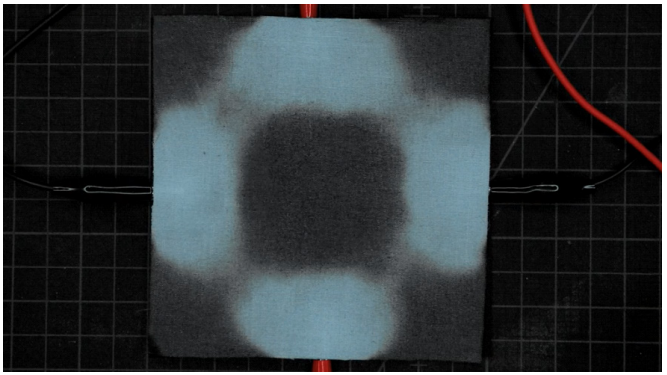


Figure 86 - Heat distribution of EonText with 4 connectors

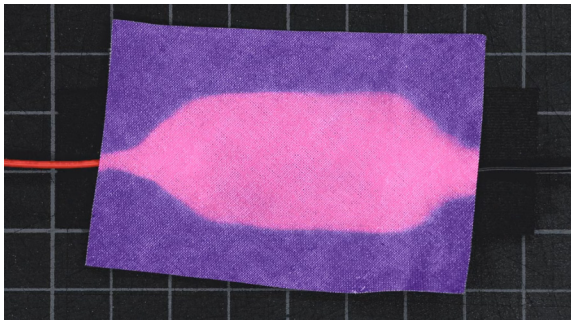


Figure 87 - Heat distribution of EonText with 2 connectors

5.5.5. Air pockets

The goal of the second actuator is to adjust the shape of the pillow and provide an active tool for the pillow to communicate with the user. The goal of the shape adjustment is not to make big changes to the overall shape but more small improvements. These improvements should make the, already comfortable and supportive, foam core even more comfortable. This is done by forming the outside of the pillow a bit to the user's body and encapsulating or hugging the user.

To do this in a way that is comfortable and pleasant to the user, a pneumatic system is proposed. This system would have to be further designed, tested, and validated, but a first version is designed here. The pneumatic system consists of multiple pockets that can be filled with air (Figure 88). These are filled using a compressor and controlled through valves. Each air pocket can be targeted separately and filled to the desired amount. This allows the pillow to shape itself into a form that fits best for its user.

When continuing this project there are several challenges with regards to the pneumatic system. The first challenge is designing a compressor that is strong enough to apply a decent amount of pressure to the user. The second is designing a system that is small enough to fit inside of the pillow. The third is ensuring that users can not feel the system inside of the pillow. The final challenge is to design the system in such a way, that it can run off a battery.

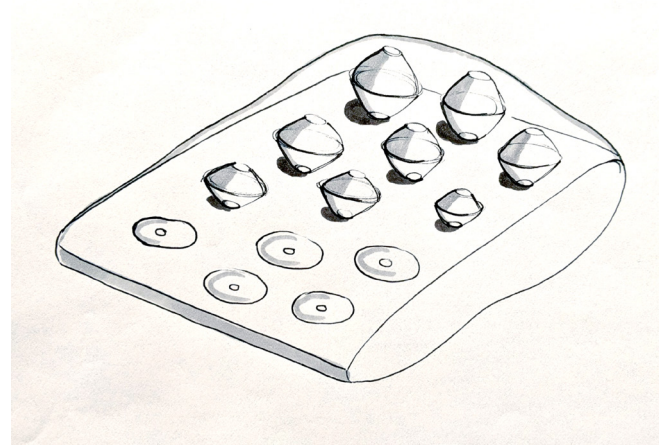


Figure 88 - Airpockets reshaping the outer shape

5.6. Conclusions

Within this phase, the concept of the pillow as an object with intent to help with recovery on the couch has been iterated upon. This was done firstly by improving the physical design of the object to make it more comfortable and more like an everyday object. Secondly by designing the behaviour of the object. This is done by designing specific responses form actuators to specific cues in data.

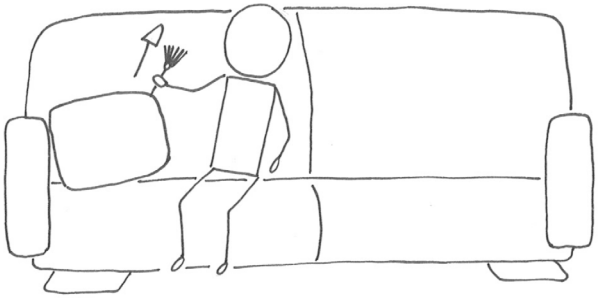


Figure 89 - Interaction with tassel

Figure 90 shows the physical design of the pillow. This pillow lives on the couch and is activated when you start using it. It is only usable if you set a timer by pulling the tassel to determine how long you wish to recover (Figure 89). When you start recovering the pillow will use its actuators to increase your comfort by providing you with warmth and softly hugging you using its air pockets. When you adjust your position on the couch it will stop hugging you and wait for you to settle into a new position to start hugging you again. When your time is almost over it will nudge you to sit in an active posture, if you are not already. This will happen through an upward motion caused by the air pockets. It will also gently remind, you on a regular interval, that your time is almost over by giving you slight pushes of increasing intensity. When the time is over the pillow will start making itself uncomfortable to use to force you to stop recovering. If you decided to come back shortly after your time was over, the pillow will immediately become uncomfortable again.

5.6.1. Reflection on the use of data for this phase

During this phase, the data gathered in phase three was continuously used to iteratively design the concept. The subjective data provided me with a solid place to start the interactions. While the machine data did not provide me with clear insights during the analysis, it became of instrumental value during the design. It started an iterative process between coming up with ideas, forming questions and answering those questions by using the videos that showed the combination of machine and behavioural data and the physical prototype. During this data-enabled design process, the 3d representation of the object and physical object allowed me to connect the behaviour of the object, to cues in data, inform iteration on the sensors when the cues were not detectable and make informed decisions when designing the actuators.

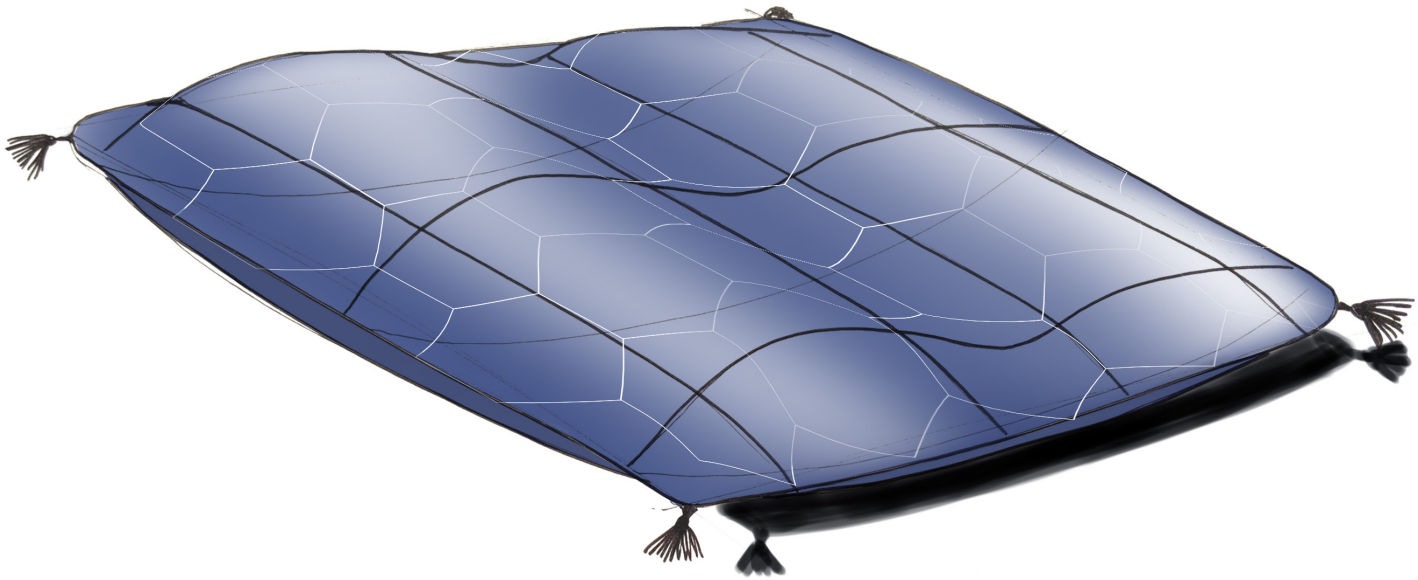


Figure 90 - Final design

6. Overall conclusions and recommendations

Within this chapter, conclusions are drawn and recommendations are presented for each pillar. Then a look is taken at how they worked together in this project. Finally, the usage of the three types of data is discussed.

6.1. Leisure

The design goal of the project was to improve the quality of people's leisure time. This was achieved by designing a pillow which improved the quality of peoples recovery-detachment on the couch. This improved the quality of people's leisure time, by improving the specific recovery-detachment part, but also by enabling users to engage in other activities and have more energy when they do so. The pillow improves the quality of people's recovery-detachment in two ways. Firstly by making users think about how long they wish to recover and by enforcing this length. Secondly, by making the recovery more comfortable. The additional comfort achieved through the shape and the actuation of the pillow. The shape of the pillow is comfortable and supportive which allows users to be comfortable in a wide variety of postures on the couch. The actuation makes the users more comfortable by providing them with warmth and by hugging them.

6.1.1. Recommendations

While this all has a basis in user-centred research, the effectiveness is still to be determined. To do so I propose an iterative process with user tests. In this process, the design can be validated and iterated upon. While the comfort lab is a great place to start with this and worked well within this project, I recommend making the transition into real-life contexts. Real-life is messier and more complicated than the controlled environment of a research lab, the pillow should still be effective in that environment.

6.2. Object with Intent

For this pillar, the research question was: "How to design an object with intent that can detect cues and respond with behaviour that contributes to achieving its intent?" To answer this question I have split it into three parts.

- Designing an object with intent
- Designing behaviour that contributes to achieving its intent
- Ensuring that the object can detect cues to which it should respond with the designed behaviour

For designing an object with intent I took a user-centred approach to explore and understand the users and the context of leisure in the living room. Through this, I was able to create a design goal which would tackle a relevant issue to the users and improve their quality of life. Based on this design goal and the insights from the user-centred approach I was able to first design an intent that aligned with the needs and wishes of the user. By exploring how a hypothetical OwI could achieve its intent through storyboarding I was able to get insights into what the object should be able to do. With those insights and the insights of context, I was able to design a pillow, as an object which naturally fits into the daily lives of the user and is capable of achieving its intent.

To design the behaviour of the pillow that contributes to achieving its intent I also took a user-centred approach. Since the intent is in alignment with the needs and wishes of the user, the behaviour of the pillow should work with the user. Therefore, users were involved by co-creating the behaviour of the pillow. To enable this co-creation a sensor-equipped prototype was utilised.

To detail and further define the behaviour of the pillow I engaged in an iterative process. The process aimed to not only detail the behaviour but also to ensure that there were detectable cues to which the pillow should respond with this behaviour. In this process, I worked towards a storyboard which shows the user with the pillow, and the pillow with its sensors and actuators. To help with this I tried to answer the questions to the right for each interaction with the pillow.

Questions	Example answers
What should the object do?	The object should provide the user with active comfort.
How should the object do this?	By providing them with warmth.
With what actuators?	By using conductive fabric.
When should the object do this	During recovery
How does the object know when to do this? What conditions should be met?	• The user should have set a timer. • The orientation sensors detect that the user has settled down • The pressure sensor detects sitting.

By creating the storyboard and answering the questions above I was able to design the behaviour of the object with intent and to connect the behaviour to the sensing capabilities of the object.

To enable this iterative process, the sensor-equipped prototype was used for half an hour by four users. During this time, the prototype gathered sensor data and the user recorded using a camera. From this data, videos were created in which the recording of the usage can be seen next to a 3d representation of the object with the data it gathered. These videos were crucial to designing the behaviour and connecting the behaviour to the sensing capabilities of the object. They showed what currently could be detected by the object, inspired by what could be detected and allowed for informed improvements to the design of the sensors.

Through this process, I was able to design a pillow as an object with intent which can detect cues that trigger behaviour that contribute to the pillow achieving its intent of improving peoples recovery.

6.2.1. Recommendations

While I stand by the design I have proposed, it is still important to test, iterate and improve on this design. For testing the design and the behaviour of the object with intent I suggest utilising a WoZ approach. When applying this approach it is important to include the sensor data in the test. Although you are still faking the intelligence, it should still be implementable into the OwI. By having a live visualisation of the data available during the tests you can utilise the connection made earlier in the process to control the actuators of the OwI. To start I recommend to stay in a controlled environment, such as the comfort lab, and iterate and improve on the design. However, I do think it is important to transition to testing in the real-life context of users. The object should be able to deal with the messiness of real-life contexts. When doing this, data-enabled design (J. van Kollenburg & S. Bogers ,2019) can be a useful resource.

6.3. Data Centric Design

For this pillar, the research question was: "How can data-enabled design be used by design students and become part of their designers' toolkit?" For me, the core of using data-enabled design lays in making data tangible through visualisations and then utilising these visualisations in the design process. Within this project, I showed the different tools I have used to create the visualisations and make the data tangible. I found that the visualisation in which the data was visualised in a digital representation of the object to be the most effective. The visualisations of machine data also worked the best when they were used in combination with other data or when the visualisations were used to gain specific insights.

While the visualizations were effective and played an important role in my design process, I would not recommend a design student to use data-enabled design in the way that I did. At least not with the same tools that I used. The reason for this is that the tools I have used were not meant to be used in the way I used them. This made the process and creating the visualisations and analysing them harder and more time-consuming.

One of the main issues with the tools I have used is that they were not meant and optimised to handle the amount of data I wanted them to handle. This caused the programs to slow down, sometimes to the point they were unusable. For example, a half-hour video made in After Effects that took over 40 hours to render.

The process of creating a 3d representation of the object was also not a fluent one. For this, I decided to use Blender because it was open and could be used for multiple purposes including mine. However, this openness made the program a lot more difficult to learn. Additionally, the purpose I used it for was not a common one, so to learn how to create this representation I had to combine multiple, sometimes contradicting, tutorials and resources. While I did manage to create the representation in data, the program was still not built to handle the amount of data and the animation ran at 12 fps.

Finally, while ATLAS.ti is meant for qualitative analysis and can also code video, it was not ideal. That is because the order and the length of the codes are relevant to me. For example, knowing the code 'sitting straight on the couch' has been coded 8 times does not say as much as knowing the code 'sitting straight on the couch' has a total length of 2 minutes. Knowing how these two minutes are distributed over the observations is also something that was not clear within ATLAS.ti. However, knowing if these codes that happen within the first 3 minutes of the observation are spread out evenly across the observation is relevant information.

Because of these issues, using machine data in my project was a time-consuming process. Quite a large portion of this time can be contributed to figuring out what tools to use and learning how to use these tools. However, if I would have to go through the process again, with the knowledge I now have, it would still be a time-consuming process. This is because the tools are still not designed to be used in this way. Therefore I argue that in order for design students to be able to effectively use data-enabled design, new tools have to be developed. While ideally there would be one tool which was able to do it all, different tools which optimize and streamline the process would already help. In the recommendations I summarized the lessons and frustrations from working with existing tools as guidelines and recommendations for a new tool.

6.3.1. Recommendations

In my project, the DCD hub has helped me to easily collect and store data from a sensor-equipped prototype. In this chapter, a look is taken at what kind of features could be useful in tools that visualise and analyse data.

Firstly, as the DCD hub is already the platform used to store the data, it would be easy if these tools would be integrated or at least connected to the hub. As the server uses MQTT it would also allow the tools to directly visualise the incoming data to the server. Creating an almost live connection between the prototype and the visualisation tools. The organisation of data and prototypes would also be easier as the principles used in the DCD hub could be copied. Additionally, for organisational purposes, it would be useful if labels of specific user tests could be added to data sets.

For the visualisations, I have found a 3d representation of the product with visualisation of the data to be most insightful. I do not think it is necessary for the tools to be able to create 3d models, allowing for common file types, such as obj, to be imported would suffice. The visualisations should also be interactive and dynamic. This means that a 3d model should be viewable from all angles. It also means that you can zoom on graphs, to see specific changes or get a complete overview. Visualisations of sensors or other parameters should also be toggleable.

To analyse the visuals the method of coding from ATLAS.ti was found useful. However, there is some room for improvements. Firstly, I found the machine data most insightful when it was connected to the videos of the observations. Secondly, the length and distribution of the codes were found insightful especially when they were visualised. These could be automatically produced by the tool. Finally, by implementing code like in ATLAS.ti in a system that is linked to the DCD hub, direct links with the data could be made. This could make showing additional insight easier. For example by directly showing all the data which was coded as 'sitting upright'. Through this, the data could be easily compared. This also sets a first step in the direction of creating classification algorithms. Which could be used to control the object, but also for the analysis tool to categorize and code the data for the researcher.

Finally, I would like to mention digital twins as a potentially useful resource when further developing these tools. A digital twin is a digital representation of an object. Which sound exactly the same as the tools I propose. However, they are used differently. Siemens ("Digital Twin | Siemens", 2020), for example, has three types of digital twins, a product, a production and a performance digital twin. These digital twins are mostly used for evaluative proposes. This, however, is different from using them as creative design material usable throughout the process.

6.4. Combining the pillars

This project would have been completely different if only two or one of the pillars were present. If leisure would have been the only pillar, I almost certainly would not have ended up designing a smart pillow. I still would have taken a user-centred design approach. However, when looking at the needs and desires found in this approach I would have a hard time finding an appropriate solution. This is because I am used to applying the smartness of a solution to integrating it with phone use. However, the use of a phone in itself was a problem for some people.

By introducing objects with intent as a second pillar I could apply the new perspective they provide on smart products. By applying this perspective I could take a comepletly different look at my solution space and look further then phones. This allowed me to design a pillow, a smart pillow, which is an appropriate and effective solution. It builds on and is aligned with the needs and desires found in the user-centred design. And it does so in a way that could easily be integrated into people's daily lives.

The design of this smart pillow would be a process of hypotheticals and guesswork without the addition of data-centric design. Data-centric design enriched the insights gathered by the user-centred research of leisure. Data-centric design also allowed design decisions for the OwI to be inspired by and validated in data.

6.5. Usage of three types of data

Within this project, I have made a distinction between machine, observational and subjective data. This distinction allowed me to keep an overview and communicate clearly what data I was working with. Throughout the project, the importance and relevance of each type of data varied. In the first two phases, the subjective provided the most relevant insights. Followed by the behavioural data and finally by the machine data. In the third phase, the subjective and behavioural data provided the clearest insights. Working with machine data was found difficult. In the fourth phase, the behavioural data created a starting point for the design. But in the iterative process that followed the combination of machine and behavioural data were found to be of great value.

While making the distinction between the data types provided clarity most of the times, near the end of the project they started adding complexity. As I was also working with the perspective of the object and of the user, the different types of data added an additional layer of complexity. Near the end, I was also working in an iterative process where I continuously went back and forth between different types of data and the design. Therefore, insights did not come from specific types of data, but rather by the combination of them. While this had a positive effect on the process and results, it made reporting on it harder.

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8. Appendix

8.1. Preparation Exploration test

Introduction

I will receive my participants outside of the room in the hallway. There I will tell them the following:

" Hi, thank you for participating in my user test for my graduation. The aim of this test is for me to get a better understanding of how people relax inside the living room. So, in a moment I will ask you to go inside the room and spend an hour there with the goal to relax. You can relax in any way that you want. Except for that there are no shoes allowed on the couch. Afterwards there will be a 10 minutes interview where I will ask you about your experience inside the living room and relaxation in general. If you need to go to the bathroom during the test you are free to do so. Inside the room there is a camera which I will use to record and observe the test. Hence why I will ask you to sign this consent form in a moment [show consent for]. Are there currently any questions? "

If there are any questions, I can answer without influencing the research I will do so and if there are no further questions, I will ask them to sign the consent form. Afterwards I will offer them a cup of coffee or tea before they go in and then the test will start.

Interview questions

1. How are you?
    1. Can you tell me in which activities you engaged in to relax?
    2. Do you feel more relaxed afterwards than before? If so, in what way?
2. Do you feel satisfied with how you spend your time? Why is that?
3. How does this hour compare to an hour at home in the evening?
4. Going through interesting moments:
    1. I observed you were doing X around X time, is that correct?
    2. I'd like to go a bit more in depth for this activity, can you describe what your thought process was like when deciding that you were going to do this?
    3. Can you walk me through your thought process and/or feelings you had during this activity?
        1. Can you also look at the data if there are any relevant or interesting data points during this activity?
    4. Can you describe what your thought process was like when deciding that you were going to do something else?
5. Do you have any questions, or do you want to mention anything?

Debriefing text

"Thank you for having participated in this study. <Explain the goals of the study in the context of your graduation and explain that there were additional sensors, that will eventually be used to control machine behaviour).

Please do not share your experiences of this experiment with others as I would like to ask more people to participate."

8.2 Consent form

Consent form upfrond

Informed consent form for research to explore behaviour in the living room

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The goal of this research is to explore and understand the behaviour and experience of people who relax within the living room. To do so you are asked to spend one hour inside of the comfort lab followed by an interview. You are free to spend your time however you see fit as long as you keep in mind that you goal is to relax. During this hour you are free to go to the toilet at any time. While you are in the room, I will record your behaviour using a camera. The camera is place in the ceiling. The camera footage will be stored on my laptop. The data will be removed after I have fished my graduation or at the latest after 9 months. From the footage I'd to use still images for my report, I will anonymise these images.

You are free to go at any point during the study without giving me a reason.

Consent Form

Please tick the appropriate boxes	Yes	No	
Taking part in the study			
I have read and understood the study information dated [10/10/2019], or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	○	○	
I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.	○	○	
I understand that taking part in the study involves a camera recording that will be stored on my laptop. These recordings will be removed after I finished my graduation or 9 months has passed.	○	○	
I understand that taking part in the study involves an interview about my behaviour and experience with regards to relaxation.	○	○	
Use of the information in the study			
I understand that information I provide will be used for informing further research and design within my graduation project. The findings and results of which will be in my graduation thesis.	○	○	
I understand that personal information collected about me that can identify me, such as [e.g. my name or where I live], will not be shared beyond the study team.	○	○	
I agree that my information can be quoted in research outputs	○	○	
Future use and reuse of the information by others			
I give permission for the anonymised pictures of the recordings to be archived in education repository of TU Delft so it can be used for future research and learning.	○	○	
I give permission for the quotes to be archived in education repository of TU Delft so it can be used for future research and learning.	○	○	

Signatures

_____ _____ 10/10/2019

Name of participant Signature Date

I have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting.

Tjapko Vermeulen_____ _____ 10/10/2019

Researcher name [printed] Signature Date

Study contact details for further information: [*Tjapko Vermeulen, t.j.vermeulen-1@student.tudelft.nl*]

Consent form afterwards about sensors

Informed consent form for research to explore behaviour in the living room

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As mentions in the other consent form the goal of the research is to explore and understand the behaviour and experience of people who relax within the living room. Additionally, to the camera I have also gathering pressure data through Force Resistor Sensors. You were not told about these sensors because how of it might have affected your behaviour. These were place on the couch to gather this data. The data was sent and stored to a server at the TU Delft. The main purpose of the sensor data is to inform me about behaviour however, it may also be used to train artificial intelligence. The “raw” data will be removed after I have fished my graduation or at the latest after 9 months. Or if you desire, I can arrange for the data to be removed within a week.

Consent Form

Please tick the appropriate boxes	Yes	No	
Taking part in the study			
I have read and understood the study information dated [10/10/2019], or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	○	○	
I understand that taking part in the study involves the gathering of sensor data that will be used to inform further designs. This data will be stored on a server at the TU Delft and removed after I finished my graduation or 9 months has passed.	○	○	
I consent that this data may be used as input for artificial intelligence.	○	○	

Signatures

_____ _____ 10/10/2019___

Name of participant Signature Date

I have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting.

Tjapko Vermeulen_____ _____ 10/10/2019__

Researcher name [printed] Signature Date

Study contact details for further information: [*Tjapko Vermeulen, t.j.vermeulen-1@student.tudelft.nl*]

8.3. Email exchange with Particle

Marek – Particle Support (Particle)
Sep 26, 05:13 PDT

Hi Tjapko,

I'm happy to help you with this!

We do not store any user data in this way. Our device service uses webhooks to transmit information – unless you, equipped with the appropriate access token, catch your data at the moment of transmission (eg your own integration, or leaving the Events Viewer open while a device is publishing), it essentially does not exist.

Best,

Marek @ Particle
Developer Support Engineer

Tjapko Vermeulen
Sep 26, 00:30 PDT

Hi Particle,

I have recently started tinkering with your product for my studies, and i have i enjoyed using them so far. I want to use them for doing research but to do so i want to have some information regarding the data sent throught the particle cloud.

Currently i have a setup whit a photon which sent data to a webserver with HTTPS through a webhook in intergrations. Here I can see the last 10 logs. Now I was wondering if you store more then the last 10 logs of the things i send or receive through the subsribe and publish function. If so i'd like to know what you store, for how long and what you do with that data. And I would like to know if its possible for this data to be deleted from your or any third party servers.

Kinds regards,

Tjapko Vermeulen

Operating System: 5.0 (Windows)

8.4. Flow theory

Flow theory comes from research into what makes a good, meaningful life. They found that there are three elements to go into making a good life. These elements are as follows, pleasure, engagement and meaning. These elements are not necessarily connected but when they overlap, and you have a pleasure-filled life with engagement and meaning it adds up to a good life. Flow theory talks about the element, engagement.

Flow is a state in which people are so involved in an activity that nothing else seems to matter. Mihaly Csikszentmihalyi describes seven conditions that are there when a person is in flow.

"There's this focus that, once it becomes intense, leads to a sense of ecstasy, a sense of clarity: you know exactly what you want to do from one moment to the other; you get immediate feedback. You know that what you need to do is possible to do, even though difficult, and sense of time disappears, you forget yourself, you feel part of something larger."

To predict flow there are two indicators, perceived skill level and perceived difficulty level. According to Csikszentmihalyi Arousal and control are still good areas to be in because flow can be entered by improving your skill or increasing the difficulty. From there the areas become less optimal. When watching television most people experience apathy, only seven to eight per cent of the time they experience flow. This happens when they choose a program they really want to watch and get feedback from it.

Implications

When comparing the conclusion relaxation world to flow theory there are quite some similarities. People wanted a world they could lose themselves into. Have the right amount of stimulation, should not be too difficult or easy. They want to have a sense of fulfilment. These are all characteristics of flow, however, within flow theory, Csikszentmihalyi also mentions relaxation as something distinctly different from flow. This difference probably comes from a language difference. The interviews were conducted in Dutch and the word we have for leisure is not commonly used. The translation of relaxation can be used to describe both relaxation and leisure. And when looking back at the transcript people did describe all kinds of activities, they engaged in during leisure, not just activities which would usually be described as relaxing.

From this, it can be concluded that people have the desire to engage in flow during their leisure time. The activities they engage in do not per see correlate with what they experience. Watching television can be experienced while feeling apathy or flow. Their feelings towards the activity are more important than the activity in itself.

8.5. Procedure Session with users

Introduction

The participants will be welcomed inside the comfort lab where the following will be told.

"Hi, thank you for participating with this session for my graduation. The aim of this session is to test my concept and to brainstorm about further iteration. My concept is the following [show pillow]. It is a pillow that wants you to take a conscious moment to recover. So, in a moment I will ask you to use this pillow and recover for half an hour. Besides the pillow, you can use the rest of the room to make this half-hour as effective as possible. Afterwards, I will come back in and I will first ask you a few questions about your experience. Then I would like to brainstorm together about the further development of this concept. If you need to go to the bathroom during this session you are free to do so. During this session, I will be recording your behaviour using that camera [points to camera] and our discussion using a phone. I will also be gathering sensor data through sensors inside the pillow. Hence why I will ask you to sign this consent form. Are there currently any questions?"

Questions

1. How are you?
    a. Can you tell me about your experience with the pillow?
    b. Was the pillow comfortable?
    c. Do you feel recovered?
2. Can you tell me about your routine when you get home from school/work?
    a. Do you often take moments to recover? Would you like to take more?
    b. How long are the moments usually?
    c. Do you use one or multiple pillows in those moments? How do they compare to this pillow?

Thank you for your answers, now I want to start the co-creation part of this session. As I said in the beginning, the goal of this pillow is for you to take a conscious moment to recharge. How did it do? Can you think of physical adjustments you would make so it would achieve its goal better?

Up until now, we have looked at the pillow as a passive object. However, the next step within this design is to give the object actuators to give it a more active role. I want it to actively, proactively or reactively help take a conscious moment to recover. So, I want to go from the beginning to the end of use and go through moments when and how it can help you have a recovery moment.

Start designing, co-creating with the participant, the pillow, pen and paper. At a later point introduce the live visualisation of data.

Debrief

"Thank you for having participated in this study. I would like to ask you not to share your experiences of this experiment with others as I would like to ask more people to participate. Do you have any last questions?"

Informed consent form for concept test & Co-creation

The goal of this research is to get insights into the usage of the concept I created. To do so you are asked to spend half an hour inside of the comfort lab followed by an interview and a co-creation session. You are to use your time in order to recover and the pillow is there to help you do so. During this time, you are free to go to the toilet at any time. While you are in the room, I will record your behaviour using a camera and sensors. During the interview I will also record audio with my phone. The camera is placed in the ceiling and the sensors are placed inside the pillow. The data gathered from the sensors will be stored on a server at TU Delft and the camera footage and audio will be stored on my laptop. The main purpose of the sensor data is to inform me about behaviour however, it may also be used to train artificial intelligence. The “raw” data will be removed after I have finished my graduation or at the latest after nine months. From the footage I will use still images for my report, I will anonymise these images.
You are free to go at any point during the study without giving me a reason.

Consent Form

Please tick the appropriate boxes	Yes	No	
Taking part in the study			
I have read and understood the study information dated [30/01/2020], or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	○	○	
I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.	○	○	
I understand that taking part in the study involves the gathering of sensor data that will be used to inform further designs. This data will be stored on a server at the TU Delft and removed after I finished my graduation or 9 months has passed.	○	○	
I consent that this data may be used as input for artificial intelligence.	○	○	
I understand that taking part in the study involves a camera recording that will be stored on my laptop. These recordings will be removed after I finished my graduation or 9 months has passed.	○	○	
I understand that taking part in the study involves audio recording that will be stored on my laptop. These recordings will be removed after I finished my graduation or 9 months has passed.	○	○	
I understand that taking part in the study involves an interview about my behaviour and experience with regards to relaxation.	○	○	
Use of the information in the study			
I understand that information I provide will be used for informing further research and design within my graduation project. The findings and results of which will be in my graduation thesis.	○	○	
I understand that personal information collected about me that can identify me, such as [e.g. my name or where I live], will not be shared beyond the study team.	○	○	
I agree that my information can be quoted in research outputs	○	○	
Future use and reuse of the information by others			
I give permission for the anonymised pictures of the recordings to be archived in education repository of TU Delft so it can be used for future research and learning.	○	○	
I give permission for the quotes to be archived in education repository of TU Delft so it can be used for future research and learning.	○	○	

Signatures

Name of participant	Signature	Date

I have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting.

Tjapko Vermeulen		
Researcher name [printed]	Signature	Date

Study contact details for further information: [*Tjapko Vermeulen, t.j.vermeulen-1@student.tudelft.nl*]