LUNDS UNIVERSITET

Master Thesis

An investigative study of how to utilize a smart mirror with user focus.

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Abstract

As the tech industry evolves in a rapidly increasing pace, every other company tries to keep up with the pace of development by adapting advanced systems. Users are getting more and more comfortable with smart objects which are constantly connected with the intention of improving the life of every person. The concept of introducing technology into artifacts has been a focus of the market and different distributors have contributed to the development since the concept of Internet of Things was introduced[11].

The concept of smart things has opened up a lot of doors for new innovative products to take place, such as smart mirrors. Several projects of this sort already exist on the market or are distributed in different open source communities [1] [2] [3] [4], often with the purpose of improving users daily activities. In general, the development of these products has its main focus on the functionality. Developers often forget the user perspective of the product, including how the information should be visualized and what information that is of actual interest to the user.

This report will focus on the user aspect of a smart mirror, researching both what functionality a user wants to be displayed, but also how they want to retrieve this information in an interactive way. The result will introduce The Smart Mirror which is developed as a web application and tested on a display with a two way mirror frame attached to it to give the full experience of a smart mirror with a user focus.

Keywords: *Smart mirror, magic mirror, interactive mirror, personalized mirror.*

[1] https://mirrocool.com/product/
[2] https://www.perseusmirrors.com/
[3] http://www.thejuno.co/
[4] https://nuovotec.com

Acknowledgments

We wish to give special thanks to Jayway for hosting our thesis work and contributing with high interest, knowledge and expertise. Providing us with test persons throughout the thesis has been one of the key factors in the process of developing this Smart Mirror.

Also, we wish to thank our supervisor Joakim Eriksson for providing us with feedback along the development of the thesis. His expertise in interactive design has been the extra pair of eyes that gave valuable input to the user experience.

Contents

List of Figures

List of Tables

1

Introduction

People are today getting more involved with technology as it evolves rapidly with new technology constantly hitting the market. Big companies which collects tons of user data can easily facilitate people in their everyday life struggles. As the number of smart products increases, the need of connectivity between products is becoming more important and pushing a higher demand on suppliers to optimize user experience. Smart products refers to products which combines a physical product with additional services such as integration of information and communication technologies. This leads to the development of technical centers where users can access and administrate their data/smart devices in a collective space which is easy to use.

These centers have potential to be evolved in an environment called smart mirrors which is a part of smart products. The hypotheses is that a mirror is an ordinary product which exists in more or less every persons home. This mirror might have the possibility to work as a technical center where people could access/manage their data while looking at their reflection at home or at the office. Imagine a smart mirror which could tell you how the level of energy consumptions looks like in your home or give you the opportunity to control your lamps when you are about to leave your home. This speaks for the many opportunities a connected mirror could have.

Today, such a mirror does not exist on the market while several big companies such as Samsung, Apple and Amazon is developing different kind of hubs where their costumers could connect their products within one environ-

ment. However, there are a couple of open-source projects for developers to build their own smart mirror, one example being the Magic Mirror[1].

The scope of this master thesis was to evolve a smart mirror into being interactive and to investigate what a user would wish to have in such a product. The process traversed through an iterative design process in order to optimize the user experience of The Smart Mirror. The aim was to show how an interactive mirror could be utilized to access and view user data. Finally, the goal was to facilitate morning routines as a person walks by the mirror and could then get an overview of relevant information.

1.1 Jayway

Jayway is a consultancy firm founded in year 2010. Their main office is located in Malmö but they are also situated in Stockholm, Halmstad, Palo Alto and Copenhagen. The company thrives on innovation and have contributed to several international companies within different industries in need of digitalization. Jayway combines creativity and technology to swiftly transform ideas into realities which was why a project such as this thesis deemed interesting to the company. The objective for Jayway was to have the Smart Mirror displayed at the office and shown to clients. In the future this product will be used in innovation labs where other employees can experiment on different angles of the scope and develop new features to the final product.

1.2 Related work

When researching for similar concepts to this master thesis, one quickly realize the lack of research done in the field. In this section, four different papers

[1] https://magicmirror.builders/

or projects will be introduced to give a bigger understanding of what exists as of today. Even though there was a lack of research, it did exist projects that are developing software for smart mirrors, as described in the abstract. One quite extensive open source library was the Magic Mirror forum[12], created by Michael Teeuw. It was a forum for developers who wants to contribute and develop their own mirror with the help of a Raspberry Pi, a screen and a two-way mirror glass. The source code has been distributed on Github. The MagicMirror was a portfolio platform with several different developed features which was available for all to incorporate into ones own projects. It was also possible to contribute with new features or design to the platform. The MagicMirror put together by Micheal Teeuw was for the moment the most appealing product which is in line with the focus of this report in regards to outline and design.

In the report `SmiWork` [8] the main focus was to improve the health and wellness in a work environment. To achieve this the users could retrieve information about how many steps they walked per day, if their goal was met, as well as a ranking board to see who have been the most active within the unit A simple interface for a mirror was developed where identification was achieved with the help of the workers id-card. The interaction was performed with the help of voice control.

This report was of interest within this thesis partly because of their goal, but more importantly because of the feedback received from the final product. The interface did help towards a healthier lifestyle, but the users gave feedback that they did not use the product as a mirror, which should be its main purpose. Instead they used it as an information desktop for their personal activity. It was not something they conveniently used while in the area but had to set time aside to walk over to the monitor and log in with their ID-card. If the screen would be more like a mirror it might have felt more natural to use it and in the same time see ones health and activity information.

The `Aware mirror` project[7] main focus was to create a mirror inter-

face personalized for different users and to also make it context-aware. This required a personal identifier, which in this case was represented as a toothbrush. The information shown could be viewed in two different modes being implicit or explicit. The implicit mode used icons to illustrate information, whereas the explicit mode used text which gave more detailed information to the user. To switch between the modes, the user had to move a zipper forth and back on the mirror board.

Several realizations could be drawn from the `Aware mirror` report. The usage of a toothbrush for identification instead of facial or speech recognition complies with user privacy without violating it by recording voice or analyzing images. Another interesting aspect of the `Aware mirror` was the possibility for the user to navigate between different views. Either access more information in a detailed view of the mirror or to stay in the initial view with limited information that was being displayed. The feedback that was received about the two modes showed that it was appreciated to be given the choice to get more detailed information, but preferably in another way than using a zipper. A zipper might not be the most obvious approach to interact with a mirror as it is not known to be used in similar products such as tv-monitors or displays.

In `SmartNovelMirror` [4], a mirror was developed including basic functionality of interest for the user (weather, calendar, reminders and social medias). It showed the importance of keeping the mirrors purpose intact as in keeping the interface clean. To recognize if a user was standing in front of the mirror a PIR (passive infrared sensor) was used, which was a good way to work around the use of a camera. Also, voice recognition was used as an interactive method.

This article was of very much help when starting the development of the mirror in this thesis work. The basic functionality of the `SmartNovelMirror` was interesting and was to be used as an inspiration when going forward and when deciding the functionality of the mirror within this thesis. To use an IR-sensor was one fascination way to detect a user being close by without

collecting or analyzing images, which also could be used to save power as a positive effect. The focus on keeping a mirror main purpose intact did correlate well with the purpose of this master thesis.

1.3 Purpose and goal

The purpose of this report was to investigate the potential use of a smart mirror in a home environment and to facilitate the users every day life, focusing on morning routines.

The goal was to develop a Smart Mirror with a smooth and natural interaction behavior between users and The Smart Mirror, as well as investigate what content that was of interest for the users.

In order for the process to follow purpose and goal, these requirements were set with the help of related works where some background information was collected. These requirements were divided in to two different categories; usability and user experience requirements. Usability refers to interactive products that are effective to use and easy learn. User experience refers to what the user needs and what the user values [10].

1.3.1 Usability requirements

1. Provide a tool for the users to facilitate morning routines.
2. No other additional hardware should be needed for the user.
3. Provide clear indications of possible tasks and interactions for the user.
4. Narrow down the information visible in the interface, let the user ask for more information if wished for.

1.3.2 User experience requirements

1. Keep a clean interface with only necessary information.
2. Maintain a mirrors metaphor - meaning that nothing should be taking up the space in front of ones reflection.
3. Create an icon based interface with icons understandable for the user.

1.4 Research approach

The aim in this thesis was to address the user perspective of a smart mirror, focusing on creating a good user experience for The Smart Mirror. This include both the user experience of the mirror, as well as the usability and integrity aspects of the mirror. Since the mirror should be able to address several different users, the need to investigate the possibilities of handling several users within one interface of The Smart Mirror, integrity and security would be of great importance.

The research questions that were to be addressed:

1. What purpose is suited for a connected mirror in a home environment?
2. How could the personal identification of a user be done?
3. How could the interface handle several users?
4. How could a user interact with the mirror?

1.5 Thesis delimitations

In order to achieve the goals of this thesis some delimitations had to be made. In the end, the result would conclude in a proof of concept which meant that

some limitations were made during the process as the project went along.

1. No platform for users to administrate their personal profiles will be made, instead a few predefined users would have a mock up/fake profile.
2. Voice authentication will not be fully implemented, but seen as a opportunity for future development.
3. The transportation and list of reminders (to do list) components will not be implemented as the time frame did not allow so.
4. The IR-sensor will not be integrated with the product but tested as a proof of concept.
5. The smart mirror will not be tested in a home environment as it is not feasible to transport the mirror forth and back.

1.6 Recourses

The different recourses that were used for the development of The Smart Mirror are listed separately as software and hardware recourses below.

1.6.1 Hardware

The hardware to be used for developing the smart mirror was:

- RasberryPi 3
- A display, DELL computer screen.
- A two-way mirror.

- Microphone.
- An IR sensor.

1.6.2 Software

The software tools that were to be used for developing the smart mirror are:

- React.js - is a JavaScript-library which is used to build web applications. The library is devopled by Facebook and Instagram which is released as open source project. React is built upon the three programming languages Java Script, CSS and HTML.
- Pythonscript - which is to be used to develop the IR-sensor with the Raspberry PI processor and IR-sensor led.

2

Methodology

This report will follow a design process including three states; beginning with data gathering, followed by the start of low-fidelity prototyping and continued with high-fidelity prototyping. The prototyping phases will include a testing phase before moving on with the design.

2.1 Data gathering

In order to gather an understanding of the potential market and users of a smart mirror, an intensive collection of data were needed. There are several different ways of collecting data within the scope of a smart mirror. The following methods were used in the design process of this report. These will be covered more in detail in chapter 3.

2.1.1 Questionnaire

A questionnaire were conducted with the purpose to achieve greater knowledge regarding earlier interactions with smart mirrors, existing knowledge and wished functions within a smart mirror. The advantage of using a questionnaire is the possibility to reach out to a wide range of people within different age spans and backgrounds regarding knowledge of technology[10].

Another advantage is that the participants will be completely anonymous to insure the answers to be as autonomous and informative as possible.

2.1.2 Brainstorming

A Brainstorming session is often used as a technique to generate, refine and develop ideas[10]. When conducting a brainstorming session, it is important to have an open mind, make sure that every new idea is welcomed and thought through. It is a technique often used in the design process to generate an alternative design. The reason for using a brainstorming session in this thesis work was mainly because of the quick response and feedback received from one session and the possibility to use these new ideas as a foundation when completing the questionnaire.

2.1.3 Workshop

The idea behind conducting a workshop is to get a deeper insight in how a user itself would want the interface to be designed, together with what features to include in the interface. It is a very interactive and productive method as the group is actually working and producing something of value within a workshop.

2.1.4 Personas

With personas, an interpretation can be made about individuals illustrating the data retrieved from the earlier data gathering methods *habtimap* [p.77-79]. It is a good technique to visualize the need and purpose for a product in regards to a specific or several users and to understand the context of why a user would want to have a smart mirror.

2.1.5 Triangulation

In order to validate facts, triangulation is used to validate the information from different sources and perspectives[9]. To possibly validate the retrieved data at least two different sources should be used as of methods and groups of participants generating data. Since there are two authors of this report, two different perspective was given throughout the work. However, as both are around the same age and have similar insight in the product and the technology surrounding it, all the methods mentioned above are needed and are sufficient in order to retrieve good perspectives and sources of information.

2.2 Low fidelity prototype

To be able to retrieve quick feedback without putting too much effort into developing a product it is thought feasible to use low fidelity, lo-fi, prototyping as a first design-method[10]. When creating a lo-fi prototype the most simple way is to sketch on paper, which makes it simple and cheap to change the design. It is hard to test the functionality of the product through this concept, but a good method to use for feedback on the overall design. A lo-fi should encourage towards exploration and modification.

2.3 High fidelity prototype

A high fidelity, hi-fi, prototype is closer to the final design of the product and is most commonly designed in a mock-up tool[10], such as Sketch or Visual Basic. The reason to design a hi-fi prototype is to retrieve feedback on functionality and more specific design (color, shape). To develop a hi-fi prototype it will take more time than developing a lo-fi prototype, but not as long as to develop the final product. More importantly, it is still possible

to change the design without too great effort.

2.4 Usability testing

Usability testing is used to make sure that the design and functionality of the product is in line with what the users want and need. Usability testing can be performed in several different ways. This thesis used walkthroughs and usability testing along with system usability scale feedback to effectively receive feedback from the users after interacting with the interface.

2.4.1 Test plan

Before realizing tests a test plan can help with stating the scope of the test[6]. A test plan will state what is to be tested, how the test will be realized, who will participate, as well as the goal of the test. Test plans make it possible to structure the tests and analyze the purpose of the test before realizing it. Before realizing the tests and evaluating the setup of the test plan a pilot study will make sure the structure is correct. A pilot study is a trial run of the test before performing the actual tests.

2.4.2 Walkthroughs

One method to test a design is to do a walkthrough of the design. This can be performed at any time of the design process, both during lo-fi and hi-fi. Walkthroughs are more commonly used to discuss the design, not the functionality. By traversing through the product the possibility is given to detect problematic usability features in the design[10], but most efficiently retrieve feedback about the design-decisions made. Walkthroughs does not

have to involve a user, but can instead be done with someone understanding the user and preferably also design.

2.4.3 Usability tests

Usability tests is used to measure how usable a product is in controlled environment [10]. The controlled environment is necessary to ensure that there are no distractions for the user, as well as having the ability to control what the user should focus on in order to complete the intended task. A usability test can be performed in different ways, either by focusing on time it took for the user to perform different tasks, or how many mistakes they did before completing a task[10]. The user can be asked to think aloud in order to have the possibility to follow their thoughts.

2.4.3.1 System usability scale

As a part of usability tests, the product will be evaluated by using system usability scale, SUS. SUS is proven to be efficient in gathering statistically valid data and is a good practice to use in order to easily receive feedback from the users when they have interacted with the interface. It is simply a form of 10 predefined questions, phrased by John Brooks in 1989, which the user is asked to fill out as soon as they have finished testing the mirror [1]. It is cheap since it does not need a lot of effort from either the administrators nor the testers. It is also quick since it is an existing framework. The result from the SUS will be a score which indicates the user satisfaction of interacting with the product. The score is calculated by a given standard which in the end concludes in a score out of 100 to indicate whether the product is complaint with the concept of usability.

3

Data gathering phase

Before starting designing the mirror, data was gathered to have an idea of what the users did and did not want. This data was later the foundation of what was included in the design, as well as how it was designed.

3.1 Established information

This section explains the information that was established up until this state. It includes established requirements as well as drawn insights from the related works. These realizations formed the framework for The Smart Mirror.

In the background research, several different concepts of mirrors appeared. One fruitful realization was regarding the different states for the mirror. If the mirror could be initialized with help of movement or by similar simple interaction, the screen could stay in sleep mode as long as no user were present.

Another reason to have several states was because of the aspect of user interactions. If all the information were shown at the same time the interface of the mirror would be filled up and hard to interact in. This resulted in the decision of creating three different states:

1. Default state

2. Personal state
3. Personal-detailed state

The encountered concepts of smart mirror were developed in different ways, but in general it included this in regards of hardware:

- A microphone
- An IR sensor
- Raspberry pi
- A screen with mirror glass

With this in mind the data-gathering phase was initiated.

3.2 Questionnaire

A Questionnaire was realized to gather information on what approach users had towards the concept of a smart mirror, together with the initiation of new technology into ones household. One reason to perform a questionnaire was to retrieve proof on the implications drawn from reading other articles, along with stated assumptions. The information retrieved from the questionnaire gave support to these assumptions and made it possible to move forward in the project.

Number:	Question
Q1:	What gender are you?
Q2:	How old are you?
Q3:	Which is your current country of residence?
Q4:	Have you come across a similar concept such as a smart mirror before?
Q5:	If you answered yes in the previous question, please explain the concept of the smart mirror you have experienced in short.
Q6:	How many are you in your household? (Do not include children under the age 5)
Q7:	How many mirrors exist in your household that you personally use?
Q8:	Rank these mirrors according to how much time you spend in front of them in the morning?
Q9:	How much time do you spend in front of a mirror in the morning?
Q10:	What are your most stressful activities in the morning?
Q11:	Which mirror(s) would you like to be "smart"?
Q12:	Would you like the content to be different depending on where the smart mirror is located? (e.g. news feed in bathroom mirror, reminders in hallway mirror)
Q13:	If you do not want a smart mirror, what is the reason?
Q14:	What features would you like to have in your smart mirror?
Q15:	Would you be comfortable with others seeing your personal information in the smart mirror, e.g. your calendar?
Q16:	Would you be comfortable with an IR (infrared) sensor in your mirror which would be used for sensing when a person is near?
Q17:	Would you be comfortable with a camera in your mirror which would be used for user identification?
Q18:	Would you be comfortable being identified with voice recognition when using a smart mirror?
Q19:	How interested are you in new technology?
Q20:	How likely is it that you would want a smart mirror in your home?

Table 3.1: Questions asked in the questionnaire

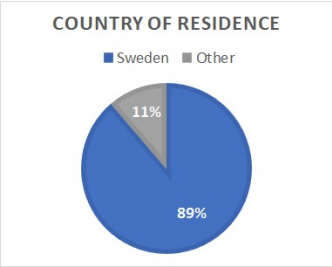

Figure 3.1: Country

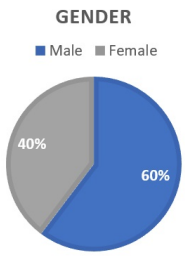

Figure 3.2: Gender

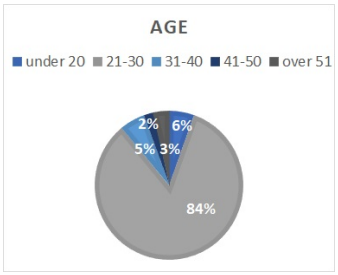

Figure 3.3: Age spectra

GoogleForm was used to set up the questionnaire, mostly because the easy way of sharing it on different medias. It was also possible to retrieve an excel document with the answers if graphs were wished to be made. The questions for the users to answer can be found in Table 3.1. Answers from the questionnaire are summarized in several Figures, all of them presented in percentage of the total pool of answers. A total of 147 answers were gathered throughout social medias such as Facebook, Email and Messenger. These medias were used to establish a broad spectra on the users, which can be seen as successful from Figure 3.1, 3.2 and 3.3. Although it would be desirable to have a broader spectra of the users, this gave a wide enough view to use as a foundation.

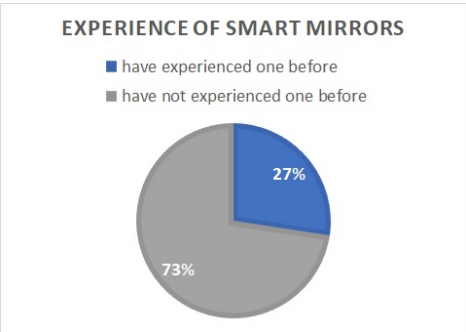

Figure 3.4: How many have come across the concept of a smart mirror before.

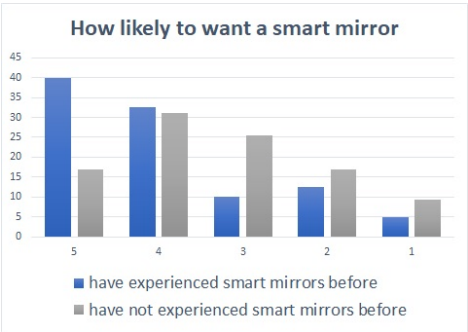

Figure 3.5: Likelihood to want a mirror if you have or have not experienced it before.

One can see that the concept of smart mirrors are still something users only briefly have experienced. The majority answered they had never experienced a smart mirror before, see Figure 3.4, which made it more important to focus on creating a design supporting simple and intuitive interaction with the interface of the mirror.

As seen in Figure 3.5, one can see that if a user have experienced the concept of smart mirrors before, they were more eager to have one themselves. This result can have different reasons, but one conclusion possible to retract is that users who have experienced a smart mirror had a positive experience and would possibly want to see a future for the concept of a smart mirror in their own home.

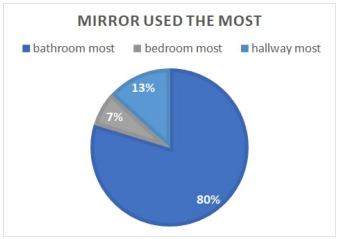

Figure 3.6: Which mirror is used the most.

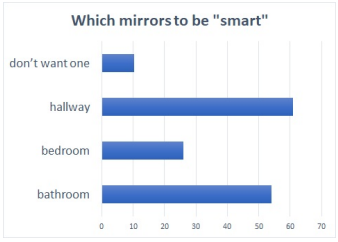

Figure 3.7: Wished mirrors to become smart.

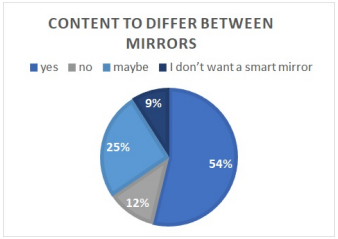

Figure 3.8: If the content of the smart mirrors should differ.

As seen in Figure 3.6 the bathroom mirror was used the most and it, together with the hallway mirror were the ones wished to become smart mirrors, see Figure 3.7. It was interesting to see that even if the hallway is not used at all as much as the bathroom mirror, the hallway mirror was still the mirror users want to become smart. The reason for this could be that it is not as common to have a mirror in the hallway, meaning introducing a smart mirror there would not interfere with already existing mirrors. Users also wanted the content of the mirror to differ, see Figure 3.8. This was hard to design for in this early state, but could be of interest later on. The people who answered they do not want a smart mirror was also able to state why. It was either because of a skepticism towards having one more screen in your

surroundings, or a worry about the mirror being expensive. The cost-aspect was outside this thesis scope, but the skepticism-aspect was important to remember. The smart mirror must still be able to be used as a mirror and not be received as *"one more screen"*.

Figure 3.9: Moments people experience as stressful in the morning.

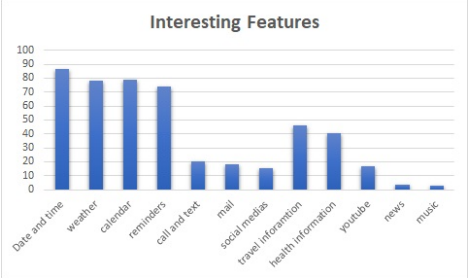

Figure 3.10: Wished features retrieved from the questionnaire.

The feedback retrieved pointed on several different areas that felt stressful in the morning, as seen in Figure 3.9. With this in mind it was important to design a interface to address and avoid these stressful instances within morning routines. From the Questionnaire it was also possible to state wished functionalities for the mirror, these functionalities can be found in Figure 3.10. These functionalities did correlate with what was assumed to be the main functionality of the mirror. In general it is easier to retrieve ideas on functionality from a brainstorming session, which was performed. The result from the questionnaire was merely one way to confirm that result.

Considering security and integrity, the assumption was that users were not yet ready to introduce one more camera into their home, see Figure 3.11, but more acceptable towards being identified by their voice and with the help of an IR-sensor, see Figure 3.12 and Figure.3.13. This was discussed in the related work session and confirmed by this questionnaire. When asked about how people felt about private information being shown on the mirror, most

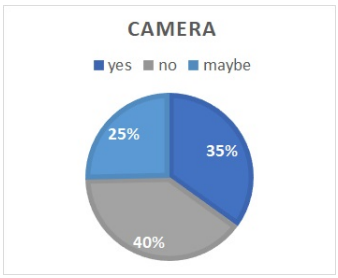

Figure 3.11: Comfortable with camera for identification.

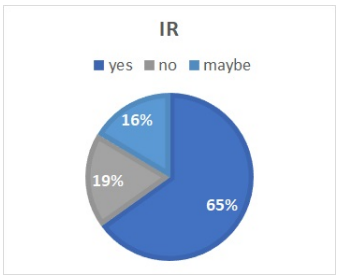

Figure 3.12: Comfortable with IR for identification.

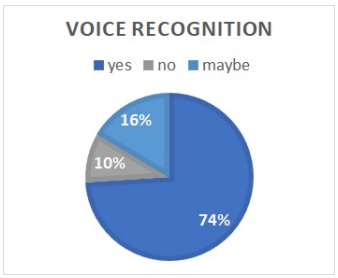

Figure 3.13: Comfortable with voice recognition for identification.

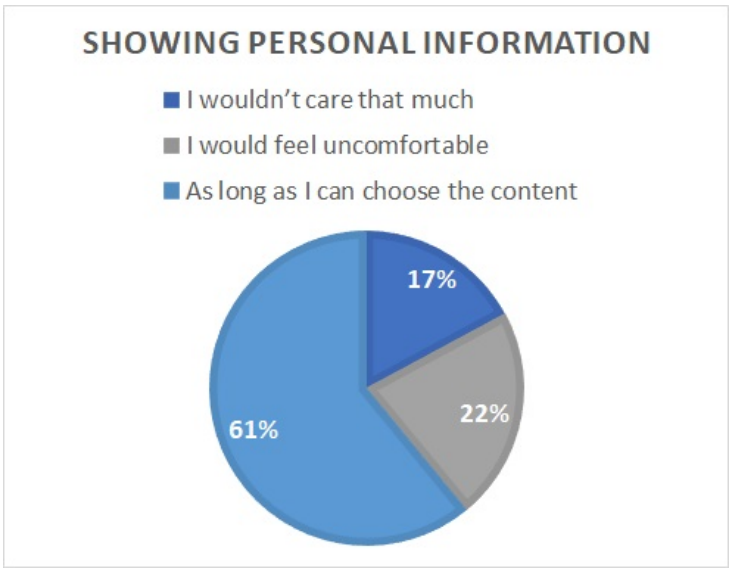

Figure 3.14: How comfortable people feel about others seeing their personal information.

people answered that as long as they had the opportunity to decide what was to be shown, then it did not really matter if other could see it, as seen in Figure 3.14.

These answers gave a deeper insight of what purpose users thought of the mirror and what functionalities they desired. One could also retrieve how comfortable they felt about different interaction possibilities such as camera, voice or IR-sensor. With the result at hand it was decided to not use a camera and focusing on creating an interface using speech and movement as input. This was taken into consideration when designing the low-fidelity prototype.

3.3 Brainstorming

The reason behind the brainstorming sessions was to retrieve new ideas for the interface of the mirror, together with how information could be presented on the mirror. As of this state, a rough idea of how the concept and design of The Smart Mirror could look like has been evolved from earlier discoveries, both from related work and the information retrieved in the questionnaire. Therefore the purpose of this brainstorming session was to gain new perspectives and ideas from different angels.

The session took place at the Jayway office in Stockholm. The time for the session was set to take no longer than 60 minutes. The reason for the relatively short time limit was set in respect of the participants working hours. The brainstorming was split up in two sessions with the same outline. Every session had four Jayway employees, mix of both female and male participants with different working titles such as developer, designer and management.

One concern was that the session would have a strong technology driven discussion since the participants was quite involved with technology and close to half of them had some form of smart technology within their home en-

vironment. However, this was not necessarily the case. The session had a wide platform for what The Smart Mirror could be developed into as of both design and purpose. The session was set to be an open forum for discussion were no framework was set other than the thought of a smart mirror which led to many new and different ideas. The discussion was centered around the purpose and the functionality of the mirror and where it could be located, meaning which rooms and surroundings. The key takeaways are presented below.

The mentioned purposes of the mirror:

- To show impact on climate, sustainability.
- To connect smart devices as a hub for smart homes.
- Facilitate and organize routines within the home environment.

The mentioned functionality of the mirror:

- Personal and friendly phrases.
- Reminders for activities and items.
- Alarm and timer.
- Weather.
- Traffic information, public transport connections.

New thoughts that was brought up during the brainstorming session:

- There should be a mode where the mirror is idle or inactive. More specifically, one should be able to demand the mirror to be inactive and enter idle mode as well as it should always be in idle state when no one is near the mirror. Names that were stated:
  - Idle mode.

  - Focus mode.
  - Inactive mode.

  The names on the modes later changed to Idle, Default and Personal state.

- A mobile platform where you can organize the interface of the mirror and where you could contribute with new functionality and features.

Not many mentioned time, date and weather as a feature in the mirror during the brainstorming session. This could be because earlier experience with smart mirrors which means that these features was by default included in the concept of a smart mirror. However, these features were always included in the interface in the workshop.

The brainstorming sessions was a success where some new insights were made along with earlier theories which was in line with the discussions from the participants.

3.4 Workshop

The brainstorming session did bring up new ideas of functionality, but to get a more concrete example of how the users imagined what their mirror would look like and how the interface would be organized, a workshop was organized. The workshop took place in one single session, 90 minutes long, at the Jayway office. The participants were seven employees where two of them did not participate in any of the brainstorming sessions. The same concern as for the brainstorming was that all the participants had experience of how other smart mirror looked like and how they worked which could affect their perspective of things and also in a sense be more technology driven. On the other hand, they already had the insights of what is somewhat possible to feature and what is not.

The aim for the workshop was to use the data collected from earlier methods, questionnaire and brainstorming, in order to get closer to what the scope of this project was to be built around. Therefore the participants were not involved in an open discussion of how the mirror will work, but instead was told what hardware that would be a part of the mirror and what the hypotheses was. The used recourses were papers of size A3 which represent the display of the mirror. Post-it-notes were used to write and draw on and then to put on the paper representing the mirror. The outline of the workshop was structured as follows:

Scope

First, the participants were instructed on what the concept of the mirror was within the scope of this project, including the different states of the mirror. They were also informed on what hardware that were to be be part of the mirror.

Mind map

The participants were asked to draw a mind map with the mirror in the center. The mind map should be titled with the purpose of the mirror and what features to include. This was asked to be done with themselves as the user of the mirror. The mind map worked both as a road map for the participant to lean back on when going forward in the workshop as well as it produced several conceptual models for the development as it would progress forward.

Design default state

Next up was to design and construct the default state. The attendants were asked to fill out post-it-notes with features without labeling what the feature was but instead sketch the content of the feature and place it on a paper mirror.

Design personal state

The personal state is when a user has been identified and the mirror then enters the specific users profile. Same thing was asked of the participants for designing the personal state using post-it-notes.

Design personal-detailed state

When designing the personal-detailed state the participants were asked to choose one of their features and to design that particular feature in detailed state. This could be done by taking another paper, a mirror, and draw the detailed view of that one feature, or use post-it notes to demonstrate the usage of that feature. Another aspect was to demonstrate how this detailed view should be accessed from the previous view.

Design idle state

When progressing through the workshop, the participants prompt that they wished to design an idle state which also had been mentioned in the brainstorming sessions. The decision was made that if the participants wished to have an idle state in their mirror then they could design the interface for that as well. This meant that four different views for the mirror was designed.

Present the design

Lastly, a presentation was planned for every participant to present their design and to go through their thoughts. This gave the possibility for the participant to add words to their design and to describe more thoroughly the purpose of the design.

The key takeaways that was gathered from the workshop session were collected and are presented below.

Design approaches:

- All wanted to see the time and weather at all times (except from the detailed-personal state if the weather was not the detailed feature).

- 6 out of 7 kept the main area in the middle free from information making it feasible for the user to see ones reflection.
- 4 out of 7 designed a smart home feature.
- Some designed a microphone in feedback purposes for the user showing that voice recognition is enabled.
- The idle state was included in the design. After seeing the different designs it was realized that the detailed-personal state would not be needed as its own state, but rather include the possibility to retrieve detailed information in the personal state. This resulted in three new states for the mirror:
    1. Idle state
    2. Default state
    3. Personal state
- One design showed an interface structured with box dimensions. Implying that the user could structure their personal interface by filling out boxes with the features wished for by the user.

A representation of Time was presented in every design but the date was not always included. The idle state was as mentioned commented on earlier and was therefore included in the workshop which was not the plan from the start. However, the importance of an idle state for the users was apparent. The idle state would then be the earlier state before the default state and it could also be a positive effect as for power savage.

3.5 Personas

After investigating the collected data, from previous work, a third method was used to illustrate a user which would benefit from a smart mirror. It

came down to two different individuals with different needs and background. The purpose of these are to pinpoint situations where this concept of a smart mirror should have a great impact and improve the lives of these personas. These two individuals are living different lives but have a common pain point which was during their mornings.

David - Family member of 5

David has a rather hectic morning when trying to get organized for himself along with his 3 kids, one of them being a teenager. The time is pressed and bags needs to be packed before leaving the house. The most concerning problems David has in the mornings are:

1. To get everyone out of bed.
2. Not enough time to plan and organize, but instead just doing everything that comes to mind.
3. To remember everything that is needed to be brought leaving the home.

This person has a lot going on in the mornings from waking up till leaving the house.

Sara - Living alone

This person is having a hard time to structure her morning routines and often forgets something when leaving the apartment. Sara is living by herself and does not have too much to do in the mornings which often leads to her staying in bed too long. By the time she gets out of bed the time is pressed and a lot needs to be done in a short time. Sara usually has her day filled out with activity such as work, exercise and hanging out with friends.

The stressful moments in the mornings for Sara are:

1. To get out of bed in time.
2. Not forgetting anything when leaving the apartment.

4

Low-fidelity phase

Moving forward from the data gathering phase and entering the low-fidelity, lo-fi, phase. By using the collected data, a prototype was to be made by taking into consideration all the different aspects of the previous work that had been done.

The reason for doing a lo-fi at this stage was to reach a closer design of the final product that was later to be developed. Since there were some features that were unexpected in the data gathering phase, the lo-fi experienced some changes along the way while being tested and iterated. The testing was done with walkthroughs together with potential users.

4.1 Prototyping

The method for the lo-fi prototyping was to use regular white papers to demonstrate the mirror in its simplest form by some sketches. The features were drawn and then cut out to be placed on the paper representing the mirror. The features were moved around and tested with different layouts and positions. The playful setting of the design made changes welcoming and easy to make by not giving the feeling that the design was final.

Before beginning to draw the lo-fi, the functionality for the three different states of the mirror were defined in order to know what to include. This was

based on the data gathered from previous phase, the data gathering phase:

Idle state, minimal information to be shown. Close to a regular mirror.

1. Time
2. Date
3. Weather

Default state, general information.

1. Time
2. Date
3. Weather
4. Holiday calendar
5. Travel information

Personal state, more personal information which can be extended.

1. Time
2. Date
3. Weather
4. Calendar
5. Reminders
6. Travel information

The positioning of the features were harder than originally thought. The feedback from users were inconclusive in the aspect of positioning objects in the interface. To keep the original metaphor of a mirror, the space in the middle of the interface were kept clean and the boarders and corners were used for presenting different information by its components. This follows the rules of the F-shape pattern, where information in an interface should be presented in a F-shape for the users to interact with it easily[5]. To see the design of these states, see appendix C.

4.2 Usability testing

When the first lo-fi prototype was finished, the design was needed to be tested. The first design was made as an interpretation based on the data collection and inputs from participants in the different data gathering methods. The design was tested with the help of walkthroughs with employees at the Jayway office to create a design unbiased to a single persons perspective.

4.2.1 Walkthrough 1 and 2

Two different walkthroughs were performed with the lo-fi prototype. The result from the two are presented below:

Walkthrough 1 The first walkthrough was done with two male employees at the Jayway office, one backend and one frontend developer. These users had completely different takes on how the design should or could look like. Most focus landed on the transport feature along with some missing features that was wished for in their mirror. The takeaways are presented below:

- The transport feature needs to be very clear whether if the departure time was updated in real-time with delayed time or if it was based on a strict time table regardless of delays.
- Also the two different ways of representing the transport taking off from the nearest station needs to be stated where it is departing from and to which direction it is heading. The transport feature ended up in two different designs with different aims and purpose. The first design presented departure time in minutes from now, which gave the impression that the time was presented in real time and not the time from the timetable, see Figure C.2 in appendix. The other design stated

the time in the format HH:mm, which was seen as timetable slots. The second design also showed if the transport was by metro or bus, see Figure C.3.

- Feedback around the weather was to keep all the weather information together. Therefore the design changed to introduce an umbrella icon together with the current weather icon, instead of presenting it together with the other reminders. Also, a small time line over when it is going to rain during the day was introduced, see Figure C.3, compared to the weather information in Figure C.2.

Walkthrough 2 The second walkthrough was held with a UX designer at the Jayway office. It was planned to have this walkthrough at the end since the UX designer has insight in how to think when designing an interface and how the user thinks when interacting with different designs. This was obvious when the comments were based on the design as a whole and not in specific features as for the previous walkthrough.

- The UX designer commented on why the right side of the mirror was kept clear, but also agreed that it was a good idea for the possibility of seeing ones reflection.
- The purpose of showing what profiles are present in the mirror did not have the intended impact. It rather felt like it was a chat or call function where the logged in user could interact with the other users. The logged in user would probably not care about seeing other users icons that could be logged in. This feedback resulted in removing the profiles present in the mirror (see change between Figure C.2 and Figure C.3). When only showing the logged in user, the user symbol was moved up to the upper right corner.
- The "Can I help?" bubble by the microphone felt misguiding as it was associated with the other users in the mirror. If the text was to be

removed then the microphone could flash instead to show that it is active and listening. The text bubble by the microphone was removed to make the design more clean.

- The location of the weather feature was not where it was wished for. If possible it should rather be moved closer to the time and date component.

- The reminders would not work in the long run as a user becomes used to a design and the reminders would not receive the attention when needed. Instead, if they could flash as for when the user approaches the mirror then the users attention would be drawn to look at them. Flashing reminders were taken into account.

5

High-fidelity phase

When the lo-fi phase was completed it was decided that the hi-fi would be implemented as a web-page without developing a hi-fi design first. This decision was made from the aspect of interaction. The design made in the lo-fi phase included several movements in the interface to retrieve the attention of the user (reminders appearing in the middle before moving down to its position, extending calendar or weather for more information, microphone changing color to retrieve the users attention). The interaction of the interface would also be managed through voice, which was hard to implement in a prototype. These movements, together with speech recognition, was considered of high importance to the user experience, but is hard to display with a prototype. This resulted in the decision to develop the hi-fi interface in the web framework React (combination of HTML, Java Script and CSS) from the start.

As the development of the hi-fi was going to be implemented using React resulting in a web interface, it meant it could easily be visualized on any display using a computer. Since The Smart Mirror itself was heavy and not easy to move around, the hi-fi phase was split in to two parts. The first part where the hi-fi prototype was shown on tv-screen using a computer projecting the mirror interface to another screen. The second part was when the The Smart Mirror was used at the Jayway office for final testing. After each development phase, usability tests were performed before continuing the development into the next phase. This was done to make sure that the

thoughts of the user was taken into account when moving forward from the first phase of the hi-fi prototype into the next and to see if the usability feedback improved after the second phase.

5.1 High-fidelity - Phase one

As this project has a time limit the scope had to be prioritized before starting developing the web interface. The scope that was formed from the lo-fi state was then divided into different components from which only a selection was included in the hi-fi as listed below.

1. Public holidays
2. Personal calendar
3. Weather
4. Reminders
5. States for the mirror
6. Speech recognition with feedback

Components that were not included in the hi-fi prototype,

1. Public transport
2. When to leave your home
3. List of reminders in form of a to do list

The personal calendar and weather components along with the static icon reminders were of higher priority as they were more generic to all users and therefore prioritized when starting developing. The public transport component and list of reminders in form of a to do list was not developed in the hi-fi as they would take a lot more effort to be implemented and as they would be dependent on several external integrations. States of the mirror would lay the foundation of the mirror and the speech recognition with feedback is important for the user to be able to communicate with the product.

5.1.1 Improvements from lo-fi prototypes

When moving forward from the prototype produced in the lo-fi, the hi-fi did accord to very similar design. However, some small design changes did occur.

- In the weather component the list over todays weather with three predefined time slots (8:00, 12:00, 17:00), was changed to show the current time by the hour and two time slot from now with three hours in between, see Figure D.4. The initial thought was not to show the time slots before going into personal state, but was changed to be introduced already in the default state.
- The microphone was moved to the center of the bottom border of the display with the purpose of optimizing space and to be featured with more focus, see Figure D.4.
- The speech bubble was kept, but used to give the user directions of how to log in with their user name from the default state. When moving the microphone with speech bubble to the center the aim was to make it more easy to notice, as well as leaving the left border for icon reminders. Feedback about when the microphone was noticing sounds was added by adjusting the opacity of the microphone, making the microphone flash.

- The extend function for the weather component was moved to the bottom instead of the top to correlate with the other components with extend functions, see Figure D.5.

The states for the mirror however did not change and was categorized as three states:

1. Idle state
2. Default state
3. Personal state

The *personal-detailed state* was merged into the personal state. The reason for this was that the information displayed in the personal-detailed mode was the same as in the personal state with the same components but extended when asked for by the user.

5.1.2 User interactions

There are four different types of user interactions that could be adapted to the mirror which are: movement, voice, appearance and physical contact. The requirements of this Smart Mirror is restricted to not use any video or image recording which means that appearance will not be a factor that is feasible. The hardware is also limited as it can not interpret physical contact which means no touch functionality can be adapted. The intention is then to use voice and movement to interact with the mirror.

5.1.2.1 Speech and Speaker recognition

The initial chosen technology for accessing the personal view of the mirror was by using Speaker recognition so that the user could be identified by

simply speaking without having to speak a specific pass phrase. It has been adapted in a bank in America where the bank authenticates the speaker by its voice over the phone [2]. This technology is rather new and the available suppliers which offers this service is charging for every single transaction as in whenever a voice is to identified. These insights concluded that the technology that enables speaker recognition is very attracting to the concept of The Smart Mirror but was not feasible to be integrated in this project since it was not a free software.

For the user to be able to communicate and interact with the mirror, it was initially thought to be done by voice recognition. When different methods of implementing voice recognition was investigated it was proven that speech recognition can be developed for the interface, but was then going to be very limited due to available resources on the web. There were some softwares available for free and from which Annyang was chosen for this project [3]. The limitations and difficulties to import the technology into the product was quickly discovered. A lot more time was needed to be able to use the source code of Annyang as intended in a optimized and simple way. A decision was then made to limit the speaker interactions and to implement different key-press commands to simulate the intended speech interactions.

The possible phrases to be used by the user when interacting with the mirror:

- Log in [username]
- Log out
- Extend weather
- Hide weather
- Extend calendar
- Hide calendar

5.1.2.2 IR sensor

The other way to interact with the mirror was with the help of an IR-sensor to detect movement in front of the mirror. The IR-sensor was to be used to let the mirror go into *sleep mode*, which then would give the possibility to save power. The IR-sensor was put together with the code to support the intended functionality but it was not integrated with the mirror. The reason was that it required a different set up for testing the product as the sensor had to be plugged into the computer when tested outside the mirror which was not optimal since the interface was projected to a tv-screen when the look of the interface was tested. The ability to interact with movement was not integrated but it was proven to be feasible in a future product. This interaction was however simulated through a key-press command which triggered the actions of the IR-sensor. Because the IR-sensor could not be tested as intended, it is hard to tell how well the functionality would work. The flow could however be tested to see if it should be removed or kept when developed further in the future.

5.1.2.3 Design changes

The calendar was imported from Google calendar, which resulted in additional information on every event that was not taken into account in the previous design. Some events could be full day events in the calendar. These events should be shown throughout the whole day, as well as indicated as being a full day event. It was decided to show these events in the top of the calendar list without any time given, representing the full day and using different icons to illustrate what kind of event it was. For testing purposes two different icons was introduced: one for birthdays and one for other type of full day events, see Figure D.8.

As decided in the lo-fi prototype the reminders were introduced in the center before moving down to its fixed position in the personal state, see

Figure D.6, and Figure D.7. The same goes for the rain reminder introduced in the default state, see Figure D.2, Figure D.3 and Figure D.4. The reason was to draw the users attention towards it. The lunch and workout reminders were only shown when events in the calendar triggered them. The workout reminder was triggered if the heading of the event includes the word *Workout*. To trigger the lunch bag, the time stamp of 12:00 should not exist in the list of events from the calendar and so the assumption was then made that nothing was planned for the lunch break and therefore food should be brought. The key and wallet icons did not appear in the middle like the other reminders, but was instead always shown at its fixed position when a user has logged in to the personal state. This decision came from not wanting too many reminders appearing in the middle to prevent a bad user experience, together with the importance of keeping the space clean in the middle for the mirror to keep its purpose.

There are three different lists in the interface of the mirror, one in the extended mode of the weather displaying further weather information, one for the calendar as well as for the public holidays. To indicate a difference in time a fadeout was implemented, giving the list-items furthest away in time a lower opacity.

5.1.3 Usability testing

A test plan was created before performing the usability tests, together with a template to fill out throughout the test about how well every test person performed. The test was split up into two parts, one focusing on the interactions with the interface, and one on the design. For the interaction of the interface the user was asked to perform several tasks, or giving information about a specific event, which was only possible if interacting with the mirror. Before performing every test the user was introduced with necessary information about the system, including what users exists in the system at the moment. The users were also asked to *think out loud* about how they

experienced the system. The questions asked for the interaction part of the test can be seen below:

- Time, Date and weather
  - *What time is it?*
  - *What's todays date?*
  - *What's todays weather?*
- Awake the mirror
  - *Approach the mirror by moving around or walking towards the mirror.*
  - *What's the next Public Holiday?*
- Users interaction and calendar
  - *Can you log in Office?*
  - *Log in Tintin instead.*
  - *Find the last event of today in the calendar.*
  - *Log out the current user.*
- Weather information
  - *Are you able to tell me what the weather forecast is for tomorrow?*

During the other half of the user testing, the focus was on the design. Instead of giving the user tasks to perform, questions were asked about what was seen on the screen. The questions regarding the design are stated below:

- Reminders, what does these reminders mean to you?
  - *Keys*
  - *Wallet*

  - *Lunch bag*
  - *Dumbbells*
  - *Umbrella*

- Fade
  - *What do you think it means with the difference in color furthest down in the three different lists of the components?*
  - *Do you believe the fade means different things in the different lists, or have the same purpose?*

- Calendar and Weather
  - What do you think the two different icons in the calendar component mean?
  - *How can you tell what user is logged in at the moment?*
  - *What information is possible to retrieve from the weather component from both normal and extended mode?*

After every test the user was asked to fill in a feedback form about how they experienced the interaction, as well as how confident they felt when using the mirror.

The tests included three people, one facilitator guiding the user as well as navigating the mirror interface, one test person acting as a user and one annotator taking notes. Seven tests were performed for the first round together with one pilot test making sure the setup was working properly. In this setup it was decided not to use the mirror, but instead focusing on the interactions with the interface. The pilot test quickly showed that by presenting the user with the interface on a computer gave the wrong impression on the possibilities of interaction with it. The user tried to interact through clicking on the screen, or on the sidebar of the computer. The reason behind this is not clear, but could have to to with the smart interfaces of phones and

tablets that are touch screens. It was decided to present the interface on a TV-screen further away, preventing the users from pressing on the screen or sidebar and instead exploring other possibilities of interaction.

Several realizations were made when the tests of both interactions and design perspectives were performed, which resulted in changes of the design. The interactions within the product was not changed as the users were mostly concerned of the given feedback in regards to the interactions. A summary of these realizations with decisions of changes are presented below.

- The design of the mirror was completely in English, whereas the first language of the users testing the design was Swedish. To keep the design in English was a decision made right from the start, to keep the product generic and available for a wider range of users. Users had during these tests a hard time understanding what the next public holiday was. This was mostly because they did not recognize the name of the holiday and therefore picked the one they recognized from the listed public holidays.

- When asked to present the weather for tomorrow, the users were unsure how to retrieve this information, or if this information existed. It was the first interaction done by voice, because they needed to say *extend weather* to retrieve further weather information. It was also some confusion about the timestamps presented for todays weather. The user thought these were dates instead of timestamps. Users quickly realized this was not the case and tried to say *extend weather* in an attempt to find the weather list.

  To ease the retrieval of tomorrows weather, the date of tomorrow will be presented with the text *Tomorrow*, instead of the date which can be seen in Appendix E, Figure E.3.

- When attempting to log in with the office profile, users only said *log in* instead of *log in office* forgetting to use the user name. The purpose

of the speech bubble was to indicate of how to log in, but instead it created confusion about what to say.

To ease the login process, the speech bubble will be removed and replaced with several different possibilities of voice commands. These commands will then be added and hopefully help the user towards an easier interaction with the interface. For an example it will be possible to switch user both by saying *Change user to [username]*, as well as *Login [username]*.

- In the calendar, the users were asked to find the latest event of the day. This caused some discussion about whether the last event showing in extended mode actually was the last event of today, or if there are more not showed. This confusion came from using a fade in the calendar, both for extended and non-extended mode.

- The fade was supposed to be an indication of events further away in time, but when asked about it, users had several different assumptions about its meaning. It was seen as a hint that the calendar had more content than was shown, or that the faded events were removed or not of importance for the user at the moment. Users also thought the faded rows indicated things happening outside of work or during ones spare time.

  To clarify the last event in the calendar, the fade will be removed when transitioning into the extended mode. This resulted in a new purpose of the fade, indicating that there is more to show in the list, which most users assumed it meant when performing the tests. To keep a consisting design the faded rows in the weather was decided to be removed as well.

- The full day icon in the calendar was hard to understand for the users. They understood it as it had to do with the events of the day, but assumed it to be either a spare time event, an alert, or an imported event from another calendar. This could be a result of not understanding the icon connected to the event, or not being familiar with the concept of full day events in Google calendar. To change the icon was decided

as not prioritized and that the user will be educated when interacting with their own events in the calender.

- The four different icons in the bottom left corner from the personal state had several different interpretations and merely a few understood the intention of them. The key icon got interpreted to containing passwords, or settings for the calendar. Ideas like *find my phone*, or *add event to calendar* was mentioned. The wallet was mostly seen as way to digitally pay invoices, or an indication of information about different payments. The two remaining reminders are not always visible because they are associated with the events of the calendar. The users did often connect the lunch bag to the calendar, but the confusion emerged whether it was a indication of a lunch meeting happening, or if one were supposed to bring a lunch bag to work.

  The dumbbell also resulted in some confusion about its purpose, where the users assumed the dumbbell was an icon for retrieving more information about the workout booked for today, or a possibility to book workouts to the calendar, as well as the possibility to see todays workout schedule at the gym. The reminders did in general create some confusion and users did not see them as reminders, but tools to retrieve more information.

  To clarify that all icons are reminders, they will appear the same way, moving from the center down towards the bottom left corner. The argument not to do this before was to keep the interface clean and keeping the space in the middle clean for the mirrors purpose. It will be tested to make the reminders appear in pairs to minimize the time when the icons move and they will also have a text underneath describing the reminder.

- Users did understand the meaning of the umbrella icon, but did not connect it to the list of weather information. The list indicated when rainfall was going to occur during the day, but most users assumed the umbrella only meant it was going to rain some unknown time during

the day.

To clarify the connection of the umbrella to the list of todays weather, the umbrella icon will instead move from the center down towards the time for when it is going to rain. If it will rain over several timestamps one umbrella icon will move down towards each time stamp, seen in Figure E.5.

5.1.4 System Usability Scale

By the end of each test the user was asked to fill in a SUS form consisting of 10 questions. The statements were asked as follows, rating their relevance between 1-5, 1 being strongly disagree and 5 strongly agree. The average outcome for every question are represented in 5.1:

Questions	Result
I felt very confident using the system	3,7
I found the system very cumbersome to use	2,0
I think that I would like to use this system frequently	3,7
I found the system unnecessarily complex	1,4
I thought the system was easy to use	4,6
I think that I would need the support of a technical person to be able to use this system	1,4
I found the various functions in this system were well integrated	4,1
I thought there was too much inconsistency in this system	1,6
I would imagine that most people would learn to use this system very quickly	4,4
I needed to learn a lot of things before I could get going with this system	2,0

Table 5.1: SUS result in Hi-fi phase 1

The final SUS score out of this phase was calculated to **80,357**.

5.2 High-fidelity - Phase two

With the feedback received form the user tests it was decided to iterate through the design once more, focusing on creating a even better user interaction, and focusing on making the users understand every functionality. To make sure the result was not affected by the fact that the interface was shown on a screen and not an an actual mirror, the performed tests in this iteration used a mirror for the presentation of the interface. This iteration consisted of a discussion about how to solve the different design flaws from previous face, how to develop it and to finally perform user tests to evaluate the changes made.

5.2.1 Improvements from hi-fi phase one

Looking at the test results from previous iteration some changes were implemented to try to receive better results. These changes were then evaluated in this test round. The changes made are described below.

- To make it more clear what day the different rows in the weather list were connected to. The row showing tomorrows weather was therefor renamed into *tomorrow*, instead of only showing its date. The reason was to guide the user towards a quicker understanding of what the list represented.
- Since there were some different opinions about what the faded out rows in both the weather and calendar list indicated, it was decided to use the fade as an indication that there are more existing information available to be shown. The fade was therefore removed from the extended modes if there were no more information existing.
- When users was introduced to the reminders several different interpretations about what they meant arose. Since the reminders connected

to the weather or the calendar were easier for the users to understand, the keys and wallet were also moved towards a similar introduction in the interface. By not wanting to take up unnecessary time and focus for the user, both the key and wallet were brought in to the view at the same time in pairs, see Figure E.4. To give a even clearer indication of the meaning of the two, the text *Don't forget...* appeared in under the two icons while it was moving toward its final position. When the key and wallet was positioned correct the rest of the reminders appeared like before by moving towards its final position. One difference was that if both the workout and the lunch icons were to appear, they did so at the same time. Also here a text was introduced to give a more clear understanding of what their purpose was, this time saying *Reminders*. Also this text would disappear before the icons reached their fixed position.

- Even though the full day icons in the calendar resulted in some confusion for both an event set for a whole day and birthday event, it was hard to find a better icon for events. Therefor the icons were kept as it was and hoped that the users would learn when seeing their own events. It was also not of the highest priority. Therefore this icon is still in the design and will most likely retrieve the same feedback as before.

- To indicate a closer connection between the umbrella and its meaning the umbrella icon were to be animated to go from the center down towards the time slots, where an umbrella already was shown. It would indicate that the user should bring an umbrella and that the movement of the icon would point out the reason that it was going to rain a certain time, see Figure E.5 . If it were to rain in more than one time slot the umbrella was to be split up and move towards each time slot. The goal was to get the user to see that the umbrella indicates that it will rain today on a specific time instead of that it is raining at this moment, which some users thought with the previous design.

- To help the user interact by voice, the mirror would guide the user by giving more thorough feedback of what the mirror can do and for when it is listening. An icon under the microphone for showing that the user could speak as an interaction was introduced together with explanatory text. When in default state the text *login with username* should guide towards how to login. The text *logout user* was introduced by the user profile to help towards logging out. With these hints the aim was that it will hopefully be easier for the user to interact with the interface form the start, also giving the hint about using speech as the way to interact with the interface without having to tell the user how it should be done.

- Finally, the interface was being tested on the mirror to see how the colors worked in the new setting. Since no actual colors had been used it seemed to be working as intended on the tv-screen without any further development. What was realized was that the faded texts of the interface was hard to see since the mirror reflects light in the room as well. The change that was made was to brighten the faded out parts resulting in brighter scale for the whole mirror.

5.2.2 Usability testing

In order to compare the result between the two iterations, the same setup with questions was used, but then using the mirror instead of a TV-screen. The interface was also zoomed in on the mirror by 200%, making the design more clear and easy to follow. This time around the design was tested on 8 different users. These users had not been involved in the previous user tests. Key takeaways are presented below:

- This time around the users did not have a hard time understanding the next public holiday, even though no changes had been made in the design. In the previous design the holidays were quite hard to interpret.

This date had in fact passed in this iteration which was a fault in the software, which probably was the reason why users could easier relate to the name of the holiday.

- Regarding finding weather information easily about tomorrows weather, users did manage to successfully succeed in this task with the changes made, even though the design of the commands themselves were not changed. Since some improvements were done in the hope of achieving a better understanding of how to interact with the interface by voice, those changes could affect this interaction as well in a positive way. It did still take the users some time before they started interacting with the mirror by voice and giving the correct commands, but they did not need any extra indication and understood it without further help.

- When asked to log in, the same confusion about what to say appeared as in the first test round. Even though the indication now said "Login with username", instead of "Login...", the users still had other creative ways to ask the mirror to login. The realization is the same here, that it would be needed to add several commands of how to log in so that it is feasible for the user to have alternative requests for the mirror for the same task. The task to change the logged in user to another user was managed without any greater problems. Since the indication text *"log out user"* was introduced more users used the path to log out a user and login again, instead of using the shortcut to login the next user from the personal state.

- When asking about the faded out rows in the interface it was now much more clear for the users what it meant. Everyone had the same understanding of what the faded rows were indicating. In the previous iteration several users thought the fade meant that it existed more information (more events in the calendar, more days in the weather information) to retrieve, even in the extended mode, which was correct if the list was not extended. Removing the fade and only using it in this purpose created a more clear design and a much better understanding

from the users.

- With the new design on the reminders quite some confusion disappeared. The umbrella did now have the desired connection to the list, removing the confusion about if it was raining now, or later in the day. The key and wallet was now connected to the reminders, without users believed they had any extra functionality behind them.

5.2.3 System Usability Scale

Users was then again asked to fill in the same SUS form in order to receive feedback on the product. The questions within the form were stated as follows, rating their relevance between 1-5, 1 being strongly disagree and 5 strongly agree. The average outcome for every question is represented in 5.2 with hi-fi 1 representing the previous phase of the hi-fi and hi-fi 2 representing the outcome of this, second, phase of the hi-fi:

Questions	Hi-fi 1	Hi-fi 2
I felt very confident using the system	3,7	4,4
I found the system very cumbersome to use	2,0	1,8
I think that I would like to use this system frequently	3,7	3,7
I found the system unnecessarily complex	1,4	0,6
I thought the system was easy to use	4,6	4,7
I think that I would need the support of a technical person to be able to use this system	1,4	1,4
I found the various functions in this system were well integrated	4,1	4,2
I thought there was too much inconsistency in this system	1,6	1,7
I would imagine that most people would learn to use this system very quickly	4,4	4,8
I needed to learn a lot of things before I could get going with this system	2,0	1,8

Table 5.2: SUS Result of Hi-fi phase 2

The final SUS score out of this phase was calculated to **81,25** which showed an improvement from the first hi-fi phase.

6

Discussion

When building up the foundation and defining the concept of The Smart Mirror a few obstacles was met on the way which are to be discussed in this section. There are some aspects that could have been considered in advance and some that was not expected to appear through out the work that was done. Learnings was made from existing papers written about the same category being smart products such as smart mirrors and the hope is that new learning can be presented from this work in this discussion.

6.1 Data gathering phase

As the initial phase was the data gathering phase, a lot of thought was given about the aimed target group as of what age group this project should be developed for. The decision was made that it should be able to speak to a wide span of age but also that the questionnaire should be able to tell what range is appropriated, which it did. The outcome of the questionnaire regarding the age spectra spoke for the obvious fact that the form was filled out by a age group correspondent to the age of ourselves as the authors. However, as the age span was very wide, the time limit for building this project did not make it reasonable to think about the accessibility of the design to be adapted by the younger and older ages.

Another aspect of the data gathering phase was that once the questionnaire

was sent out, the questions could not be changed. Even though it was tested with a pilot group at first it still felt like there were some gaps that was left unfilled with answers. For example, one question showed that 54% of the people who filled out the form thought that the content should differ regarding where the mirror is located in the bedroom or in the hallway. We went forward with the The Smart Mirror to be developed as a hallway mirror since it was the easiest kind of mirror to test with users in a later stage. However, the content that should be specific for a hallway mirror was never researched other than in the brainstorming and workshop sessions which both were conducted with people from the Jayway office which are very good with technology and the majority of the employees of Jayway had experienced a smart mirror before. A lot of these features that were brought up during those sessions were not developed since we had to define a scope appropriate for the time limit.

6.2 Low-fidelity phase

The lo-fi phase proved to be very fruitful as the design evolved and was continuously tested. A lot of time was spent to think about the layout and to go through the data collected from the data gathering phase. The workshop was conducted mostly to retrieve input to the design. The obvious limitation throughout the lo-fi was that the functionality could not really be tested and the main metaphor of that the user should be able to see its reflection in the mirror could not be simulated with a piece of white paper with some sketches on it.

6.3 High-fidelity phase

When moving into the hi-fi phase, we felt confident that the design that had been formed to this point was something that could be built and we were very eager to implement a testable prototype where the user actually could interact with the product. Since there were so many different factors we wanted to test, which could not be developed in a click-able prototype, we decided to implement the hi-fi prototype as a web-page where we could potentially integrate with external systems if needed.

None of us had any experience of web development prior to this project and we used this as an opportunity to learn. Since it took us longer time to set up the mirror with a web-page than it would if we had done a click-able prototype without any written code, we had to tighten the scope of what had been designed in the lo-fi phase. However the outcome was much better than we could have expected, the hi-fi phase did have some complications that arose as we began to write code. Our hope was that we could re-use components from the MagicMirror [12] open source project but it was not as easy as we had hoped for. The MagicMirror did not use the same standards since they did not use React as web framework. This meant that we could get inspired from the MagicMirror project but could simply not take advantage of the existing code.

Some of the external APIs that we had to use for integrating weather into the mirror along with public holidays was hard to use since most of them charged you for every time you collected some kind of data using their service. Also, some of the APIs used was subject to change their structure which would make our project to crash when we did not know that the external services had changed their set up. We also experienced a lot of difficulties with the speech recognition service called Annyang [3]. This meant that we could not rely on that the mirror would understand or be active for when the user is speaking their command to the mirror. The solution was then to implement key-press actions that we could use for when we performed the

tests to simulate the same actions that would have happened if the speech recognition was optimized. Of course this meant that the user could sense that the mirror was not really responding the way they thought it would when they saw that we were pressing the keyboard for every action that was spoken and shown on the mirror. However this did not likely effect the result and outcome of the tests as in that the features did what they were suppose to and triggered when the user asked for it. Further it was discussed to use a more advanced system for speech recognition, such as integrating the mirror to a digital assistant such as Google Home [1] or Alexa [2]. This thought was disregarded, since the focus of this report is on the design and interaction, and not on the development.

One aspect of the hi-fi testing was that the mirror was never tested in a home environment but instead always operated at the office of Jayway. The reason was because the mirror was not easy to transport. During the tests, the users never naturally approached the mirror for the reason to look at oneself in the mirror. The first part of the hi-fi did not have a mirror since it was tested with a tv-screen. The second part was tested with the actual mirror but still the tests could not really simulate the same set up or feeling of a hallway mirror in a home. The reason for why a smart mirror have such great potential is because a mirror itself is frequently used and can be utilized with information to be projected through the mirror, optimizing the time spent in front of a mirror in the hallway or anywhere in ones home. It is really hard to test the concept of The Smart Mirror in an office environment where the natural sense of looking in a mirror is not a natural movement. This should definitively be taken into consideration when evaluating the result from the tests.

Finally, the users never had the chance to see their own data or information projected on the mirror. The only user profiles on the mirror were ours and the Jayway Office profile. This meant that the people performing user tests

[1] https:store.google.comgbproductgoogle_home

[2] https:www.amazon.comAmazon-Echo-Bluetooth-Speaker-with-Alexa-BlackdpB00X4WHP5E

could not relate to the information shown and they therefor had a hard time to interpret the information about another user. The conclusion here was still that the information visible on the mirror about another person was understandable enough to make the right conclusion about its purpose. When looking at the SUS feedback it can be seen that the user felt much more confident when testing the mirror during the second part of the hi-fi phase and also thought that is was easy to use. Overall, the feedback gave a great output with values close to perfect. It can also be seen that in general, the final output from the SUS score proved that the users liked our product and would recommend it to other potential users. Whenever the SUS score reaches 80,3 or higher the product is measured as well adapted to usability standards and is highly appreciated by its users.

6.4 Future work

As mentioned earlier, the concept of Smart Mirrors has great potential and this project only captured a fraction of what the product could have been if completed to the full extent. This means that there are several aspects that could have been developed and tested in future work. As a starter, by addressing accessibility for elderly people and to develop the mirror with several languages would increase the spectra of potential users.

When discussing future work, it is both in the sense to improve the already existing design, but also including new features. Looking back at the result, after phase two of the hi-fi development, there are still some improvements in the design that could have been prioritized if time would have allowed it.

The original thought for the different voice commands was to help the user to easily understand how to interact with the mirror in a intuitive way. This was not fully accomplished, since the users rather logged out the active user before logging in themselves (if someone is logged in already). These help indicators could definitely have been improved if another iteration of

the design was to be done.

In regards of speaker and speech recognition, they would both need to be tested with a user to be certain that it is a desired feature of The Smart Mirror. More time was definitely needed for improving the speech recognition in order to find a more stable API to integrate with. It would have a great impact as it would mean that the key-press functions could be removed during tests. With a better API it would also be possible to introduce a *help* feature, giving the users help with smart indications if the system did not recognize the words that was being spoken.

The reminders was in the final test easier to understand, but still had some minor confusion. If a user would have the mirror at home, these reminders would be static for a long time meaning that they would be easy to miss when leaving home. To give the reminders more focus one idea would be to make an animation for icons to be triggered when movements was detected.

Looking at the design from the lo-fi prototype, the public transport was not implemented in the hi-fi. As mentioned before, the transport component was down prioritized but had a lot of focus during the entire lo-fi phase. Because of the high interest from the users, this component could definitely improve time spent by users in the mornings if time for more thought was given and then developed.

This kind of product requires a platform for the users to set up their profiles in order to sign in to the mirror. It would require that the user can accept terms to give the mirror the rights to show the user data and the user also needs to sign in with third party integration systems such as Google calendar. One aspect, which this project had the ambition to do, was to give the user the possibility to choose what components that should be visible and also to chose where the component should be placed in the view. The opportunity to investigate further into what other systems that could be integrated in order to make the mirror even smarter and enhance the user experience would have been done if time allowed. One possible integration could be to enable the

mirror to receive or to make phone calls to other mobile devices or why not other smart mirrors.

7

Conclusion

This section concludes what has been achieved with this thesis work and how the final result corresponds with the initial stated goals.

The first goal was to *investigate the potential use of a smart mirror in a home environment in order to facilitate users every day life, focusing on morning routines*. Since the data gathering phase was focused on analyzing what users would want in their home, together with how their morning routines looked like, this has been the highest focus throughout our work. As discussed in future work, several desired functionality from the users were not included in the final product because of time and resource limitations. In order to facilitate every users morning routines, the interface of The Smart Mirror needed to be more adaptable, in regards to accessibility and also expanded functionality. The potential of this product is of no doubt huge, both considering that several different startups were found in the same category and also since the feedback that was received throughout the project pointed towards a demand for this product.

The second goal was to *develop a smooth and natural interaction behavior between users and The Smart Mirror, as well as investigate what content is of interest for the users*. One aspect that arose in the data gathering phase was that the majority of the users did not want to use a camera in the mirror, which was the only reason to why only voice and IR was used as interaction methods for The Smart Mirror. As discussed earlier, the interaction method through voice, using the existing software `Annyang`, did not work as desired.

However, the voice interaction was aid with the help of key presses during tests, which did affect the user feedback as they could notice that we could control their commands. The content of the mirror was formed by the answers from the data gathering phase, resulting in a content desired by the users which also received a great response in the user tests.

In general the received feedback from the conducted tests, together with the SUS result shows that this is a desired product. The project has always received positive feedback and people are in general very eager to learn more. Since the interface was very clean, keeping the mirror functionality intact, users felt safe using the mirror. This was one important task from the start, making the users feel in control of the mirror and not being scared to use it.

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Appendices

A

Test plan

User Tests - Test Plan

Background information

The reason why you are here and why we are performing these tests are to understand how users think when interacting with the mirror. There are no right and wrong answers in these tests and we want you to be playful and to “think out loud”. When thinking out loud, we wish that you state your thoughts cause it helps us to know what complications the user might encounter and whether the flow is easy to understand or not.

We will first let you test the product where we will ask you to perform some tasks with the help of a few instructions. When these user tests are done we will have a few minutes where you will be asked general questions of how you think and feel about the design and user experience, this is open feedback where you will be free to do what you want and play around with the functionality.

In the end, you will be asked to fill out a usability feedback form which is anonymous and will be about general feedback about the product. Feel free to be completely honest as it will help us with further development of the product.

Test users

The smart mirror will be tested on several different users, including people on the Jayway office, as well as potential users in home surroundings. These tests will only test the interface of the smart mirror from a screen without the actual mirror.

Test Scenarios

The instructions given to the test user.
All the answers are collected by the help of google form.

Time, date and weather

Can you tell me;

1. What time is it?
2. What’s today's date?
3. Whats is today's weather?

Awake the mirror

Let's pretend that you are moving closer to the mirror.

1. Approach the mirror by moving around or walking towards the mirror.
2. What is the next public holiday?

Weather information

1. Are you able to tell me what the weather forecast is for tomorrow?

Log in user

1. Can you Log in office.

Change user

2. Log in Tintin instead.

User calendar

1. Find the last event of today in the calendar.

Log out user

3. Log out the logged in user.

Design feedback

Reminders

What does these icons mean to you?

1. Keys
2. Wallet
3. Lunchbag
4. Dumbbells
5. Umbrella

Fade

- What do you believe the purpose of the change in colour of the bottom lines in the different components mean?
- Do you think they mean the same all the time, or do they have different intentions at different times?

Calendar

- What is the meaning of the two different icons in the calendar?

Weather

- What information is possible to withdraw from the weather widget in normal mode?
- What extra information is provided in the extended mode?

Login symbol

- Is is possible to see who is logged in at the moment?
    - How can you see this?

B

Software Requirement Specification

Software Requirement Specification

Table of content for the SRS (Software Requirements Specification)

Introduction

This document is mainly created for development purposes to make sure that the intended features are present throughout the implementation. A brief presentation of the background describing the concept and goals for the mirror of what the scope is both in regards of short and long term.

Background and goals

1.1. Main goals

The main goal for the system of The Smart Mirror is to connect users by voice interactions. Users are intended to have their own “profile” for the user to access by interacting with the mirror in a home environment. The main objective is to facilitate morning routines with a few features that is feasible for a MVP. The MVP of this project will only consist of a frontend web interface.

1.2. Actors and their objectives

Frontend: The view which is visualized to the user. The frontend communicates with localhost and voice recognition.

Hardware: The hardware consists of a display(monitor) and a mini processor (raspberry pi 3).

External API:

- *Google Calendar.*
  Where events are fetched from a users calendar.

- *Open weather API*
  Collected information regarding weather.
- *Public Holidays.*
  Where information regarding public holidays are collected.

Terminology

User	Person using the mirror.
API	Application programming interface.
MVP	Minimum viable product.
Idle state	The initial state where only basic information is visible.
Default state	Additional information is shown but no-user related information.
Personal state	Information connected to the logged in user is presented on the mirror.
Component	An available feature to be shown on mirror.
Movement	When the IR-sensor is detecting movement in front of the mirror.
Normal mode	The component is in a not extended view.
Extended mode	The component is in an extended view.

1. Functional requirements

1.1. Idle State

1.1.1. **Requirement:** Date and Time component is shown.

1.1.2. **Requirement:** Weather component is shown.

1.1.3. **Requirement:** Scenario 1.1.3.1 shall be suported by the system.

1.1.3.1. **Scenario:** When *movement* is detected the *Default state* shall be entered.
Precondition: Mirror is in *Idle state*.
1. A user is approaching or passing by the mirror.
2. Movement is detected in front of the mirror.
Postcondition: Mirror is in *Default state*.

1.1.4. **Requirement:** Scenario 1.1.4.1 shall be suported by the system.

1.1.4.1. **Scenario:** When a user is logging in using voice recognition.
Precondition: Mirror is in *Idle state*.
1. A user is speaking to the mirror identify oneself.
2. The mirror recognises the speaker's login by username.
Postcondition: Mirror is in *Personal state*.

1.2. Default State

1.2.1. **Requirement:** 1.1.1 is shown.

1.2.2. **Requirement:** 1.1.2 is shown.

1.2.2.1. **Requirement:** Shall comply with req. 1.4.1.

1.2.2.2. When in normal mode, today's weather can be seen.

1.2.2.3. When in extended mode, the weather report for the four upmost coming days can be seen.

1.2.2.3.1.

1.2.3. **Requirement:** A public holiday component is shown with the four upmost coming public holidays.

1.2.4. **Requirement:** Scenario 1.2.4.1 shall be supported by the system.

1.2.4.1. **Scenario:** A user is logging in using voice recognition.
Precondition: Mirror is in *Default state*.
1. A user is speaking to the mirror with the purpose of being identified.
2. The mirror recognises the speaker by username.
Postcondition: Mirror is in *Personal state*.

1.3. Personal State

1.3.1. **Requirement:** 1.1.1 is shown.

1.3.2. **Requirement:** 1.1.2 is shown.

1.3.2.1. **Requirement:** Shall comply with req. 1.4.1.

1.3.3. **Requirement:** A personal calendar component is shown.

1.3.3.1. **Requirement:** When in normal mode, the four upmost coming events of today shall be shown.

1.3.3.2. **Requirement:** Shall comply with req. 1.4.1, if today's events exceed 4 entries.

1.3.3.3. **Requirement:** When in extended mode, the possibility of showing the up to 8 upmost coming events of today shall be shown.

1.4. Extended mode

1.4.1. **Requirement:** The possibility to extend and hide the component for more or less information.

1.4.1.1. Scenario 1.4.1.1.1 shall be supported by the system.

1.4.1.1.1. **Scenario:** A user is speaking to the mirror with the purpose of extending a component.
Precondition: Component is in normal mode.
1. The user speaks to extend a component by saying *"extend"* followed by the component which is wished to be extended.
2. The mirror recognises the command and process the mirror.
Postcondition: Mirror is displaying the component in extended mode.

1.4.1.2. **Requirement:** Scenario 1.4.1.2 shall be supported by the system.

1.4.1.2.1. **Scenario:** A user is speaking to the mirror with the purpose of hiding a component.
Precondition: Component is in extended mode.
1. The user speaks to hide a component by saying *"hide"* followed by the component which is wished to be withdrawn.
2. The mirror recognises the command and process the mirror.
Postcondition: Mirror is displaying the component in normal mode.

2. Design

2.1. **Requirement:** The view must be implemented in such a way that the main space in the middle is free from projected information.

2.2. **Requirement:** The last two events in user calendar listview shall be faded out when there is more events to be shown going from normal mode to extended mode.

2.3. **Requirement:** If a component support the possibility to be extended, users will receive feedback on how to perform the task.

3. General Requirements

3.1. **Requirement:** The view must not be scrollable. All information shall be visible within the display.

C

Lo-fi prototype

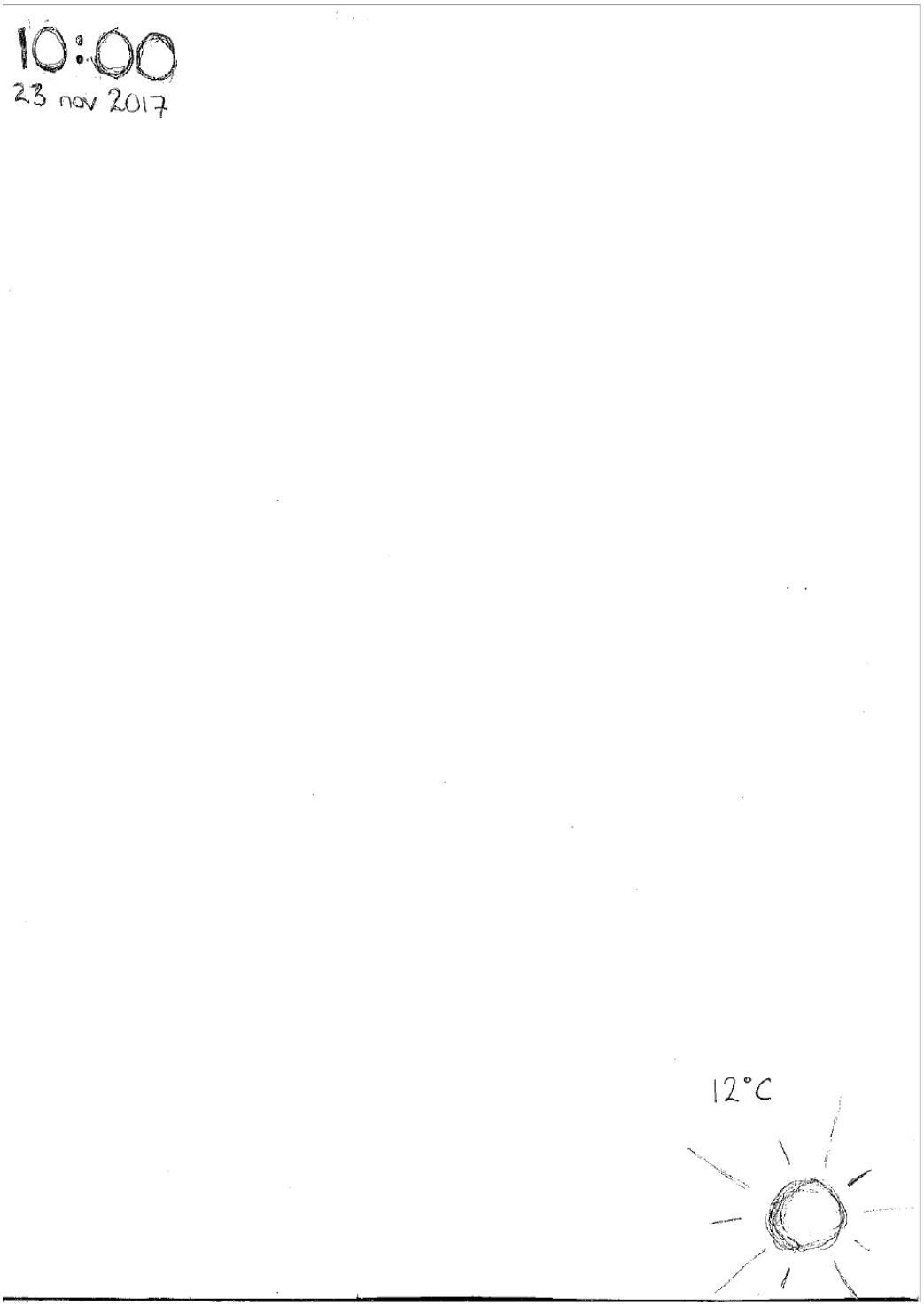

Figure C.1: Lo-fi prototype of the idle state

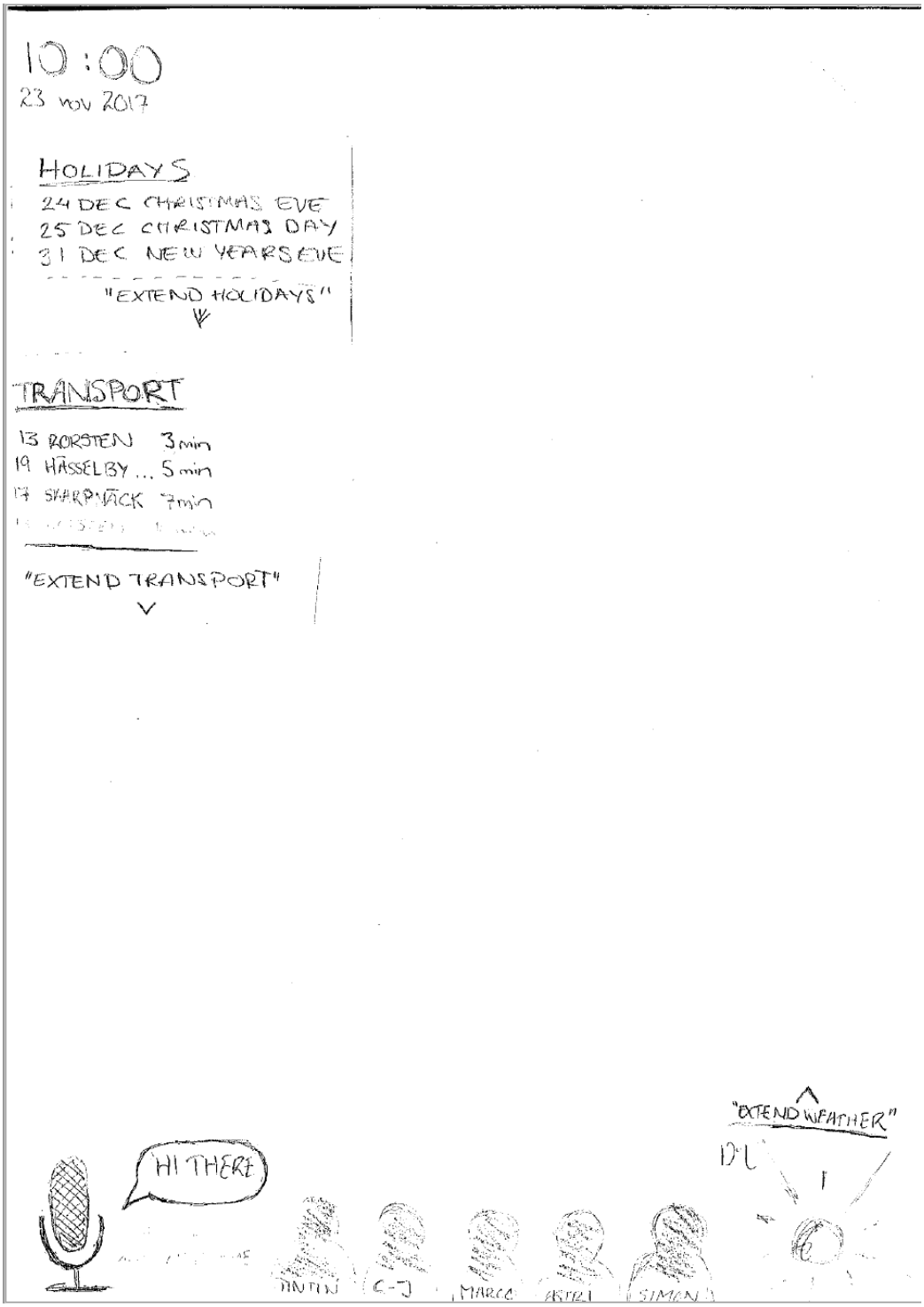

Figure C.2: Lo-fi prototype of the default state

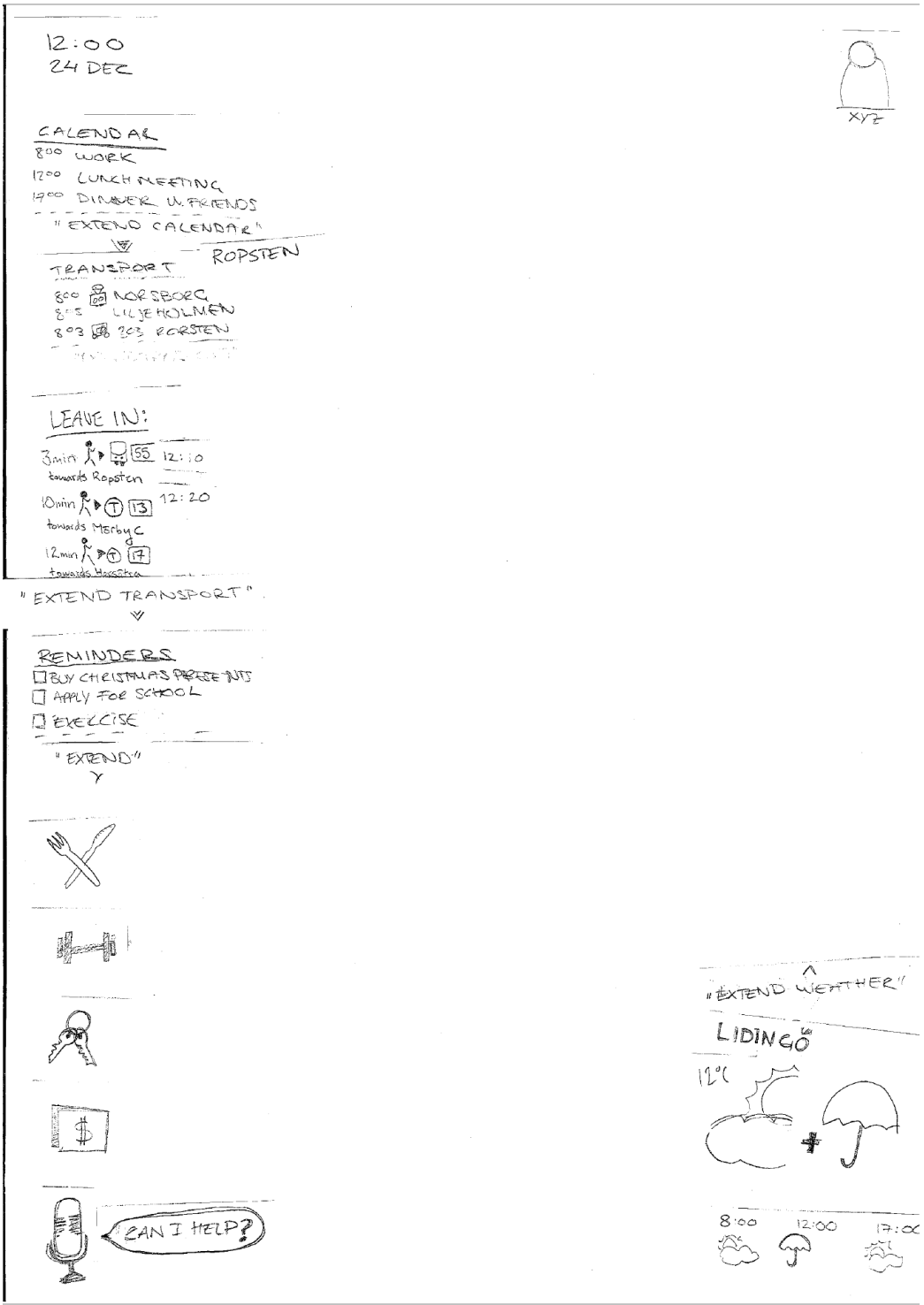

Figure C.3: Lo-fi prototype of the personal state

D

Hi-fi, First prototype

Figure D.1: The Smart Mirror in its idle state

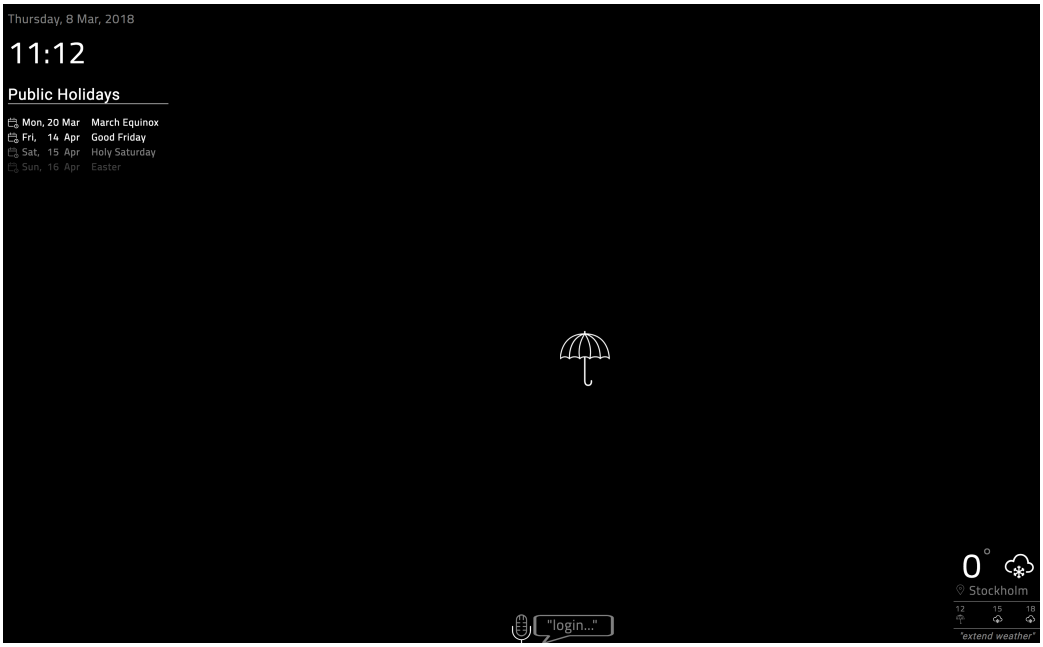

Figure D.2: The Umbrella appearing in default state

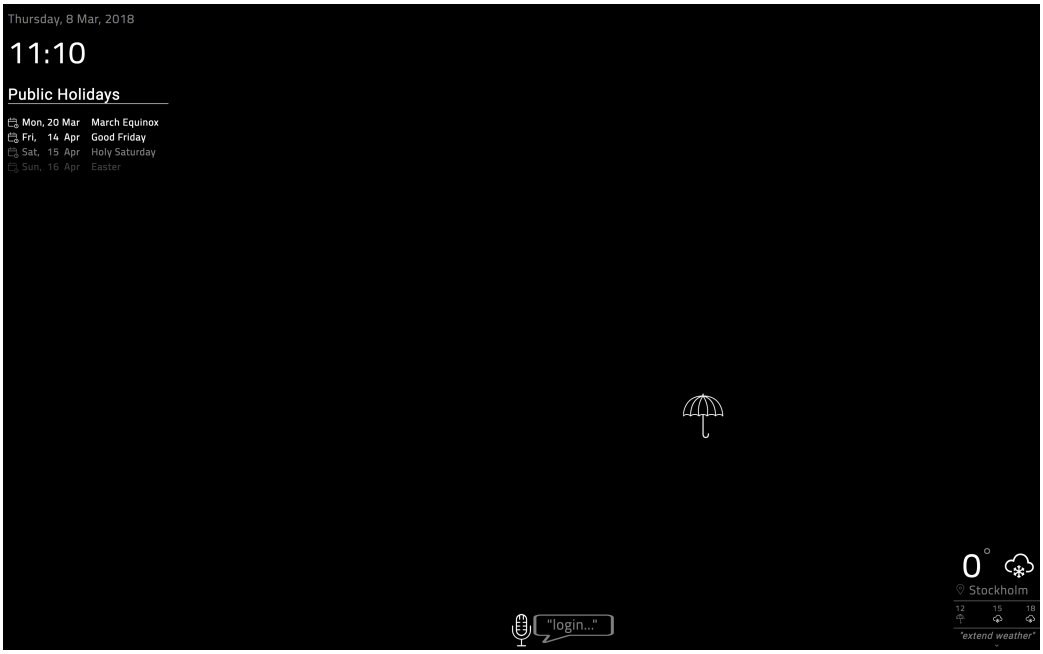

Figure D.3: The Umbrella moving towards the weather component in the default state

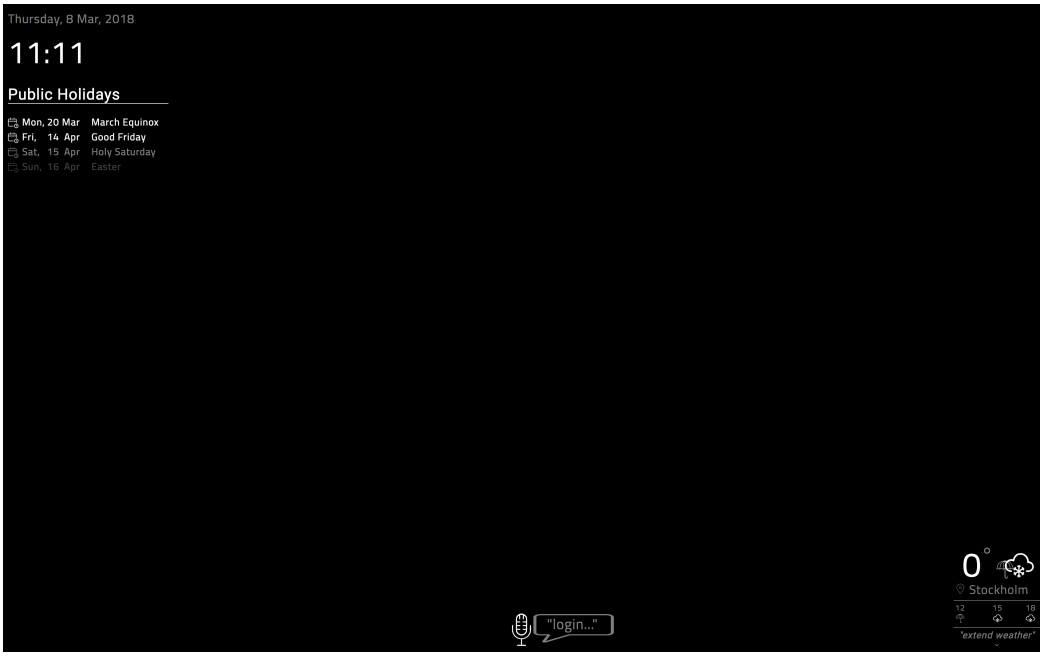

Figure D.4: The Umbrella positioned by the weather before disappearing

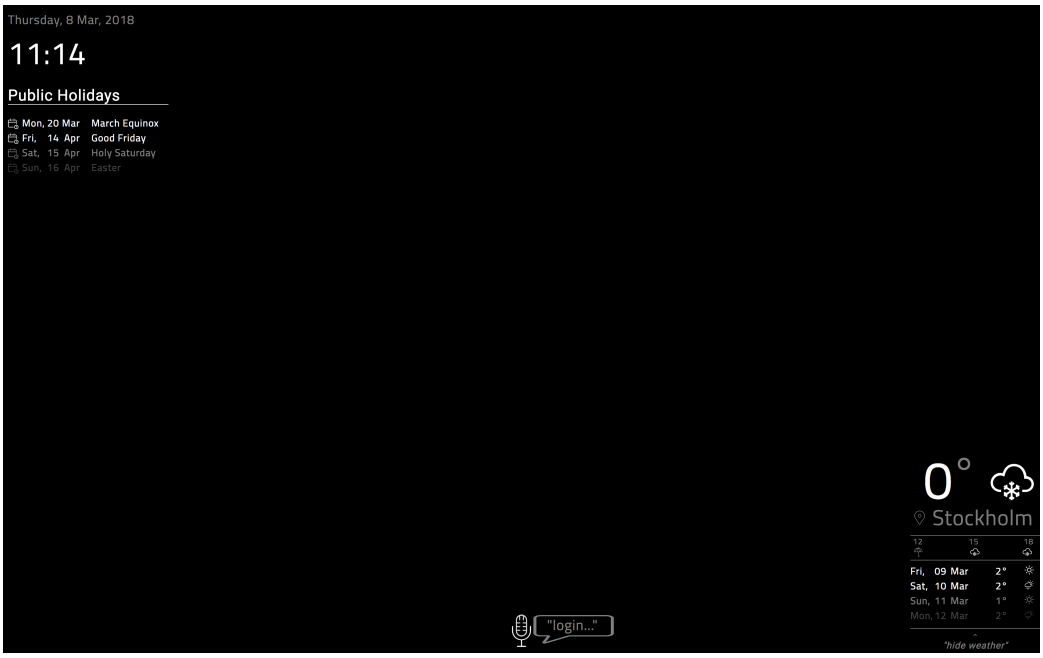

Figure D.5: The Weather component extended in default mode

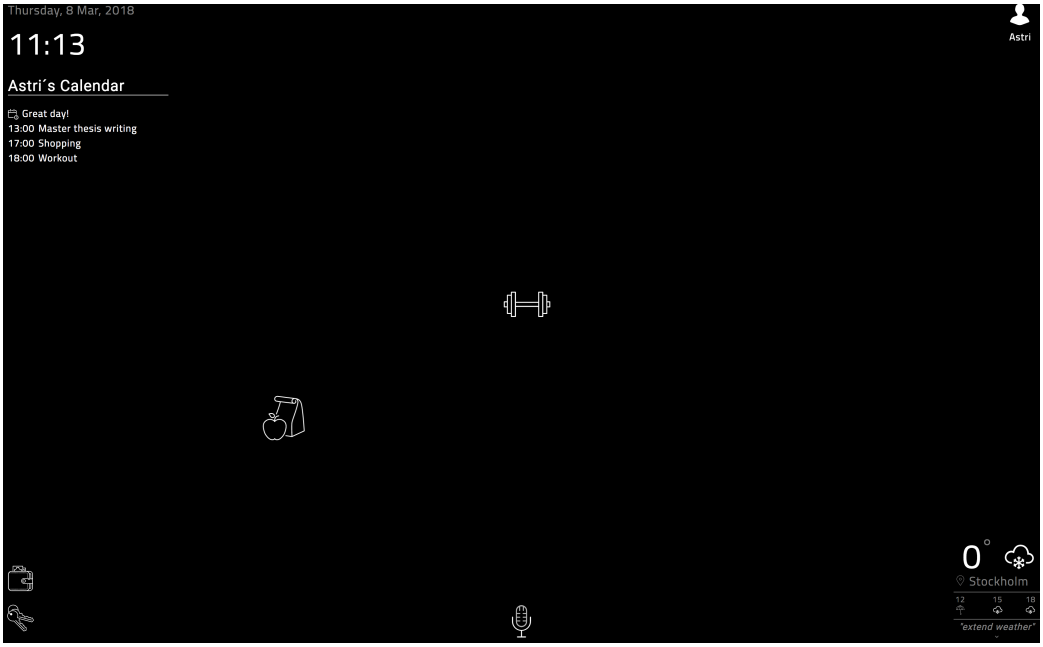

Figure D.6: The Reminders appearing in the personal state

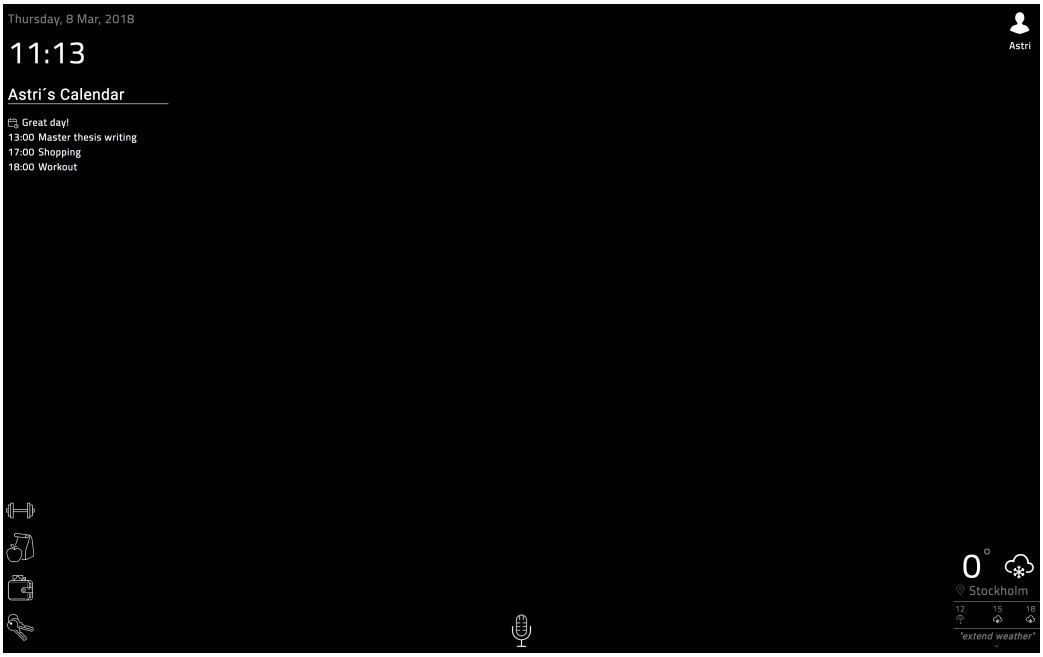

Figure D.7: The Reminders positioned at its final position

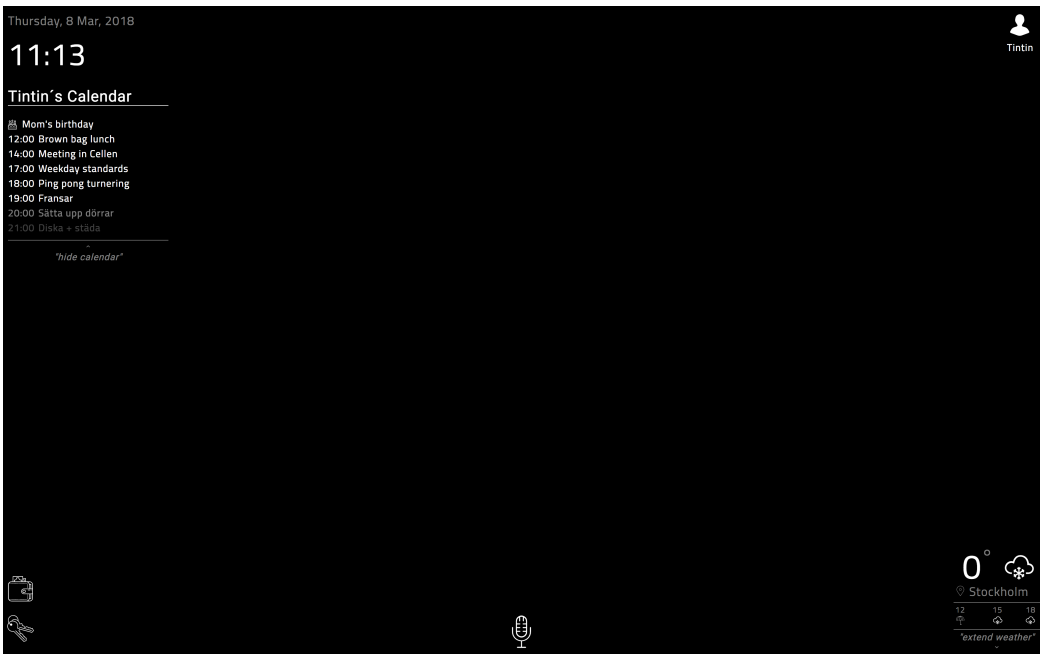

Figure D.8: The calendar in extended mode in personal state

E

Hi-fi, Final prototype

Figure E.1: The Smart Mirror in its idle state.

Figure E.2: The Smart Mirror in its default state.

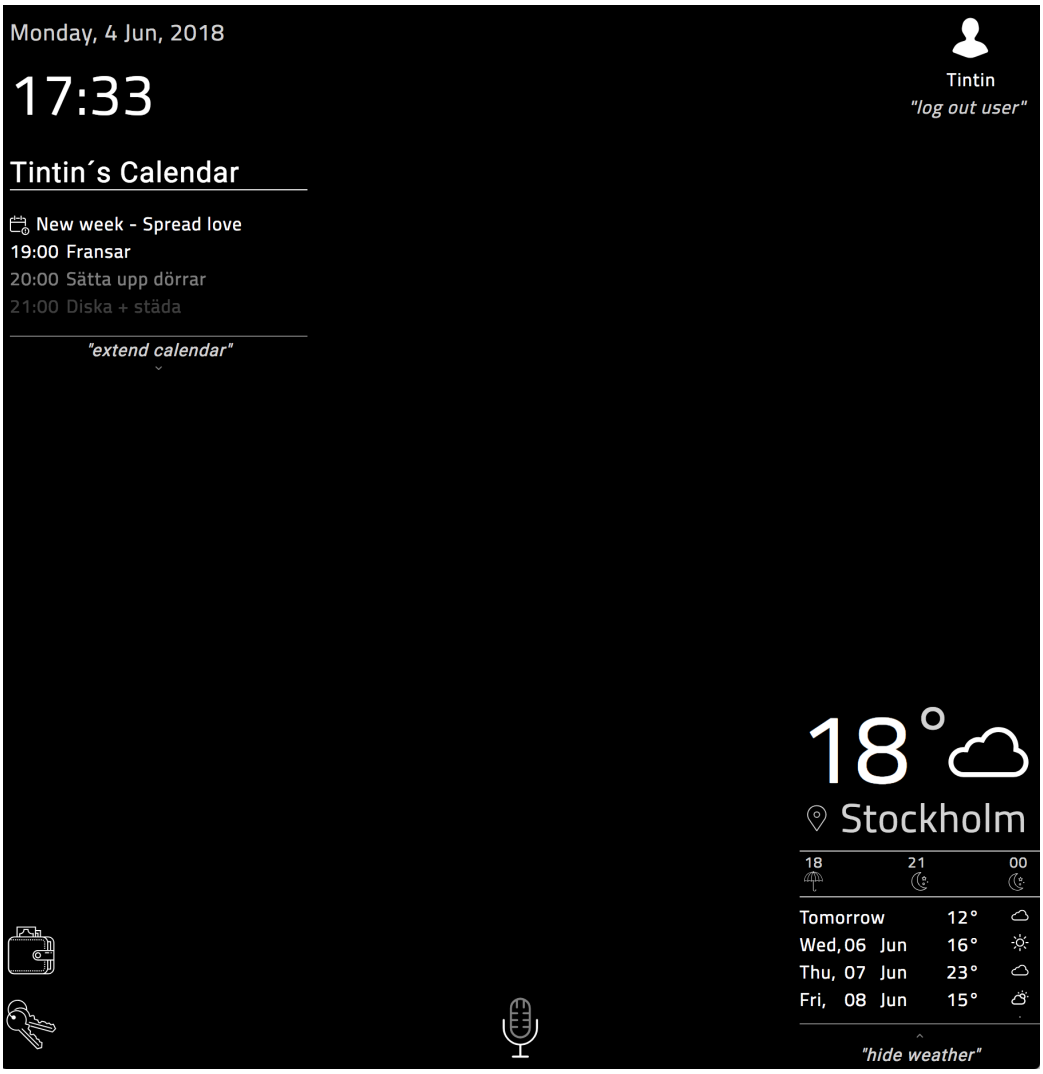

Figure E.3: The Smart Mirror in its personal state, loged in user: Tintin.

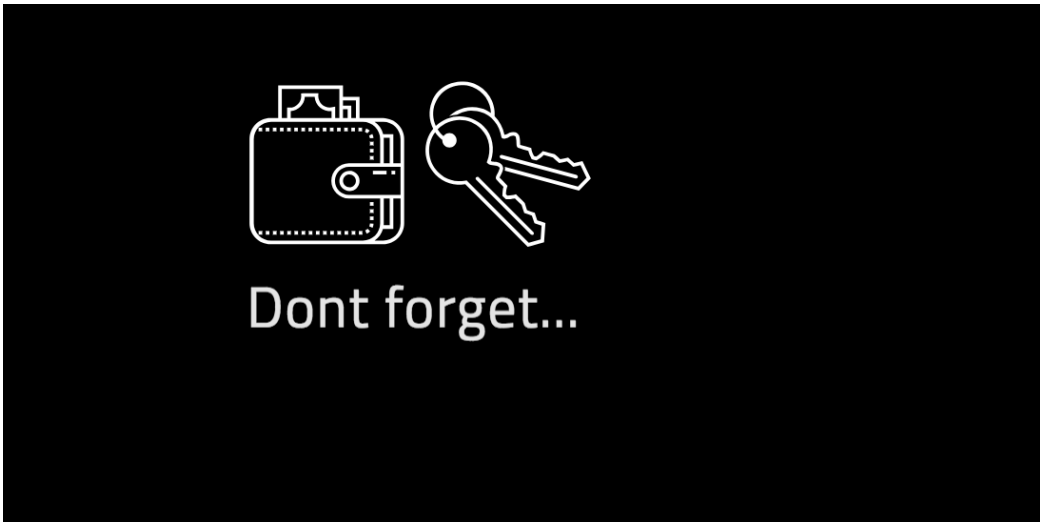

Figure E.4: The reminders appearing in the center of the mirror, going to the bottom left corner.

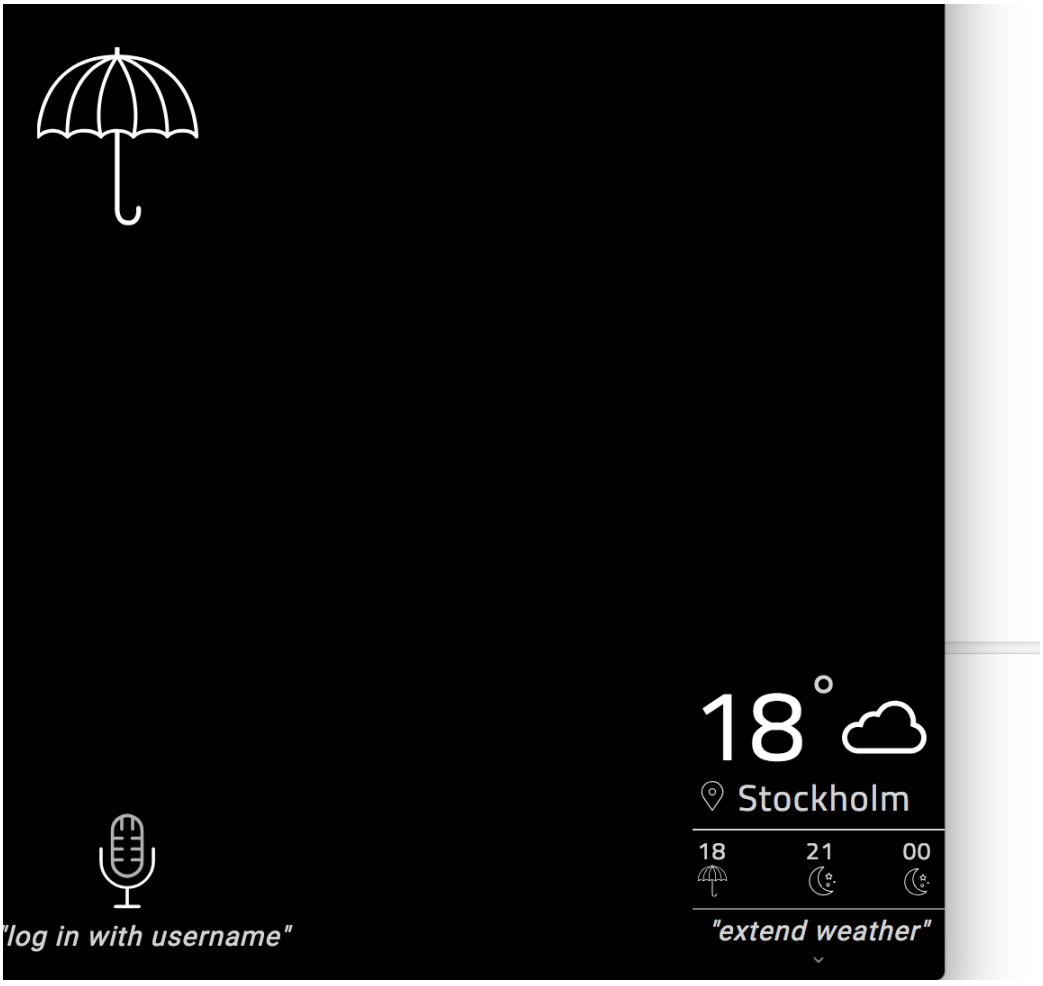

Figure E.5: The umbrella from the weather component, appearing in the center of the mirror and going to the bottom right corner to the dedicated time slot.