Smart Homes: Design & Development of an Application From a User Centered Perspective

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Smart Homes: Design & Development of an Application From a User Centered Perspective

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Abstract

With the growing development and general interest of smart living, made possible through Internet-of-Things, a need for the exploration and studies of how smart homes can be made more accessible has been increasingly more evident. This master's thesis examines how the interaction with smart home technology can be improved via high accessibility and usability, regardless of any end-users technical expertise. To do this, the thesis explores what kinds of expectations the users may have both on the design of such a system and what kind of functionality they value the most. To further the potential of this kind of design, the different ways of how information and functionality should be presented are also explored. This is done by first evaluating and performing usability testing on an existing system for controlling a smart home. The results of this evaluation are then discussed and analysed in order to lay the basis of the coming design phase, an iterative design process, which is employed in order to develop both Lo-Fi and Hi-Fi versions of a prototype for controlling a smart home. This prototype is then evaluated and user-tested, to gain further data regarding how it compares to the original system and as a design alternative when interacting with smart homes. This resulted in a Hi-Fi prototype that shows improvements in accessibility and usability in comparison to the old system, and a general appreciation from the test participants regarding the design and features within the prototype.

Keywords: Smart Homes, Internet-of-Things, Usability, Usability Evaluation, Iterative Design, Prototyping

Sammanfattning

Med den växande utvecklingen och generella intresset för smarta boenden, som har gjorts tillgängligt med hjälp av Internet-of-Things, har även ett behov av att undersöka och studera hur smarta hem kan göras mer tillgängliga blivit allt mer tydligt. Det här examensarbetet kommer undersöka hur interaktionen med smart hem-teknologi kan förbättras med hjälp av hög tillgänglighet och användbarhet, oavsett hur hög teknisk kompetens en slutanvändare har. För att undersöka detta kommer arbetet utforska vilka typer of förväntningar användarna har på designen för ett sådant system, samt vilka funktioner och funktionalitet som har högst efterfrågan. För att vidare förbättra en sån här typ av design utforskades även hur man på olika sätt bör presentera olika typer av information och funktionalitet i designen. Detta gjordes genom att först utvärdera och genomföra användartester på ett existerande system som används för att styra ett smart hem. Resultaten av detta användes sedan som underlag för diskussion och analys som användes för att lägga grunden för kommande designfas. I denna designfas applicerades en iterativ designprocess för att utveckla både Lo-Fi- och Hi-Fi-versioner av en prototyp för att kontrollera ett smart hem. Denna prototyp utvärderades och användartestades sedan för att få resultat kring hur den stod sig mot det ursprungliga systemet och som ett eget design alternativ för att interagera med smarta hem. Resultatet av detta blev en Hi-Fi prototyp som visar framsteg i tillgänglighet och användbarhet i förhållande till det ursprunliga systemet. Testdeltagarna visade även en generell uppskattning för den nya designen och funktionaliteten i den utvecklade prototypen.

Nyckelord: Smarta Hem, Internet-of-Things, Användbarhet, Användbarhetsutvärdering, Iterativ Design, Prototypande

Acknowledgements

First of, we would like to thank our supervisor Dr. Günter Alce for his time and invaluable support during this entire project. We would also like to thank our supervisor at Compare-IT, Igor Miskovic, for all the essential feedback and support during the work process that have helped to guide us during this semester. We are also incredible grateful for the overall reception and for the opportunities given by the entire team at Compare-IT during this master's thesis. Finally we would like to thank all the test participants who have been a part of our testing as you have made this entire project possible.

Contents

Chapter 1
Introduction

The following section will present some background along with the purpose & goal for this entire master's thesis. The limitations & scope as well as the related work for this project will also be mentioned and discussed.

1.1 Background

In recent times the digitalization movement has found its way in to the housing industry which has, compared to numerous other industries and business areas, been quite slow to embrace the full potential of the concept of digitalization. As a result of this both regular residents and the housing companies has now started to show increased interest in the concept of *Smart Homes*.

Smart Homes is the concept of using different kinds of devices in the home that are connected over a network to enable the residents to control and observe these linked devices via an application in for example their phone. A smart home enables automation of all the connected devices and gives the user an easy way of getting a quick overview of their energy consumption, security and various other areas of the home that a resident may want increased control or insight about [2].

If smart homes are to continue to mature and thrive in the housing industry, accessibility and usability must be in focus during the design & development of the applications that the end user will interact with to control their smart home. Technical expertise should not impede the end user from wanting to use or be able to control their smart home.

1.1.1 Compare-IT

Compare-IT is a small technology company based in Malmö. The company was founded in 2005 and has of today around 10 employees. Compare-IT focuses on smart home solutions and has developed a ”ready-to-use” package for commercial real estates, with the idea that residents should not have to be familiar with the underlying technologies in order to make use of a smart home [7].

Compare-IT has developed a central unit that is installed in the power station called the ”Home line TM”. This product makes it possible to control various wireless products from different manufactures in the home. Apart from the wire base solution, Compare-IT also offers a wireless addition that can interact with the complementary system.

Today Compare-IT offers both a mobile- and web application solution to interact with the system. The mobile application provides the basic functions that are needed on a day-to-day basis while the web application is used for more complex, however necessary, functions. They both provide different functions for the system and are both consequently fundamental for the product. The current design of both the mobile- and web application is not adapted and shaped for the end users in mind, thus making it arduous and often frustrating for the users to perform desired tasks and configuration of their smart homes.

1.2 Purpose & Goal

This master’s thesis will investigate the significance of high accessibility and usability in any application regarding the control of smart homes. The results will then be used to design and start the implementation of a platform that caters to the broadest user base possible, regardless of the end users technical expertise.

The main goal is to:

- Develop and implement an application with the end user in focus in relation to smart homes

Research questions:

- What expectations does the end user have on the design of the application?
- What functions are desirable for the end user?
- How should information and functionality be aggregated and abstracted in an application for smart homes?
- How does the developed application compare to the existing platform?

1.3 Limitations & Scope

To decrease the scope along with the, at the time, ongoing Covid-19 pandemic some limitations has to be set to achieve a reasonable result.

- Due to the limited time of 20 weeks for this master's thesis the amount of functionalities in the end product will be reduced.
- This master's thesis is being conducted during the Covid-19 pandemic and thus various necessities has to be taken. f
- The product of Compare-IT consists of a physical product which implies that all kinds of testing has to be done in office using a demo-product.
- Being limited by this demo-product and the practical resources provided by Compare-IT the design- and implementation phase will also be confined.

1.4 Related Work

Tovesson [20] explores how Augmented Reality (AR) can be used to control different devices connected via Internet-of-Things (IoT) within a smart home. The thesis included the development of a prototype used via a mobile phone which was later evaluated in a user study. The results of these tests were then used to discuss and conclude, among other things, how AR technology compares to traditional user interfaces when controlling IoT-connected devices in a smart home. The conclusion states that AR-technology was slightly more useful than traditional user interfaces, but also that it requires a higher physical effort by the users when interacting with the devices. He also implied that even though AR-technology has come a long way, it still requires some further development as an interaction method to truly take over as a preferred method of interaction with IoT-devices. The main difference between this thesis and ours is that Tovesson explored and compared a new way of interaction in the context of smart homes, while our thesis focuses on how to achieve as high accessibility and usability for as many users as possible using a traditional user interface.

Another thesis by Bergman and Johansson [3] explores the purpose of how the User Experience (UX) is considered during the development process of IoT. The study contains a literature review and an empirical study. The results from these are then used to answer the following questions:

- How is UX taken into consideration during the development process of IoT?
- How is data-driven development from a UX perspective applied within IoT?
- Are there any specific UX challenges that need to be considered during the development process for IoT?

The conclusion from the following questions are that there is a higher focus on UX in the development in product companies unlike consulting companies which also adopted data-driven methodologies to a lesser extent than the product companies. The authors came to

the conclusion that, when looking into the dependencies on other systems, it is hard to solve when it comes to UX for IoT. They state that if, for example, the IoT system is dependent on inaccurate systems, that this will have a negative impact on the UX. The solution is that standardisation and close collaboration between companies are essential for an adequate UX.

From these three following questions the last one is especially related to our work in which we focused the entire development phase to achieve a satisfactory UX and considered many UX challenges along the way.

Chapter 2
Theory

This chapter will describe the different theories that will be used in this thesis.

2.1 Internet-of-Things

IoT can be thought of as the networked interconnection of everyday objects. IoT has made it possible to integrate common objects for interaction via embedded systems leading to larger networks of systems and applications working together with human beings as well as other devices in a network [23].

2.2 Smart Homes

The idea of a Smart Home has been around for a couple of decades, as early as 1996 Smart Rooms where invented by MIT Media Lab [8]. Since then a lot of work and research have been made on the subject.

Today the idea of a Smart Home is to incorporate comfort, security, healthcare, safety and energy conservation in a home using computers and IoT. The technology this provides offers a better life quality for the user by providing various automated tools to better control ones home. Today remote monitoring systems are used to allow the user to control their homes from a distance. Other various functions using IoT allows the user to control their home and automate assorted devices to optimise user comfort [2].

2.3 Usability

Usability can be used to describe how easy different user interfaces are to use. Usability can be be broken down into five more concrete factors, that each constitutes a core concept of usability [16] [11]:

- *Learnability* - considers how easy it is to use a design for the first time.
- *Efficiency* - measures how quickly the users can perform certain tasks with the design.
- *Memorability* - is it easy to return to a certain design after a longer absence of use and still being able to use it efficiently?
- *Errors* - considers the numbers of errors, the gravity of these errors a user makes and whether the user can recover from them or not.
- *Satisfaction* - does the design promote enjoyment when being it is being used?

2.4 Usability Evaluation

This section describes the different theories and methods related to usability evaluation that will be used in this thesis.

2.4.1 System Usability Scale

The System Usability Scale (SUS) is a tool used to gain subjective assessment regarding the usability of a certain system, developed by John Brooke in 1986. The SUS is comprised of ten statements regarding usability, with each statement having a likert scale between 1-5 where 1 is "Strongly disagree" and 5 is "Strongly agree". A likert scale is used to explore how a user agrees or disagrees with certain statements [12]. A SUS is typically answered directly after a user has used whatever system is being evaluated [4]. The SUS-score is calculated and can range from 0-100, with scores above 68 being considered as above average. The article [14] discusses and concludes that a score of 68 can be considered as a benchmark for an average experience, when evaluating SUS-scores. This benchmark is based on several previous surveys and usability studies. A SUS does not only measure ease-of-use, but also shows whether a system promotes learnability or not [19].

2.4.2 Semi Structured Interview

A semi structured interview is a procedure that is being known for its wide ranges of uses, one of them is to make the participant more prone to elaborate their answer in an interview. Using the semi-structured interview incorporates both the flexible and more theoretically driven questions. The idea is to elicitate data from the participants own experience as well as data from the existing structure of the interview conducted by the one making the research. The semi-structured interview differs from a structured interview in a way that lets the person asking the questions to be able to ask follow-up questions to retrieve more information.

A semi-structured interview allows for broad questions that should create openings for the participant to speak from their own experiences about the subject. The flow of the interview should always be well designed so that the questions asked can guide to a direction that relates to the research topic [10].

2.4.3 Test Data

Data gathered from usability tests can be divided into objective, subjective, qualitative and quantitative types of data. Objective data can be described by observed results or measures, while subjective data regards how a person perceives a certain task or what impressions they receive. Qualitative data consider why a user performs a task in a certain way, while quantitative data is a way of how well a user perform a certain task [18]. Combined, they form four types of data that can be gathered from usability testing:

- *Objective/Quantitative Data* - time for completing task, task completion
- *Objective/Qualitative Data* - what kind of clues did the test moderator provide, spontaneous comments from test person
- *Subjective/Quantitative Data* - system usability scale
- *Subjective/Qualitative Data* - post interviews with open questions

2.4.4 Usability Heuristics Evaluation

Usability Heuristics are a set of principles developed and formulated by Jakob Nielsen that can be used to evaluate the interactive design for different types of systems and products. These should be seen as guidelines rather than strict rules and can be used to gather quick and simple information regarding the usability of a certain system. The following are the 10 Usability Heuristics as formulated by Jakob Nielsen [15]:

1. **Visibility of system status** - The design should always keep users informed about what is going on, through appropriate feedback within a reasonable amount of time.
2. **Match between system and the real world** - The design should speak the users' language. Use words, phrases, and concepts familiar to the user, rather than internal jargon. Follow real-world conventions, making information appear in a natural and logical order.
3. **User control and freedom** - Users often perform actions by mistake. They need a clearly marked "emergency exit" to leave the unwanted action without having to go through an extended process.
4. **Consistency and standards** - Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform and industry conventions.
5. **Error prevention** - Good error messages are important, but the best designs carefully prevent problems from occurring in the first place. Either eliminate error-prone conditions, or check for them and present users with a confirmation option before they commit to the action.

6. **Recognition rather than recall** - Minimize the user's memory load by making elements, actions, and options visible. The user should not have to remember information from one part of the interface to another. Information required to use the design (e.g. field labels or menu items) should be visible or easily retrievable when needed.

7. **Flexibility and efficiency of use** - Shortcuts — hidden from novice users — may speed up the interaction for the expert user such that the design can cater to both inexperienced and experienced users. Allow users to tailor frequent actions.

8. **Aesthetic and minimalist design** - Interfaces should not contain information which is irrelevant or rarely needed. Every extra unit of information in an interface competes with the relevant units of information and diminishes their relative visibility.

9. **Help users recognise, diagnose, and recover from errors** - Error messages should be expressed in plain language (no error codes) and should precisely indicate the problem as well as constructively suggest a solution.

10. **Help and documentation** - It's best if the system doesn't need any additional explanation. However, it may be necessary to provide documentation to help users understand how to complete their tasks.

2.5 Design Process

This section describes the different theories and methods related to the design process in this thesis.

2.5.1 Iterative Design Process

An iterative design process is a way of through multiple versions of the same design, steadily receive feedback and improve the design by analysing and understanding this feedback. This is done by involving potential end users in each iteration, letting them test the design and then provide any feedback or comments that they may have. By then acting on this information, the design can be improved in the end of each iteration and the process can then be repeated by again having potential end users test and give feedback on the new version. This gradually leads to the design having less and less usability problems, the more iterations it goes through [17]. The process is illustrated in Figure 2.1 below.

2.5.2 Low Fidelity Prototype

Low Fidelity prototype (Lo-Fi) is a tool to produce quick and cheap prototypes early on in the design phase. These prototypes are usually made with pen and paper and can be seen as rough sketches of the potential final product where they differ in interaction style, visual apperance and level of detail. Lo-Fi prototyping can help test design ideas without spending to much time and money. Making a Lo-Fi prototype, which is usually a quick process, leaves more time to iterate between usability tests. [22]

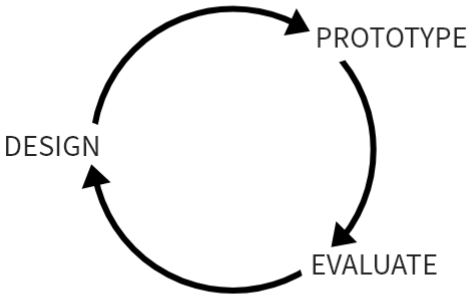


Figure 2.1: Iterative Design Process

2.5.3 High Fidelity Prototype

In contrast to a Lo-Fi prototype, a High Fidelity (Hi-Fi) prototype is designed using computer software and allow for more realistic interactions with the potential design and is also more visually realistic in how the final design will look. Hi-Fi prototypes require more time and thus cost more to develop than Lo-Fi prototypes, and are typically used later on in the design process when it is required to get realistic feedback on the entire design [21].

2.5.4 Wizard of Oz

The method Wizard of Oz is a way of simulating and emulating certain system features or providing feedback of certain user input during a design process. During the design process it is more than often crucial to receive quick feedback early on, even when the prototype or design lacks substantially parts of the end functionality or features. This is where the Wizard of Oz technique allows the designers and engineers to test the prototypes as if these missing features or functions actually were in place. During prototype testing with Wizard of Oz, the missing functionality or feedback on certain interactions are emulated by the test moderator, making it possible to receive user feedback on functionality that has been yet to be developed or implemented [9].

Chapter 3
Planning Phase

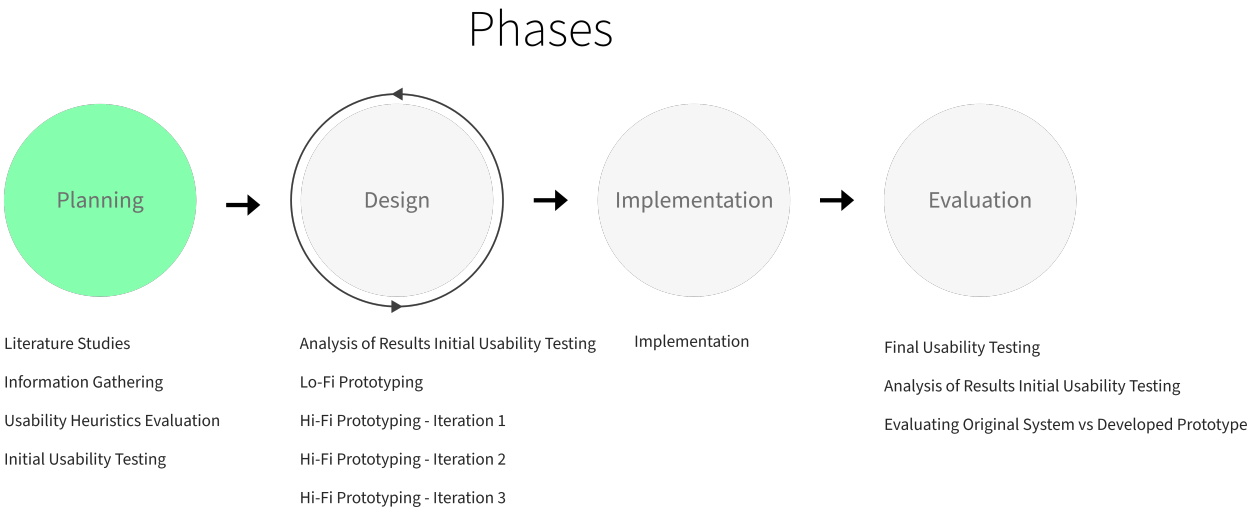


Figure 3.1: Current Phase

This chapter describes and outlines the work process in the first phase of this master's thesis which consists of initial literature studies and general information gathering. Planning and designing was also made for usability testing on the already existing solution provided by Compare-IT and concluded with the actual usability testing of said solution.

3.1 Literature Studies & Information Gathering

The planning phase started with literature studies regarding the field of smart home technologies in combination with user centered design and the different problems that may oc-

cur when developing smart home solutions. Also, to set up for the initial usability testing & evaluation and to prepare for future phases, literature concerning usability testing, general challenges about the design of mobile applications for a broad user base and user experience were studied.

One part of the information gathering was to get familiar with Compare-IT's current system for controlling a smart home. This included retrieving information from customer support in order to get a better understanding about the common questions and problems about the system. Compare-IT's system provided the underlying functionality that will be used during the future implementation phase as well as enabling initial usability testing of the current mobile application and website to gain further knowledge and information regarding existing difficulties and common requested features for smart home control.

3.1.1 Current System

This section will outline how the system provided by Compare-IT works, with a description of the mobile application and website that is used to control and configure a smart home. During this master's thesis the smart home is represented by a Demonstration wall that is located in Compare-IT's offices.

Mobile Application

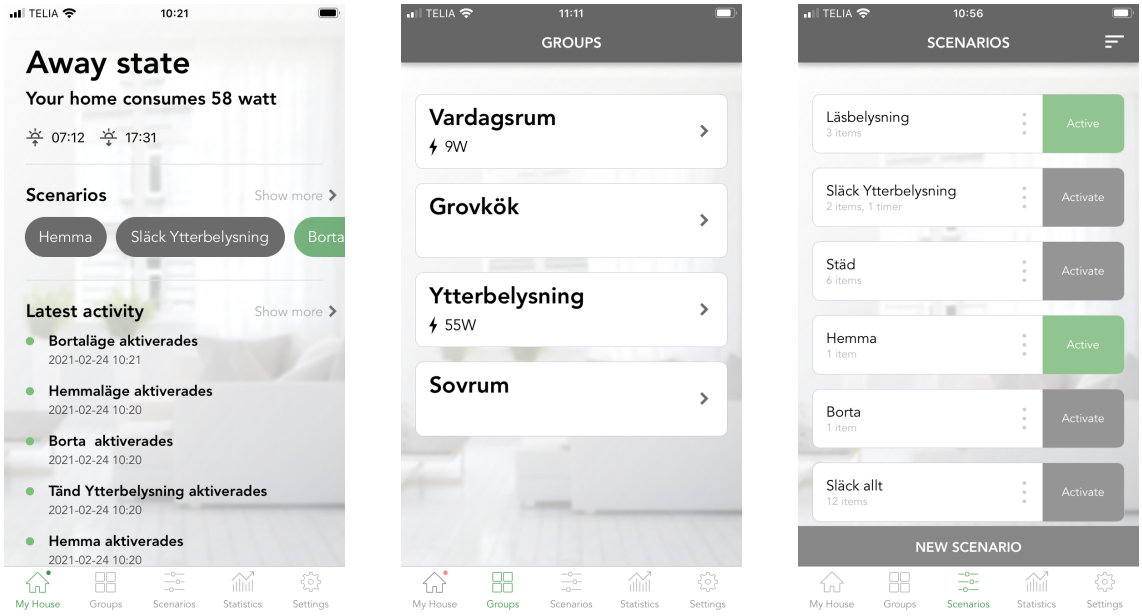
The mobile application consists of a navigation bar with five different views, that allows the user to control and interact with their smart home for common everyday activities, see Figure 3.2.

As seen in Figure 3.2a, the user can see some basic information regarding their smart home. Energy consumption, time for both sunrise and sunset, a horizontal scroll view for the different scenarios as well as latest activity is presented. The user may via the horizontal scroll view activate different scenarios directly. Depending on if the user has activated the home or away scenario, the state at the top of the screen is changed.

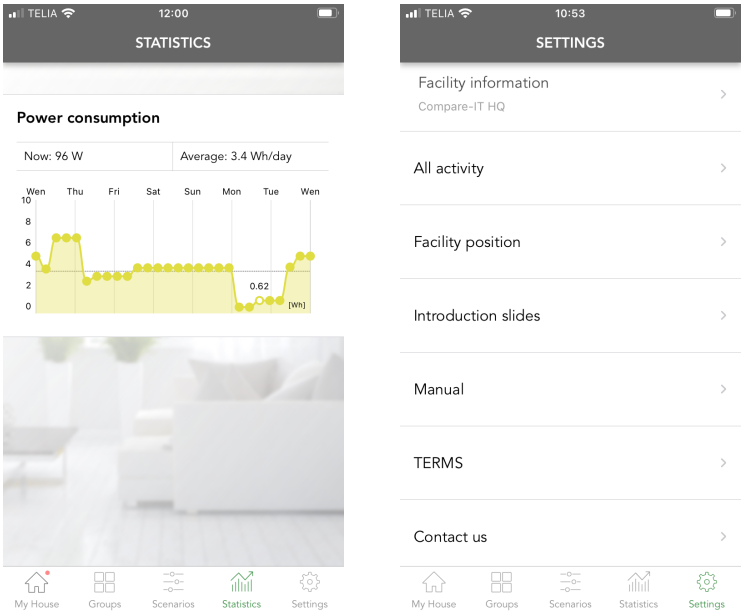
Figure 3.2b displays the view that contains the different groups in the users home. A group is a collection of different devices in a certain room within the home. For example, the group *Sovrum* (eng. bedroom) represents the different devices that the user may control within the bedroom. Figure 3.3a shows how the user can control individual devices in the group.

In Figure 3.2c the user can see a list of the different scenarios that they can control their smart home with. A scenario can control devices in multiple rooms simultaneously and enables the user to schedule the scenario to activate at a specific time. For example, the scenario *Släck allt* (eng. turn everything off) turns off all the lights within the home. Figure 3.3b shows the different options for editing a scenario. The user can add new devices by clicking ADD NEW OUTPUTS, attach a timer to the scenario and choose various levels on fade in for the scenario. The live-button allows the user to view how the scenario will play out in real time.

Figure 3.2d lets the user get a quick overview of their energy consumption, and Figure 3.2e



(a) My House **(b)** Groups **(c)** Scenarios



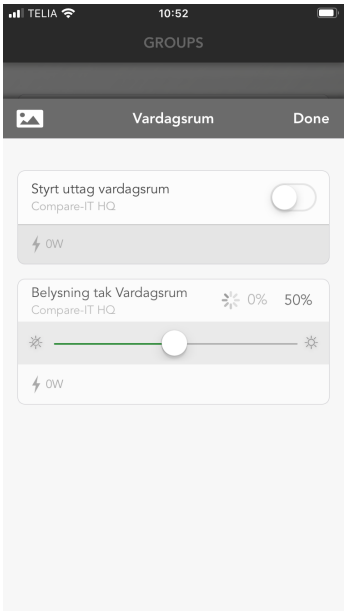
(d) Statistics **(e)** Settings

Figure 3.2: The different views in the mobile application

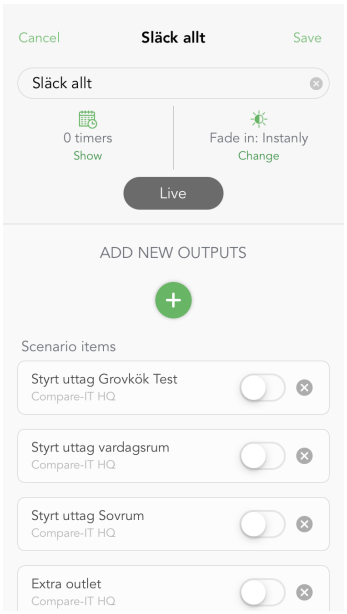
contains various options for getting more information regarding their smart house, such as a user manual, facility information etc.

Website

The website contains more information and functionality compared to the mobile application, and allows for more advanced configurations of the users smart home. The user can freely remove and add different functions to any device within the smart home, including physical buttons that are included in the system. Seeing how the website contains informa-



(a) Edit Group



(b) Edit Scenario

Figure 3.3: Edit mode of groups and scenarios respectively

tion and functionality regarding the entire system, this section will be limited to describing the different parts of the website that are most relevant to this project.

Figure 3.4 is the first page that the user sees when they log in. It contains various information about their smart home, such as system status, outside temperature, time for sunrise and sunset, energy consumption and more. However, this screen only displays information and does not offer any functionality regarding configuration of the smart home. Also to the left in figure, is a vertical navigation bar that is always visible, and contains various tabs that are grouped into different segments.

In Figure 3.5, the user can see the different groups that exists currently. In contrast to the mobile application, the user can toggle the lights within a certain group and also create new groups.

Figure 3.6 displays the view in which the users can create a new group and add the different devices that should be associated with that specific group. This view also allows for direct interaction with individual devices.

Figure 3.7 shows the various scenarios in a list view. In this view, it is possible to directly activate a certain scenario as well as a creating a new one.

Figure 3.8 shows how a user can create a new scenario. This view is similar to the create group view with the exception of the advanced settings.

Another major point interaction on the website is the tab for scheduling, seen in Figure 3.9. Here the user can schedule different devices to activate during different times, like the timer

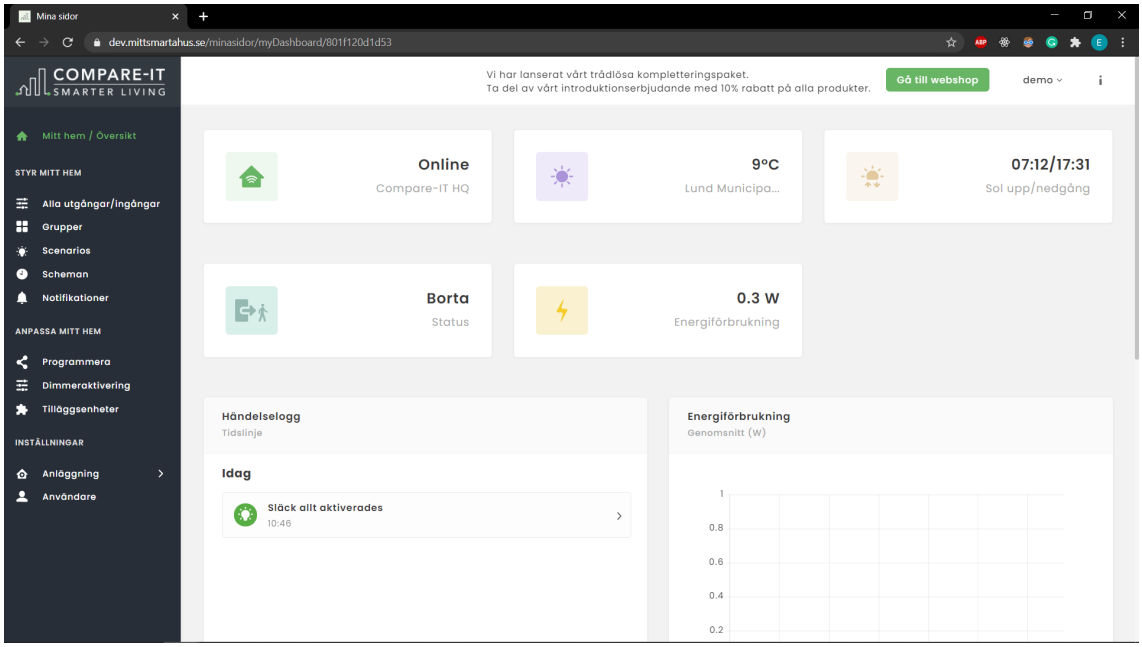


Figure 3.4: Home

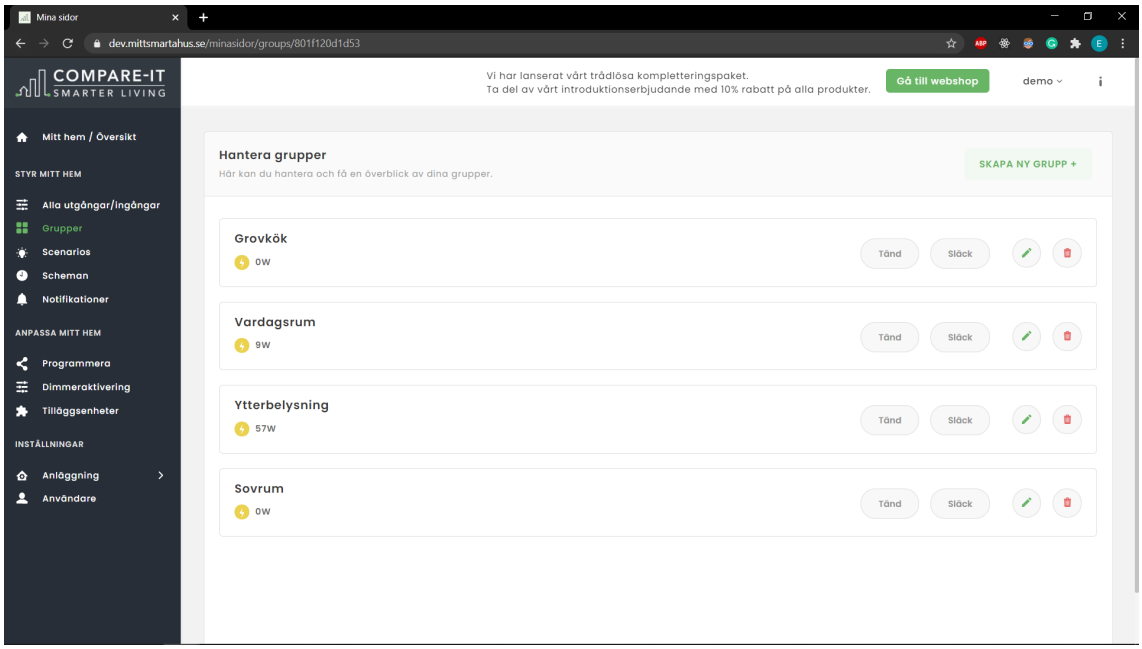


Figure 3.5: Groups

function in the mobile application. Scenarios that the user adds a timer to in the mobile application also appear here.

The Programming tab, seen in Figure 3.10, consists of a matrix which can be used to configure more advanced settings, like connecting the physical light switches to different devices. The vertical axis of the matrix is represented by objects that trigger devices like a lamp or an outlet. These devices constitutes the horizontal axis. The user can from this tab configure

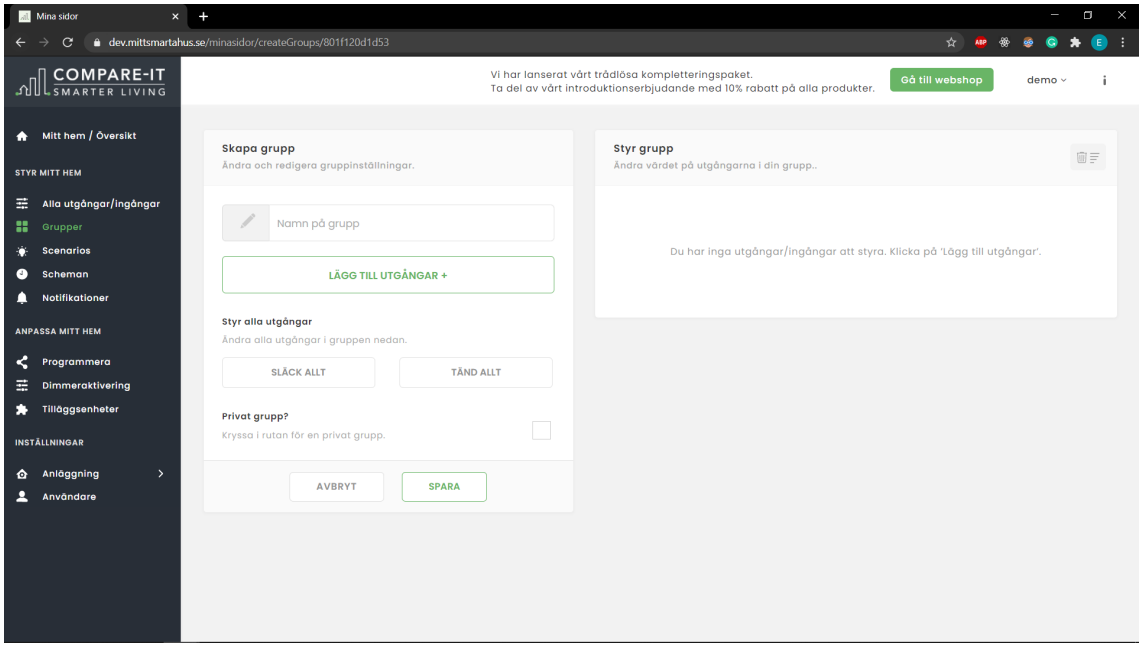


Figure 3.6: Create Groups

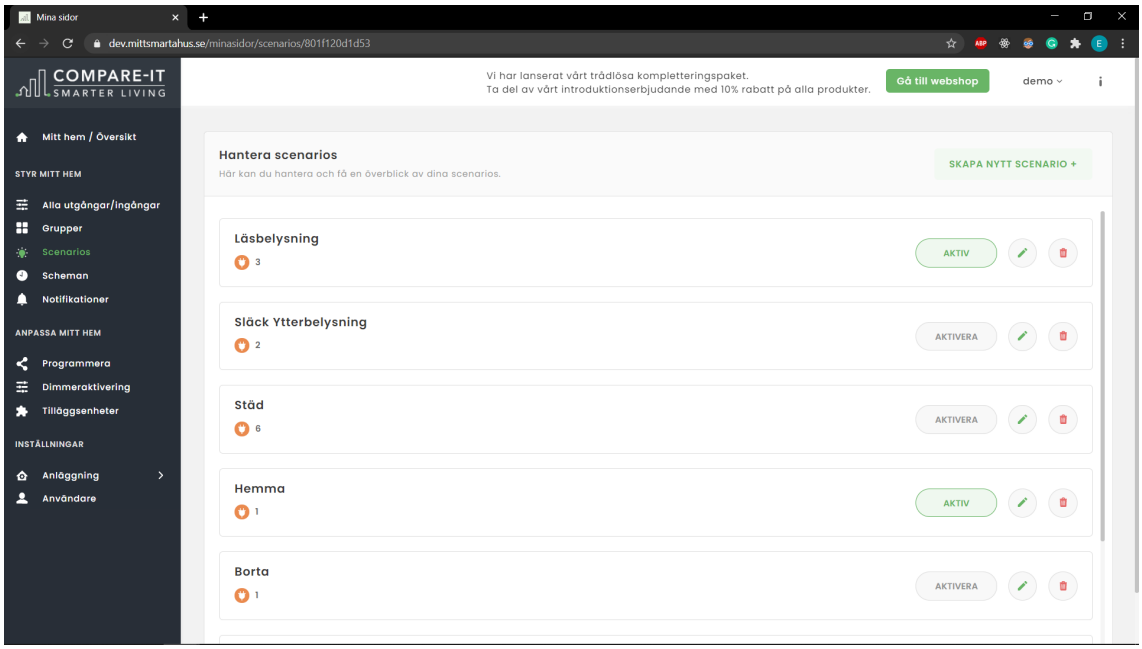


Figure 3.7: Scenarios

any desired functionality.

3.1.2 Demonstration Wall

In order to easily demonstrate how the mobile application and website can be used to control a smart home, the panel seen in Figure 3.11, which is located in Compare-IT's offices and is used to represent a smart home.

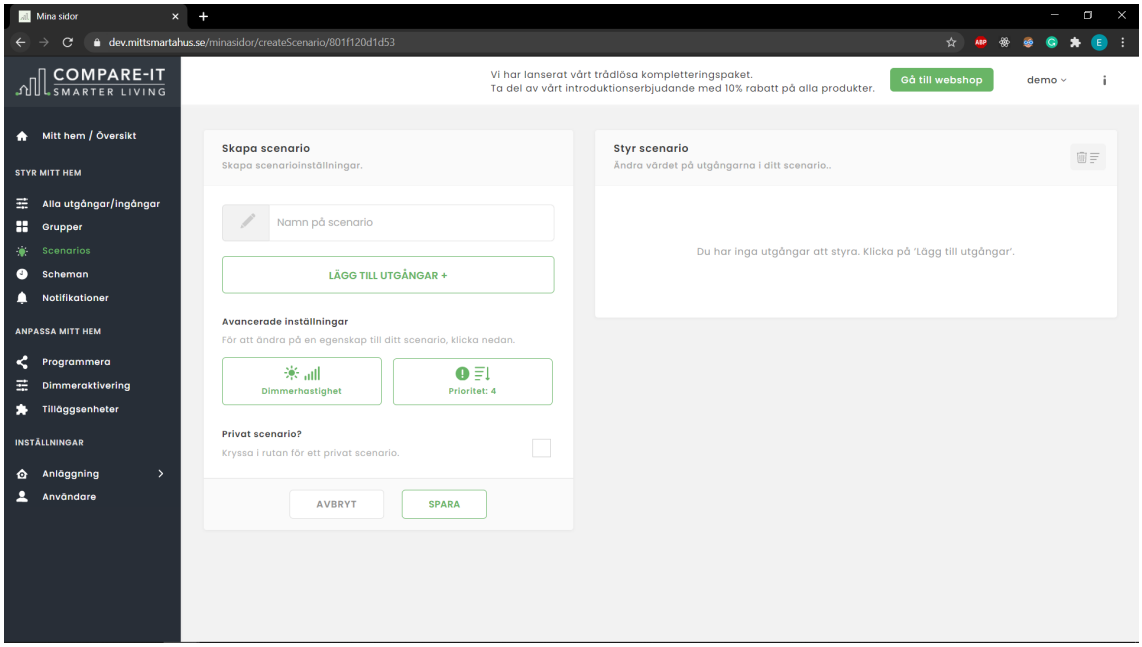


Figure 3.8: Create Scenario

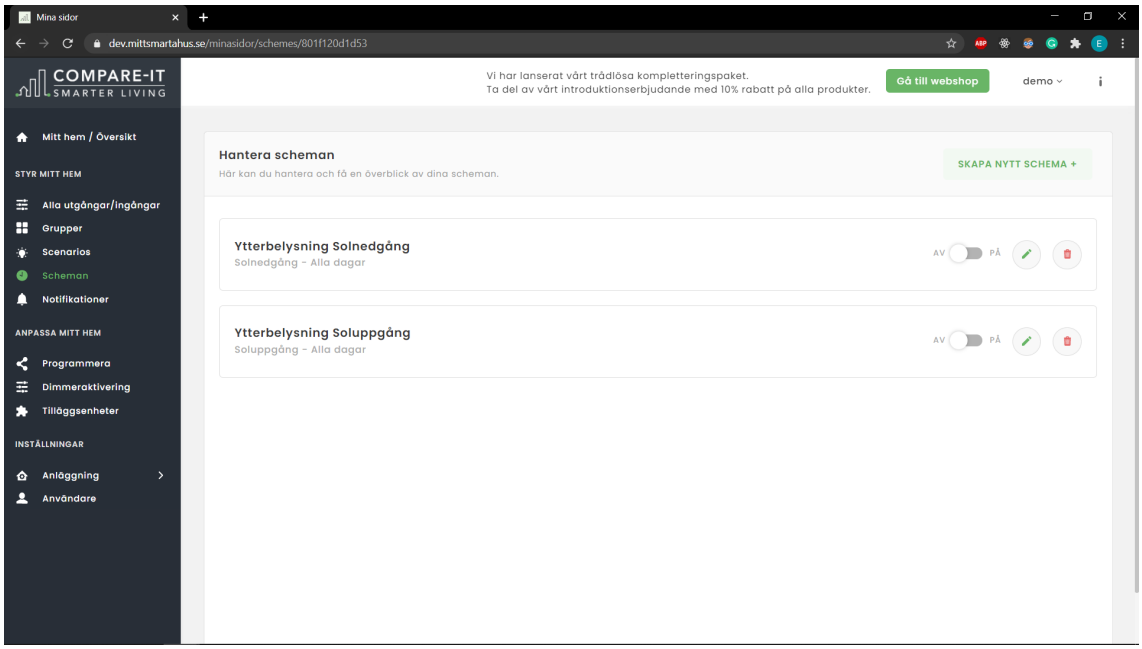


Figure 3.9: Schema

The leftmost blue part of the panel is illustrates a living room. This room contains 2 "smart" physical buttons that can be accessed and configured by the system, and 2 regular physical buttons. It also contains one light source and an outlet. The pink middle part illustrates a bedroom with the same physical buttons as the living room but with different default scenarios attached to the buttons. There is also two light sources and an outlet. The rightmost blue part of the panel illustrates a kitchen. The kitchen has the same set of buttons and light

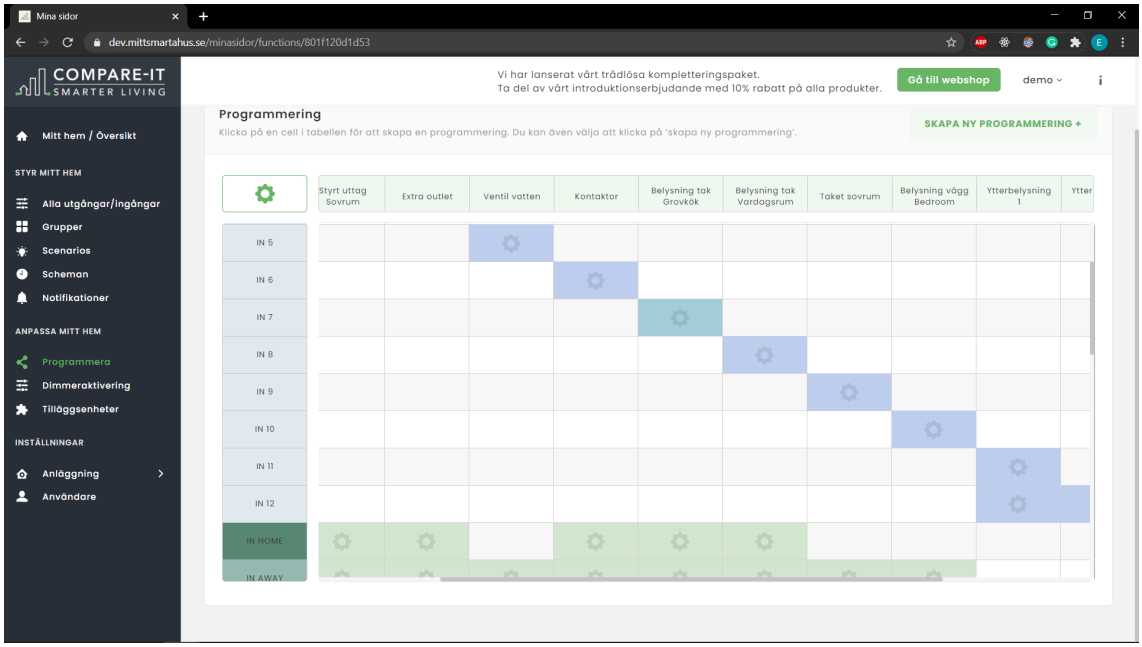


Figure 3.10: Programming

sources, but with different default scenarios attached to the buttons. Finally, the light sources on the sides of the panel is representing two exterior lights.

Figure 3.11: Demonstration Wall at Compare-IT's offices

3.2 Usability Heuristics Evaluation

An evaluation of the usability heuristics described in 2.4.4 was also conducted. This was done by discussing each principle together for both the mobile application and the website. The outcome from this yielded to the following result:

Principle 1 - Visibility of system status

When a user tries to toggle a scenario nothing happens even though the button provides feedback that it does (on Android). As of when this heuristics evaluation was performed, functionality for toggling the scenarios is not supported. This button click also triggers the latest activity view which is updated with that information. This gives the user deceptive information that some change has happened. When the user adds an item in a scenario in the mobile application, there is no feedback except that the item is added to the list of items. If this list is too long from the start, the user will not see directly if the desired item was added if they do not scroll down manually to find it.

Principle 2 - Match between system and the real world

In the app groups, for example, do not exactly fall in line with the user's language. In this case a group is meant to refer to a room (even though it is technically possible to mix groups together). Another mismatch would be the term outputs, which refers to the different devices that the user may add to a certain scenario. Other than that, a lot due to the lack luster functionality and information given in the app, the design follows this principle. For the website, with more functionality and information available, plenty of mismatches can be identified. For example inputs & outputs, where an input can be a physical button on the wall or a water leakage detector and an output is something that is controlled by the input. Furthermore, the label programming is not a very familiar concept to the majority of the users and may discourage use of this feature. Overall, the system as a whole does not fall in line with the concept of natural mapping between different components. Natural mapping is a way of making real life objects easily recognisable in different kind of user interfaces.

Principle 3 - User control and freedom

In the app, it is not possible to simply undo the activation of a scenario by clicking the scenario again. A natural way of doing this would be a simple toggle functionality, like a lamp switch in the real world. Also, the app lacks a cancel button when the user is viewing the timers for a certain scenario.

Principle 4 - Consistency and standards

One thing that does not follow this principle is the timer/scheduling functionality for scenarios. In the mobile application it is called a timer, while it is called a schedule on the website. Another issue is the fact that the UI-design for groups and scenarios is very different, even though they support similar functionality. The programming tab on the website goes against both the internal and external consistency. The way of displaying the logic between components using a matrix is not commonly used when configuring settings.

Principle 5 - Error prevention

The website contradicts this principle when the user removes a certain device configuration in the programming tab. There is no error prevention that informs the user regarding the action. This issue is magnified by the fact that it is entirely possible to remove a fire alarm or

other paramount devices just as easily as it is to remove a light source. Another issue is that, in the mobile application, it is entirely possible to remove a scenario without the user getting any sort of confirmation dialog. This is not the case however on the website, which leads to this also breaking the 4th principle regarding consistency. There is also an error prevention missing when the user clears all activity in the mobile application. Another issue regarding this principle, is that nothing prevents the user from accidentally attempting to add a timer to a scenario that is being created in the mobile application. When the user tries to do this, an error dialog is shown, informing the user that the scenario has to be created before adding any timers.

Principle 6 - Recognition rather than recall

In order for the user to see what items that are used in a scenario the user must open the scenario in edit mode. A more suitable option would be to give the user the ability to display the items directly on the scenario label.

Principle 7 - Flexibility and efficiency of use

Overall, the mobile application lacks functionality that offers the user the ability to customize the home screen etc, where they might want to put commonly used scenarios. One minor way of speeding up the interaction is the ability to swipe left on a scenario in order to remove it on the mobile application (only works on IOS). Overall, the website does not follow this principle, first of due to the lack of ability to speed up the work flow but also due to the lack of options when doing certain re-configurations of devices etc.

Principle 8 - Aesthetic and minimalist design

For the mobile application, the home view is almost covered by information regarding the latest activity, which does not provide any major information or enable the user in any way of interacting with functionality or information. The Online card in the “Home View” is something that should always be provided by the system and is therefore redundant information. Maybe just show an “Offline” Card if the system is offline. It is also not very easy to quickly get an overview of which scenarios are active at the moment, as the event log only shows when certain scenarios have been activated and when.

Principle 9 - Help users recognise, diagnose, and recover from errors

If the facility is for some reason removed on the website while a user navigates the mobile application, an error message stating the scenario does not exist anymore is shown. This does not in any way help the user regarding the fact that they need to register the facility again to use the app. When installing the product simultaneously on two devices the system crashes and the only feedback that the user gets is on the computer screen showing a log of what lines of codes that did not run. This information does not help the user recover from the problem. If the user tries to create an empty scenario an error message appears with the text “An error occurred, Please try again later” which does not provide any information to the user.

Principle 10 - Help and documentation

The mobile application currently contains a manual that only briefly explains the different concepts and functionality. The user has to navigate to settings, which might not be the most suitable place for getting help, and then open the manual and find the desired information. There is no quick and easy way of accessing information regarding the current task that the user is performing, such as a simple i-icon that provides additional help. There are no concrete step-by-step instructions that can help the user perform simple tasks, such as setting a timer on a scenario. Regarding the website, there is no FAQ or customer service available. There are only a few video tutorials explaining the different functionalities. Also, neither the mobile application or the website offers any quick help or documentation regarding the actual context of where or what the user might be doing.

3.3 Initial Usability Testing

The initial usability testing was conducted to expose concrete problems of the current system and in general problems regarding the context of smart homes. The tests were performed on test participants with different demographics to ensure a wide representation of possible user base and to cover as many functionality problems in the current system as possible.

The results yielded from the initial usability testing was then be used as a basis for future design decisions but also used as a comparison template for the final product.

3.3.1 Setup - Initial Usability Testing

This section will describe how the initial testing was prepared, outline what techniques or methods where used during the testing with motivations as to why these were chosen.

Background Questionnaire

To get information regarding demographics, technical expertise and prior exposure to smart home usage, a background questionnaire was designed. This questionnaire also included a section regarding informed consent. The following questions and statements were included:

- Age
- Gender
- I consider myself a technical person
- What kind of household do you have?
- How many people live in the household?
- Have you used a smart home product" before? (Ex. Philips Hue, Ikea wireless, Google home, Alexa ...)
  - If yes: Do you have any type of smart home product" in your home?

The entire background questionnaire can be found in the Appendice.

The background questionnaire was used to get a better understanding about how and why the test participants behaved or acted like they did during the test [18]. As described in 1.2, the goal is to design and implement a platform that is appealing and usable by the widest possible user base, regardless of technical expertise and due to this it is only logical to also include questions about demographics, living conditions and technical expertise.

Test Cases

In order to get concrete information about the different challenges that may arise when users interact with the current system, a number of test cases were formulated. The test cases were designed from our own personal initial experiences, when both gathering information and using the system. Additional information about known issues and problems about the system were acknowledged by Compare-IT's employees. Furthermore, an interview with the person in charge of the customer support regarding the current system was conducted to get a better understanding about the demands and problems that the current clients have about the system. These were the most frequent questions or problems:

1. General issues regarding first time use
2. Scheduling functionalities on different devices
3. Interacting with groups in the mobile application
4. How can the mobile application be used to reprogram functionality
5. Issues regarding the use of the programming functionality
6. What is an input/output?
7. Missing functionality in the mobile application

With this information and the prior research, the following test cases were formulated:

Test Case 1: You have just moved into your new apartment, that is outfitted with smart home technology. On the desk in front of you is a brochure with instructions and information about the system. To save some precious time, we have already downloaded the mobile application and made you an account. The login details can be found on the post-it note in front of you.
The test person registers the facility and logs in on the mobile application or the website
You can now take a few minutes to get acquainted with both the application and the website. When you feel ready, just say so.

Test Case 2: You now want to get acquainted with the mobile application to see that everything works. You want to try turning a lamp on & off in the bedroom.

Test Case 3: After you have managed to control a lamp in an individual room, you are curious about how you can turn on lamps in several different rooms at the same time. Try to turn on

lights in at least 2 rooms at the same time using the app.

Test Case 4: You notice that there is no group for "Living Room". You therefore want to create a group for "Living room" and add the units that exists in that room.

Test Case 5: In these dark winter days, you feel like it would be convenient if the lights would turn on when the sun goes down. You now want to set at least three lights to turn on at sunset every day.

Test Case 6: In the current situation, the scenario clean also turns on the exterior lighting. You find this a little unnecessary and want to edit the scenario clean so that the exterior lighting does NOT turn on when the scenario is activated. When you are done with this, test if it works by activating the scene in the application.

Test Case 7: You are interested to see if the physical button with the cleaning icon also turns on all the lights except the exterior lighting. To test this, you first want to turn off all lights using the app and then try clicking the button with the cleaning icon on the wall.
The test person clicks the button on the wall
You also see that the exterior lighting is switched on and you want to fix this, i.e. you want the physical button with the cleaning icon to turn on all lights except the exterior lighting.

Using these test cases the above issues concerning the system were thoroughly tested by covering the different common use cases, such as using the system for the first time and more complex tasks like reprogramming existing functionality.

Observations

To get objective data about the system, observations were made during the test in which the observer wrote down comments from the test participants, problems that occurred during the tests as well as general events in which could be of interest for the end analysis of the test.

Post Questionnaire

To get subjective, quantitative data about the system from the test persons, a SUS was used as a post questionnaire. For this SUS the mobile application and website were treated as one entity referred to as "the system".

Post Interview

Finally, a semi-structured interview was chosen as the form for the post interview, as it allows the retrieval of subjective, qualitative data regarding the test persons perception about the system and why they chose to do as they did.

1. Firstly, what did you think about the mobile application?
2. What did you think about the website?

3. Would you say that the application and website are well designed from a usability perspective?
4. How did it feel to work with groups in the mobile application?
5. How did it feel to work with scenarios in the mobile application?
6. Was is something that was extra hard to understand or do?
7. What did you think about the terminology?
8. What features, anything you can think of, would you use most frequently in a smart home?
9. Any final thoughts or opinions?

If a test participant had trouble expressing their thoughts regarding a certain question the interviewer could add some further context to that same question to get a more informative answer. If the interviewer thought that more information could be extracted from a certain question, a follow-up question could be asked to achieve that purpose.

3.3.2 Procedure - Initial Usability Testing

This section will describe how the Initial Usability Testing was performed practically.

Test Environment & Setup

Due to logistical issues the tests were performed at Compare-IT's offices instead of in an actual smart home environment. The panel described in 3.1.2 was instead used to emulate the interaction with a smart home. The test persons interacted with the mobile application via a provided smart phone (iPhone 6s), and the website via a laptop (15.6", Windows 10). Screen recording was active on both smart phone and laptop, and the audio was also captured. Video recording using a additional phone was also active during the testing. One of us played the part of test moderator and led the test persons through the test sessions with a pre-written script of what to say. The other one played the part of observer and measured time for each test case and documented various interesting observations, interactions by the person and other things of value during the test session.

Test Procedure

The test session started with an introduction of the involved parties and a quick tour of Compare-IT's premises and the test environment. The test participant was then asked if he or she was ready and the test session would begin. The person first filled out the background questionnaire described in 3.3.1. The test moderator then gave a brief introduction to the panel and asked the test person to think of it as their new apartment. The different test cases were performed, and if the test person had any questions, the test moderator answered these if possible without guiding the test person to much. Also, if the test moderator deemed the test person to be stuck or confused, simple hints were provided. Following the test cases, the test person answered the post questionnaire and finally the post interview, led by the test moderator.

3.3.3 Results

This section will present all the different results and observations that were acquired from the initial usability testing.

Background Questionnaire

The test included a total of eight test participants, in the age span 20-70, with the average age being 41. Of these, six were male and two were female. Four test participants considered themselves as technical persons, and the other four considered themselves as average. Four lived in an apartment, and the other four in a villa. Two lived alone, four lived with one other person in the household, one lived with two other persons in the household and one with three or more other persons in the household. The results regarding prior use of smart home products can be seen in Figure 3.12.

(a) Usage of smart home products

(b) Ownership of smart home products

Figure 3.12: Prior use and ownership of smart home products

Test Cases

The results for all the different test participants can be seen in table 3.1. The results done by test person 2 on test case 2 has been excluded due to the amount of time solving that case was far above the average time, making the total average time for the test case 2 to be unfair.

Best Case Scenario (BCS) The table below also contains the time for each task as if it were performed by a user with complete knowledge of the system and all the required steps for each task.

Table 3.1: Results for the different test cases. All the time values are in the format mm:ss.

Test Case	Successes	Failures	Avg Time - Success	Avg Time - Fail	BCS Time
1	8	0	03:32	-	00:50
2	6	1	01:00	02:44	00:05
3	8	0	01:29	-	00:04
4	4	4	03:33	01:35	00:26
5	6	2	02:42	02:33	00:21
6	8	0	01:40	-	00:14
7	5	3	05:43	-	00:28

Observations

Test Case 1 - Four of the test participants used the website to register the facility, while the other four used the mobile application. Two of test participants commented that they were unsure of what a MAC-id is.

Test Case 2 - Six of the test participants had no problems completing this test case. However, one test participant turned on and off two light sources instead of just the one. Another test participant had trouble finding the right menu to complete this test case and seemed to believe that the home state (i.e. home scenario activated) was required to be active to interact with the devices in the home.

Test Case 3 - Three test participants opted to create a new scenario, added various devices and then activated the newly created scenario. Otherwise, the test participants used the already existing scenarios to complete the test case.

Test Case 4 - Four of the test participants created a new scenario instead of creating a new group.

Test Case 5 - Six of the test participants encountered either minor or major problems. Those problems could either be that something was done in the wrong order, or that a key piece of functionality that was required for the test case to be completed was missed.

Test Case 6 - Four of the test participants chose to completely remove the two lights from the scenario while the other four adjusted the dimmer of said lights to zero.

Test Case 7 - Overall the test participants seemed uncertain of where to begin solving this test case. This often resulted in the test participants, seemingly at random, clicking around the website searching for relevant features or information that could help them solve the problem. More than often, the test moderator had to provide clues of where this particular problem had to be solved.

SUS-questionnaire

The results from the SUS-questionnaire after the test cases can be seen in Figure 3.13. The score was calculated with the method described in [19]. The average final SUS-score was calculated to 42, which can be compared to the benchmark value of 68 for an average experience of using a system.

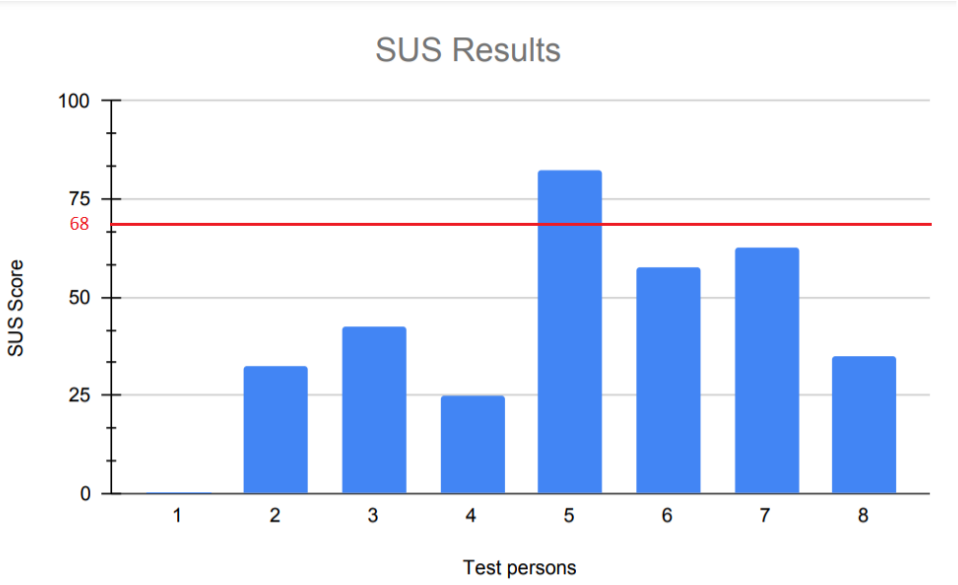


Figure 3.13: SUS Results for the original system. The red line indicates the benchmark value for an average experience

Post Interview

For each of the questions during the post interview, the most common answers from all the participants were compiled and the following results were generated:

1. *Firstly, what did you think about the mobile application?*

   Five test participants expressed a general lack of functionality in the mobile application. All of the test participants had some mixed opinions about whether the app is satisfactory or not.

2. *What did you think about the website?*

   Overall cumbersome. Hard to understand the terminology. More technical persons commented that they thought that less technical persons might find it troublesome to use some parts of the website.

3. *Would you say that the application and website are well designed from a usability perspective?*

   Six of the eight test participants did not think that it were well designed from a usability perspective. The test participants who gave more positive comments also commented that they think that people with less technical expertise would require some more elaborated introduction, support or more time to get acquainted with the system.

4. *How did it feel to work with groups in the mobile application?*

   Four of the test participants find the lack of functionality to create a group a problem. Three test participants found it difficult to fully understand the meaning of a group.

5. *How did it feel to work with scenarios in the mobile application?*

   Four of the test participants found the lack of functionality to toggle scenarios a problem. Two test participants thought the functionality regarding timers to be unnecessarily complicated. Four test participants commented that they do not feel confident about what they are doing and that they require time to get familiar with the different functions.

6. *Was there something that was extra hard to understand or do?*

   All the participants found the test case with reprogramming the button to be particularly difficult.

7. *What did you think about the terminology?*

   Inputs/outputs were a reoccurring problem. Three test participants commented that it might be a good idea to reflect further about groups as it is primarily used to control or configure the devices within a specific room.

8. *What features, anything you can think of, would you use most frequently in a smart home?*

   All of the test participants expressed the desire to effortlessly be able to turn off everything when they leave the household. Otherwise were functionality regarding scheduling different light sources easily also a desirable functionality. Automation of scenarios were overall frequent comments.

9. *Any final thoughts or opinions?*

   One of the most common comments where that everything should be able to do using only the application and that this should be easy to use. A user should always know what they are doing and basic functionality should be straightforward.

Chapter 4
Design Phase

This chapter will include a initial analysis of the results that were received from the tests on the initial system and descriptions of the following design processes that are based on the findings from said analysis.

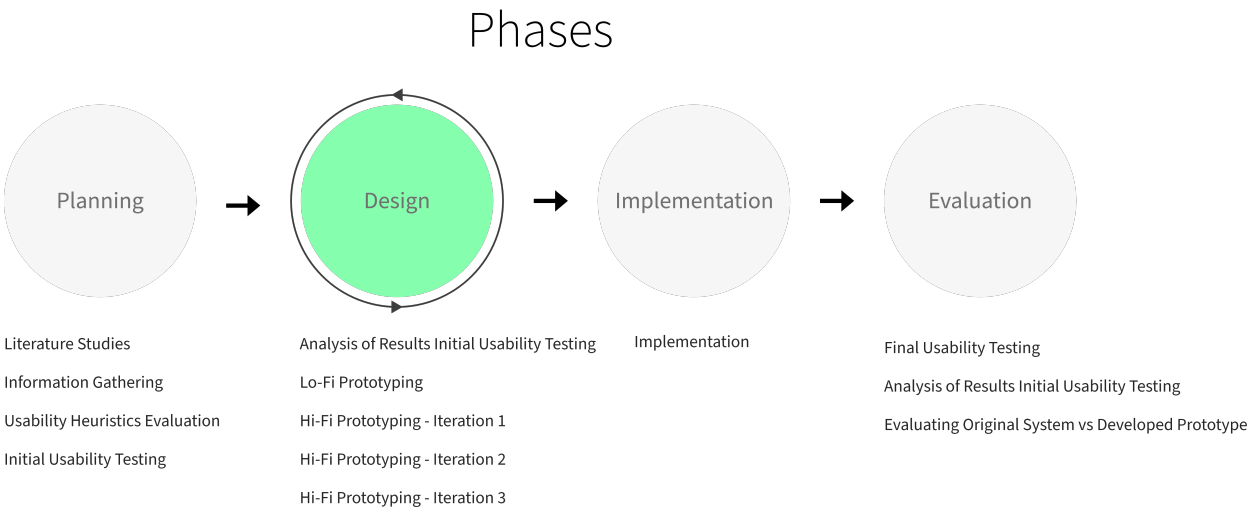


Figure 4.1: Current Phase

4.1 Analysis of Results Initial Usability Testing

In the following section, the problems and central features that have been identified from the test results, usability heuristics evaluation and literature, will be discussed and analysed to establish the foundation of the design phase.

4.1.1 Onboarding

One evident problematic factor for most applications that will be used by an end user is how you introduce them to the system for the first time, in the best way possible. It is essential to get the user familiarised with the application as quickly as possible whilst making sure that the user is encountering the least amount of problems [5]. The results from Test Case 1, which tested the onboarding process, shows that the variation between the different test participants did not differ substantially regarding the time it took to finish the test case. The fastest and slowest times are still close to the average time which shows a general understanding for the test case.

With the lack of the users opinions about the test case from the post interviews together with the fact that no clues had to be given by the test moderator we can conclude that the onboarding process as of today poses no major complications for the user. One notable piece of information to add is that this test scenario did not include the whole onboarding process of the application since it did not include any downloading and registration of the application. This because we believe that these steps do not test the users ability to acquaint themselves with a smart home application and is also regarded as a standard process in an onboarding process of any application that involves registration of an account.

4.1.2 Groups

From the results it can be proven that this part of the application presents quite the challenge for the user. Even though Test Case 2 had a low average time there was not a 100% success rate among the test participants which may indicate difficulty understanding the concept of a group. Furthermore, Test Case 4 is where the success to failure rate is at its lowest for all the test cases with half of the test participants failing the test case. Jeffrey Rubin suggests that the success rate should exceed 70% to be considered a reasonable balance between the test case being too demanding or too lax, which Test Case 4 fails to do [18].

This shows that this part of the application is in great need of a change and must be in focus during the design phase. Moreover the post interview further supports the previous claim that a change is needed. Almost every test participant considered the lack of functionality considering groups in the application to be an issue. They expressed a need of an "Add group button" in the application to increase the significance of the groups section. In addition to this many found an overall confusion of what a group really is. A lack of understanding the term group may be based on the fact that it is not a good match between the system and the real world, see section 3.2 Principle 2. The term group is a universal term, that in a smart home perspective do not provide the user with enough information about what type of functionality that can be done.

4.1.3 Scenarios

One common answer from the post interview regarding what functionality a user would use most frequently in a smart home was the ability to create different scenarios. This indicates that this part of the system has to be well designed considering the high demand. Despite

this, many users found the scenario confusing and the information about this type of feature to be incomplete. A few users suggested a small information button next to each scenario while others suggested more feedback while interacting with the different type of scenarios. All the users in the test tried at some point to click the already active scenario expecting them to work as a toggle switch where you toggle on and off. This was also a frequent comment during the post interviews. Another thing that is worth considering, is that the current design regarding scenarios contradicts almost all the principles mentioned in section 2.4.4, and thus it is clearly a matter of importance when moving forward in the design phase as to how scenarios should be handled and interacted with.

4.1.4 Time Scheduling

From the observations regarding Test Case 5, it is obvious that the functionality regarding scheduling scenarios in an easy way is not by any means achieved with the current solution. The present solution also currently allows for two different ways (timer in the mobile application versus schedule on the website) of achieving the same result regarding the scheduling of scenarios. This result, in conjunction with all the test participants expressing this kind of functionality as core in the post interview, suggests that the functionality should be easily interacted with and a system supporting end users to control a smart home should definitively support it. Addressing this type of functionality or factor is also motivated by the fact that the current solution breaks the 4th principle of usability heuristics, see section 3.2. Another issue is that the current design implies that it is fully possible to add a timer directly when creating a scenario, which is not the case. Ideally, the button for adding a timer to a scenario should not be visible, when it can not be used. Due to this, time scheduling functionality also breaks the 5th principle.

4.1.5 Terminology

Both from the observations during the test session and from the answers during the post interview, it is evident that a lot of the terminology used in the current solution is not adapted with the end user in mind. Test participants that considered themselves as more technical also commented on the fact that they think that less technical persons probably will require some additional support or help in order to fully understand the system. From the usability heuristics evaluation that was performed, it is also clear that the terminology does not support any natural mapping to the real world, see section 3.2. By breaking this principle, the current design does not allow a new user to easily get familiar with the system. By not promoting familiarity, it may often lead to users not feeling a certain product particularly enjoyable to use [13].

4.1.6 General App Design

The results from both the observations and the post interviews suggest that the participants often feel unsure about what they are doing, or if something they have done actually has any effect. This fact is also supported by the findings of the usability heuristic evaluation, see section 3.2. Another more general issue with the user experience is that the user lacks

the freedom to tailor how they use certain features. For example the user can not choose freely for what scenario that should be displayed and interacted with on the home screen. Furthermore, a frequent comment during the post interview were that it must be easier and more engaging to use the system. An absence of this can result in the user being unwilling to use the application which is also reflected in the SUS score. These two results in conjunction with each other motivates that this must be of consideration during the future design phase.

4.1.7 Findings

From the previous section where the results of the initial testing were discussed and analysed, the following features, concepts and problems are to be in focus during the design phase:

- Key features from the users perspective are functionality such as automating different events, within or across certain rooms and at specific times.
- Terminology and the concepts that are essential to the users perceptions of what certain things are and how they interact with their surroundings must be clear and feel natural as to what they represent.
- The design should promote enough flexibility for the user to be able to adjust the layout of certain features such that it matches their own preferences.
- The possibility to enable more advanced re-configurations should be available, but should not be a high priority.

4.2 Prototyping

The prototyping phase consisted of one Lo-Fi iteration and three Hi-Fi iterations. The reason for including a Lo-Fi iteration in the prototyping was to get a solid foundation of the design and the users possible interaction flows to receive feedback early on in the process. Each iteration consisted of designing and testing different features, concepts and ideas that originated either from the tests on the original system, or on a prior iteration of the prototype. The testing during the prototype phase was loosely based on the test cases used previously on the original system, but with more focus on discussions and sparking new ideas.

4.2.1 Lo-Fi

To start of the Lo-Fi iteration, multiple different sketches were made using pen and paper. For each of the test cases, we designed at least 3 different alternatives as to how a user might solve the particular task at hand. In Figure 4.2 below, two different design alternatives of the new home screen can be seen. Both of the designs focuses on making the scenarios and different rooms in the system immediately accessible from the get go and provides a immediate overview of what the user can interact with in the smart home. Furthermore, switches were added to each room card with the intention to allow the user to easily toggle all the lights within a certain room directly.

By clicking on the card of a certain room, the user would then be navigated to view that contains all the different devices that are physically present in the real room and can be interacted with via the application. In Figure 4.3 a few different designs for the room specific view can be seen.

The scenarios are represented by similar cards and are either green or grey depending on if they are active or not. The scenarios can be toggled directly by clicking on their respective cards. If a scenario should be fitted with a timer a small icon appears on the card as well. By introducing this the users can easily see what scenarios are timed or not and does not have to manually enter each scenario to see a timer status. If the user should want to edit or see what a scenario contains they should be able to navigate to a scenario specific view from the home screen.

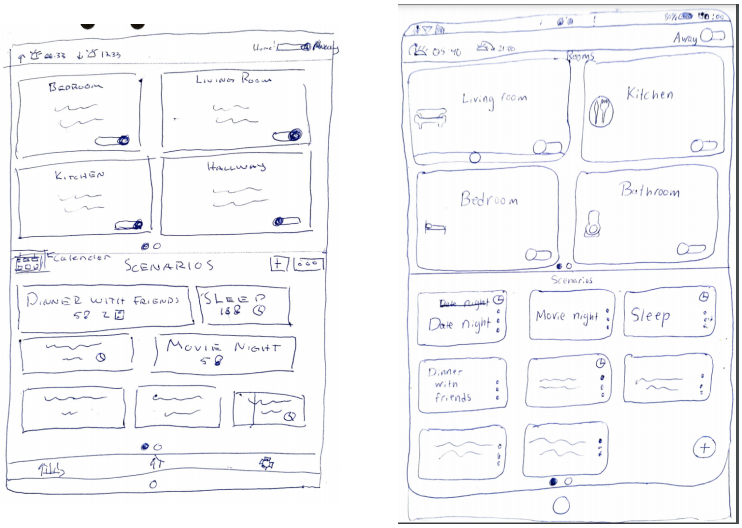
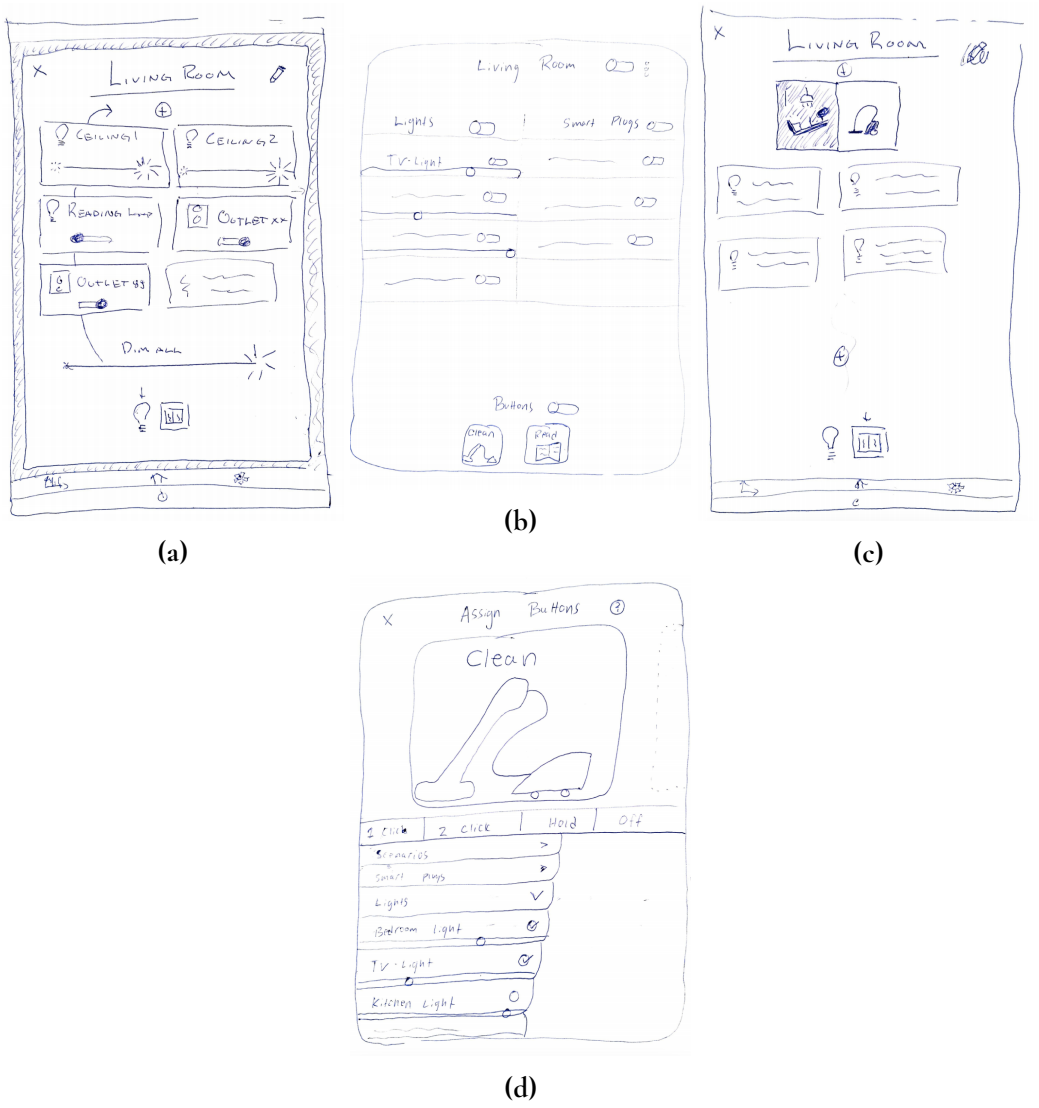


Figure 4.2: Two different sketches of the proposed new design of the home screen

The views seen in Figure 4.3a and Figure 4.3b shows two different versions of how the different devices within a room are displayed. Both the designs does however let the user directly interact and toggle individual lights within the room.

In Figure 4.3c and Figure 4.3d it is shown how the smart buttons that are available in certain rooms are included in the design. Previously these were configured and used via the Programming tab on the website of the original system, see Figure 3.10, where the user had to re-configure a matrix in order to change what a certain smart button would do. By including them in the specific room that they are physically present within the idea was to make it easier for the users to grasp where and what the certain smart button are. By clicking the buttons the user should then be able to remove or add more devices to the that certain smart button directly within the room view. Lastly, the different design ideas for the scenario view can be seen in Figure 4.4. These does not introduce any particular new features or functionality compared to original system, only slight visual layout differences.



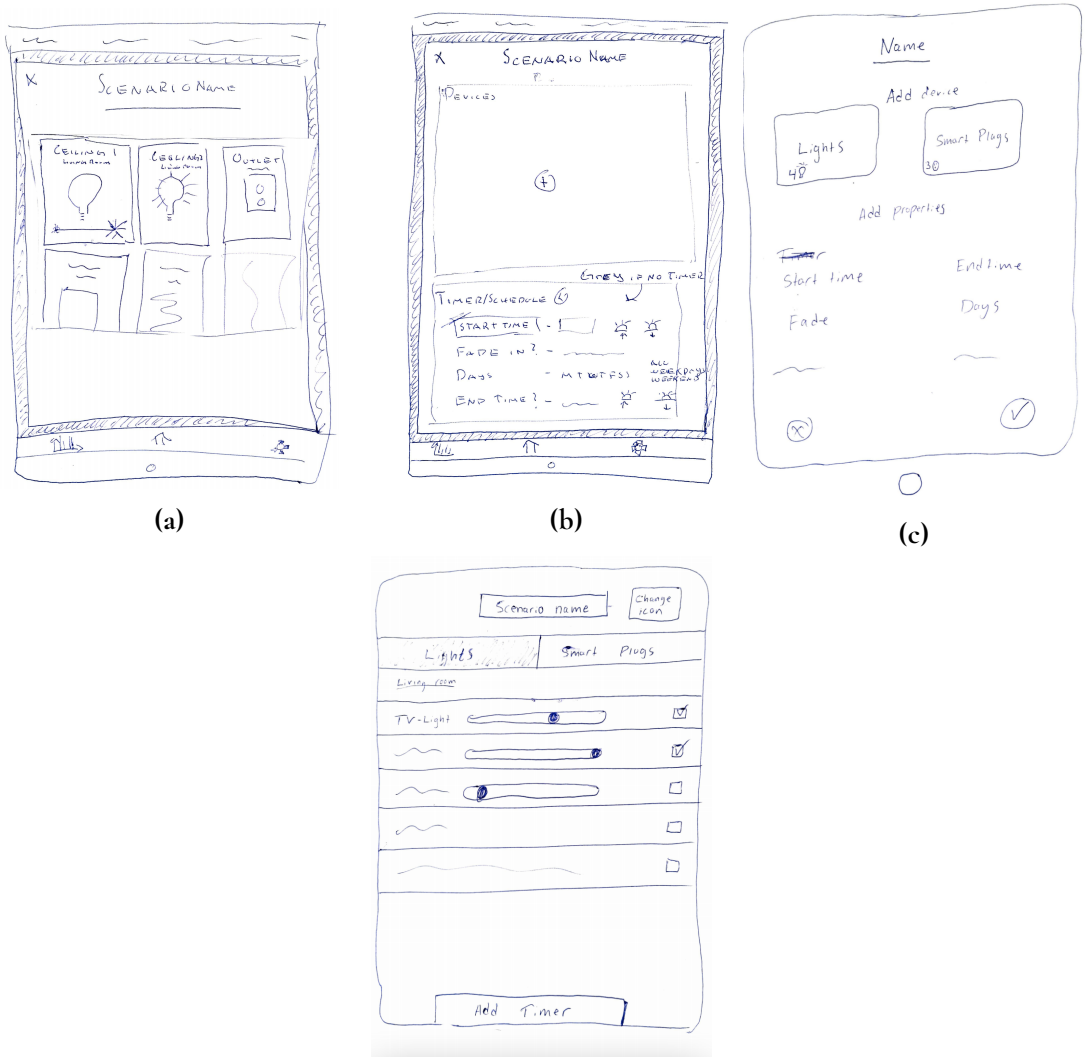
(a) (b) (c) (d)

Figure 4.3: Different sketches of how a certain room could be presented when clicked upon

A general presentation of the different designs, for which we explained the thought process behind the designs, were then presented to three different employees at Compare-IT who gave feedback on various things in these designs. This feedback was then included in the beginning of the first Hi-Fi iteration, which will be presented in the next subsection.

4.2.2 Hi-Fi

With the Lo-Fi version of the prototype done, the next step to improve the design and develop the user experience was to start working on a Hi-Fi version of the prototype. This was done using Adobe XD which is a software developed by Adobe that lets user's design and develop Hi-Fi prototypes with different animations, transitions and other features. These prototypes can also be interacted with via the corresponding mobile applications for both Android and iOS [1]. Some of the initial time during the first Hi-Fi iteration were focused on getting



(a) (b) (c)

(d)

Figure 4.4: Various designs of how a certain scenario could be portrayed

familiar with Adobe XD in order to understand its potentials and any limitations that might affect the development of the future design versions.

Hi-Fi Iteration 1

The first iteration of the Hi-Fi version of the prototype consisted of first translating the different sketches that were done during the Lo-Fi version and also including any feedback that was received from the different persons that were shown the Lo-Fi prototypes. This feedback resulted in the following:

- Removal of the navigation bar at the bottom of the screen.
- Introduction of infographics-tutorial on the home screen when first time use.

- Dimmable lights represented by wider buttons to accommodate sufficient space for slider.
- More spacious list when adding devices to either room or scenario.
- Always filter devices via where they are located physically (i.e. the actual rooms).
- Minimum button and text values being set.

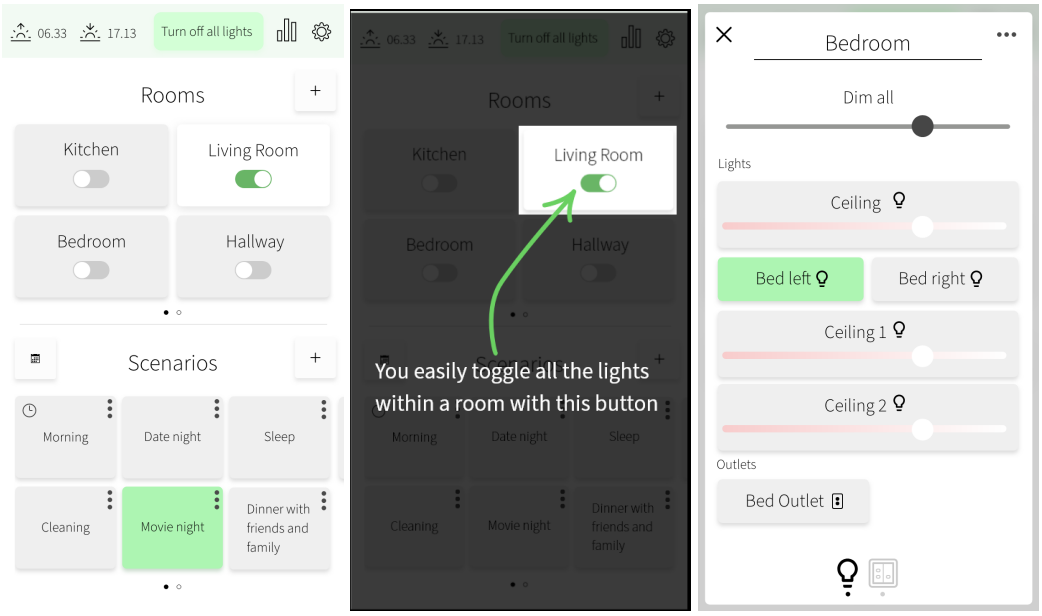
These changes can be seen in Figure 4.5 below, where different views from different use cases are shown.

In Figure 4.5c the view for a certain room can be seen which allows the user to directly interact with all the different devices within the room. This is not the case when a user enters a scenario, in this case the view is instead meant to provide an overview of the devices that are coupled to the scenario, see Figure 4.6. The user can drag the sliders to preferred light strength and add or remove more devices to the scenario directly in the view. The scenarios can also be fitted with a timer which can be found in the bottom of the view.
In this iteration two different versions of how the physical smart buttons within a certain room were designed. The first version displays a device icon and a smart button icon at the bottom of the room view, indicating that is possible to navigate between two different views within the room. The device view shows the different devices and lets the user directly interact with them, as described earlier. The smart button view shows, similarly to like how it is in a scenario, the different devices that are attached to said button. The user can then directly remove or add more devices, or configure the dimmer strength for any dimmable lights that are present. This version can be seen in Figure 4.7
The other version instead has the smart buttons directly in the same view as the devices within the room, represented by icons. If the user clicks a smart button in this view, the functionality attached to the smart button would then be triggered like if it was pressed in real life. To configure the smart button the user has to first click Edit Room and then click on the smart button that they want to configure which will take them to a view that is not extremely different from the one in version 1. This version can be seen in Figure 4.8.
With this current design of the Hi-Fi, the prototype were once again presented in the same way as described earlier, to the same coworkers at Compare-IT who got to try out the different interactive flows, give comments and feedback on whatever they found unclear or confusing for them. This feedback was then used to start of the second iteration of the Hi-Fi prototype, which will be presented in the coming subsection.

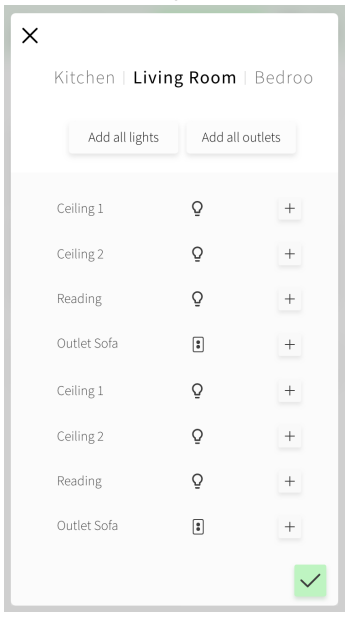
Hi-Fi Iteration 2

With the feedback and comments that were received on the first iteration of the Hi-Fi, a number of changes were made in order to satisfy the feedback and improve the prototype. These changes were mainly:

- Back arrows during infographics to allow the users to re-view certain steps in the tutorial.



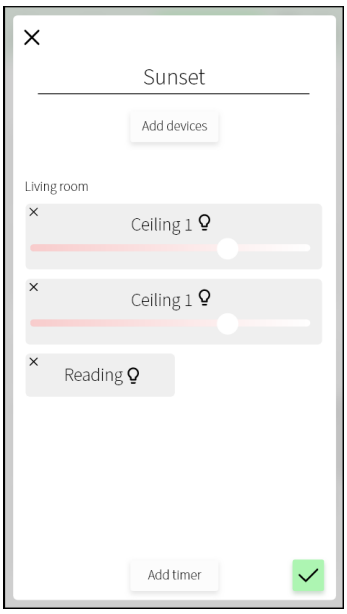
(a) Home screen **(b)** Infographics **(c)** Wider buttons



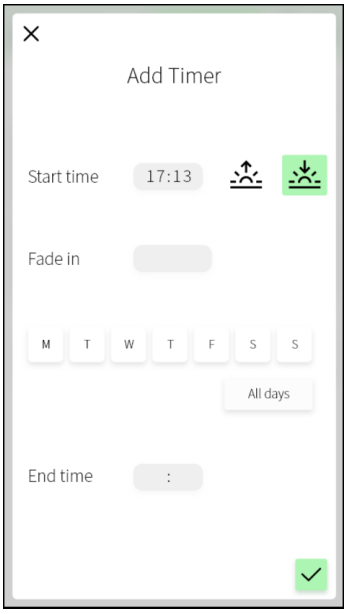
(d) List view

Figure 4.5: Different views in the first iteration of the Hi-Fi prototype

- The crosses in upper left corners, that were meant to be used to navigate back to the home screen or a previous view, has been changed to either Home or Cancel, depending on the context.
- The green check box that was placed in the bottom right corner has now been replaced with either Done or Save, depending on context. These texts has also been moved to the upper right corner.
- Elements that should not be clickable until certain previous tasks have been done are

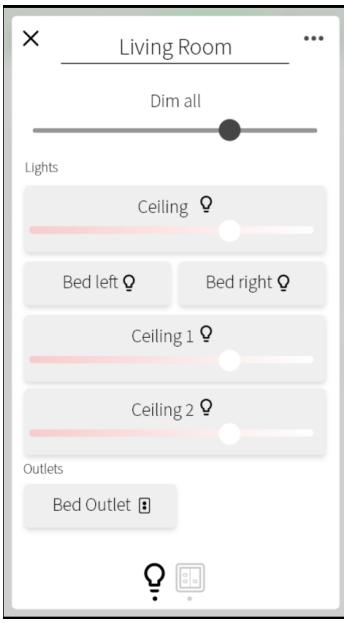


(a) Scenario view

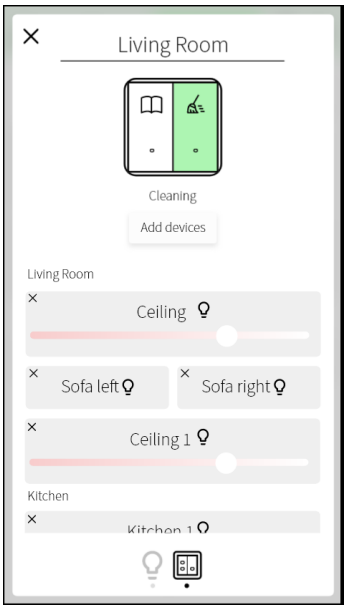


(b) Add timer

Figure 4.6: The view of a scenario with devices and the view for adding a timer to a scenario



(a) Device view

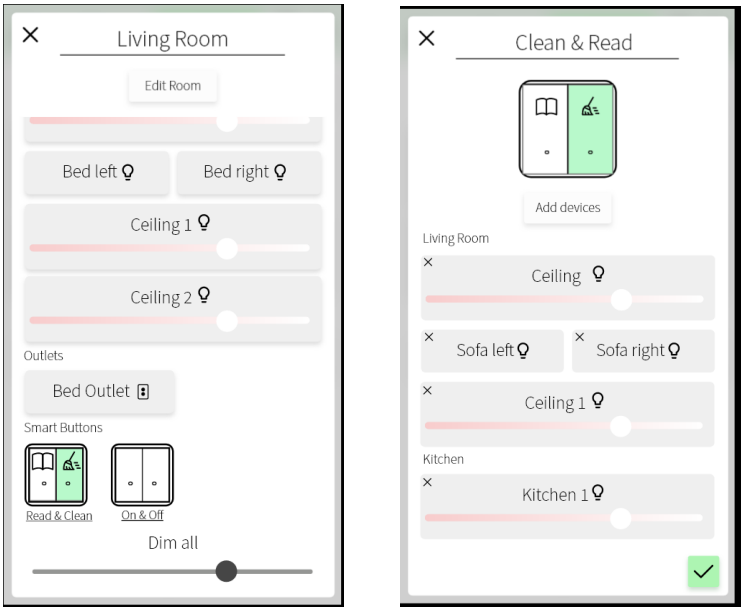


(b) Smart button view

Figure 4.7: Version 1 of representing smart buttons within a room

now greyed out until they should be clickable. One example is that devices should not be added to a room until it has a name, and until a name has been entered, the button for adding devices is greyed out.

Examples of these changes can be seen in Figure 4.9.



(a) Device view **(b)** Smart button view

Figure 4.8: Version 2 of representing smart buttons within a room

Another feature that was introduced from the feedback that was received on the first iteration of the Hi-Fi prototype were the introduction of confirm pop-ups when deleting devices from a room, scenario or a smart button. This was done to minimize the chances of the user accidentally removing something. Besides from this, a small success pop-up has also been introduced that is shown on the home screen after the user has created a new room or scenario to give additional feedback that the performed action was successful. These new features can be seen in Figure 4.10.
With the new features and design options in place, a slightly more rigorous test were conducted with 6 test participants with a majority of whom had never been in contact with the earlier versions of the system. Each test case were slight variations of the original seven test cases that were used during the initial testing of the original system. After each test case, the test participant were asked to comment on anything that they found troublesome or if there was something that they did not understand. This test also included both versions of how the smart buttons were represented within a room, see Figure 4.7 and Figure 4.8. Each one of the 6 test participant got to try both versions in order to give feedback on what version they preferred the most.

Hi-Fi Iteration 3

The feedback gathered from the tests conducted on the second iteration of the Hi-Fi prototype was overall positive and did not motivate any further changes or any new features to be added to the design. The one thing that was scrapped from Hi-Fi 2 was the second alternative to how the smart buttons were represented in a room, see Figure 4.8. This was due to most of the test participants favouring the other alternative as to how to represent the smart buttons within a room.

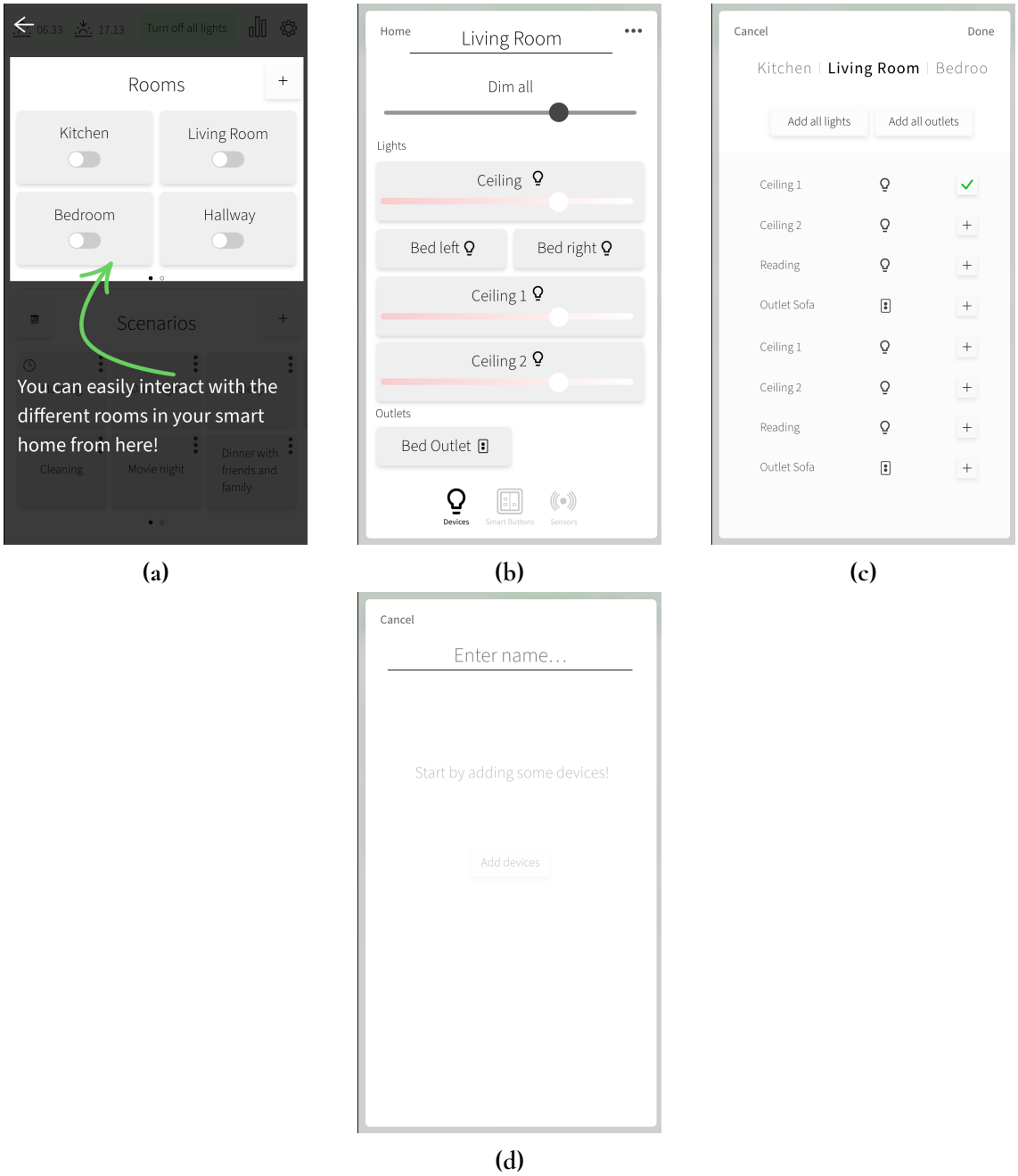
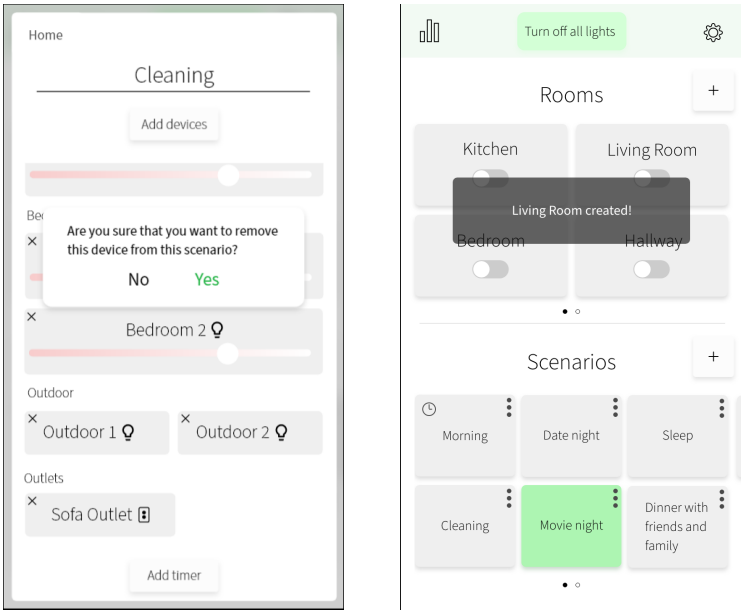


Figure 4.9: Some of the changes done from the first iteration of the Hi-Fi prototype

After this a meeting with a final test participant, with extensive knowledge in the field of UX-design, took place where he gave his opinion on the design that had been developed so far. Unfortunately, a lot of this feedback and comments fell out of the scope of this thesis and the possibilities of what we could introduce in to the design at this stage without re-working substantial parts of the design and the user flows. Some of this feedback will however be discussed further on in the Discussion chapter, as many of the ideas were something that can provide value and increased satisfaction for end users in a smart home environment.



(a) **(b)**

Figure 4.10: Confirm and success pop-ups introduced in this iteration of the Hi-Fi prototype

Chapter 5
Evaluation Phase

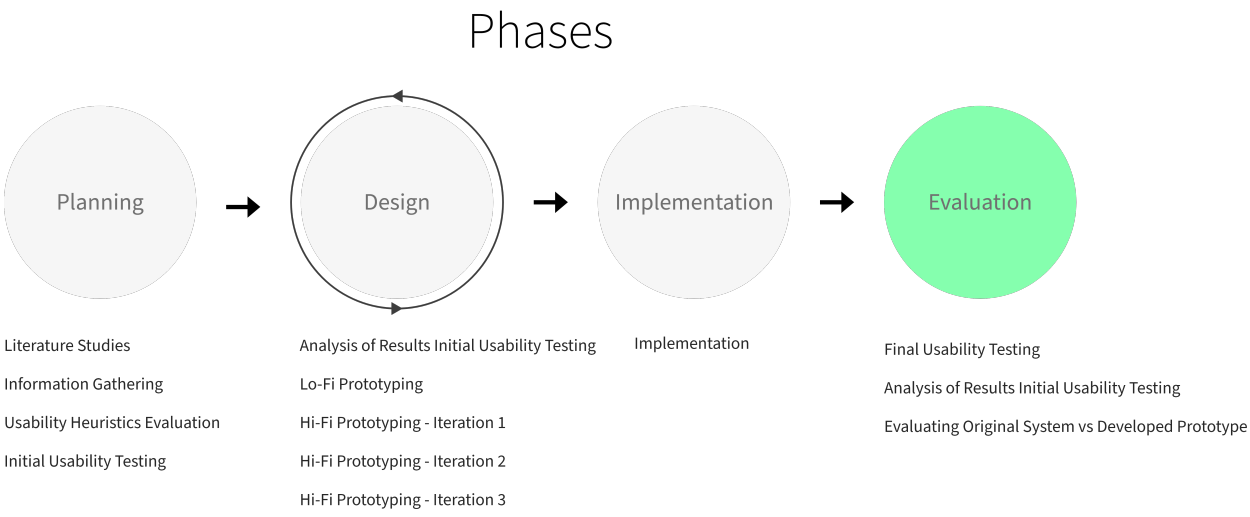


Figure 5.1: Current Phase

This chapter will describe the final usability testing performed on the developed prototype, with the results and a analysis of these results.

5.1 Final Usability Testing

In this section, the preparation of the procedure and results of the final usability testing on the Hi-Fi prototype will be presented.

5.1.1 Setup - Final Usability Testing

This section describes how the final usability testing was prepared and motivate why certain techniques or methods were used.

Background Questionnaire

Just like in the initial usability testing that was performed on the original system, a background questionnaire was once again used in order to information regarding demographics, technical expertise and prior exposure to smart home usage. The reasoning for using a background questionnaire in the final usability testing is the same as described in 3.3.1. The questions used in the questionnaire were also the same as previously:

- Age
- Gender
- I consider myself a technical person
- What kind of household do you have?
- How many people live in the household?
- Have you used a smart home product" before? (Ex. Philips Hue, Ikea wireless, Google home, Alexa ...)
  - If yes: Do you have any type of smart home product" in your home?

Test Cases

To get comparable test data and results that can be used to discuss and compare the developed prototype against the original system, the same test cases that were used in the initial usability testing were employed once again in this final usability testing. Some minor changes was made to befit the fact that it were only a single UI being tested, compared to the initial usability testing where it was both an application and a website. However, since the final usability testing were done using a Hi-Fi prototype without actual functionality for turning on lights and other features, the Wizard of Oz method were employed to inform the test participants when something happened due to any actions they did in the prototype. For example, if the test participant activated a certain scenario in the prototype, the test leader would proclaim that the devices that were linked to that scenario were turned on. This, to emulate how it would work if it were a implemented version with actual functionality that were tested.

Test Case 1: You have just moved into your new apartment, that is outfitted with smart home technology. You can see the entire apartment on this floor plan, with all the different devices. Your first task is to log in via the application.
The test person logs in and registers the facility
You can now take a few minutes to get acquainted with the application, go ahead and look around in the different views but please refrain from doing any changes.

Test Case 2: You now want to get acquainted with the mobile application to see that everything works. You want to try turning a lamp on & off in the bedroom.

Test Case 3: After you have managed to control a lamp in an individual room, you are curious about how you can turn on lamps in several different rooms at the same time. Try to turn on lights in at least 2 rooms at the same time using the app.

Test Case 4: You notice that there is no group for "Living Room". You therefore want to create a group for "Living room" and add the units that exists in that room.

Test Case 5: You feel like it would be convenient if the lights would turn on when the sun goes down. You now want to set at least three lights to turn on at sunset every day.

Test Case 6: In the current situation, the scenario clean also turns on the exterior lighting. You find this a little unnecessary and want to edit the scenario clean so that the exterior lighting does NOT turn on when the scenario is activated. When you are done with this, test if it works by activating the scene in the application.

Test Case 7: You are interested to see if the physical button with the cleaning icon also turns on all the lights except the exterior lighting. To test this, you first want to turn off all lights using the app and then try clicking the button with the cleaning icon on the wall.
The test person clicks the button on the wall
You also see that the exterior lighting is switched on and you want to fix this, i.e. you want the physical button with the cleaning icon to turn on all lights except the exterior lighting.

Observations

For the same reasons and with the same motivations as in 3.3.1, observations were once again used during the testing.

Post Questionnaire

Also for the same reasons and with the same motivations as in 3.3.1, a SUS was used after the test was done.

Post Interview

Lastly, a semi-structured interview was used again after the test was done. The interview contained the same questions, apart from some minor changes to befit the fact that it were only one UI being tested. However, the question regarding what the test participants would most frequently want to use within a smart home was removed, as that kind of information were no longer desirable when the results gathered would be used to compare the new prototype to the original system. Lastly, the question regarding what the test participants thought of the website was also removed since there no longer was any website to test.

1. Firstly, what did you think about the mobile application?
2. Would you say that the application is well designed from a usability perspective?
3. How did it feel to work with rooms in the mobile application?
4. How did it feel to work with scenarios in the mobile application?
5. Was is something that was extra hard to understand or do?
6. What did you think about the terminology?
7. Any final thoughts or opinions?

5.1.2 Procedure - Final Usability Testing

This section will describe how the final usability testing was performed practically.

Test Environment & Setup

As the final usability testing was done on a Hi-Fi prototype instead of a real application, it gave the opportunity to be more flexible regarding testing locations which was an advantage when recruiting test participants for the final usability testing. The tests were often performed in the homes of the different test participants. In order to accommodate for the flexible testing locations, a floor plan of an imaginary apartment with smart home technology were drawn and printed. This floor plan essentially mimicked the layout of the demonstration wall used in the initial usability testing. The floor plan visualised the different rooms, devices and smart buttons found within, see Figure 5.2. During the test cases the test participants had to scan a QR-code found on the hardware of the smart home system, normally located in the electrical cabinet of the facilities. For these tests, this was represented by a photo of said hardware that was taped to the wall during the test. Other than this the test participants also had to, at some point during the test, find and use a smart home button. This was also represented by a photo of said buttons, taped to the wall. Both of these representations can be seen in Figure 5.3a.

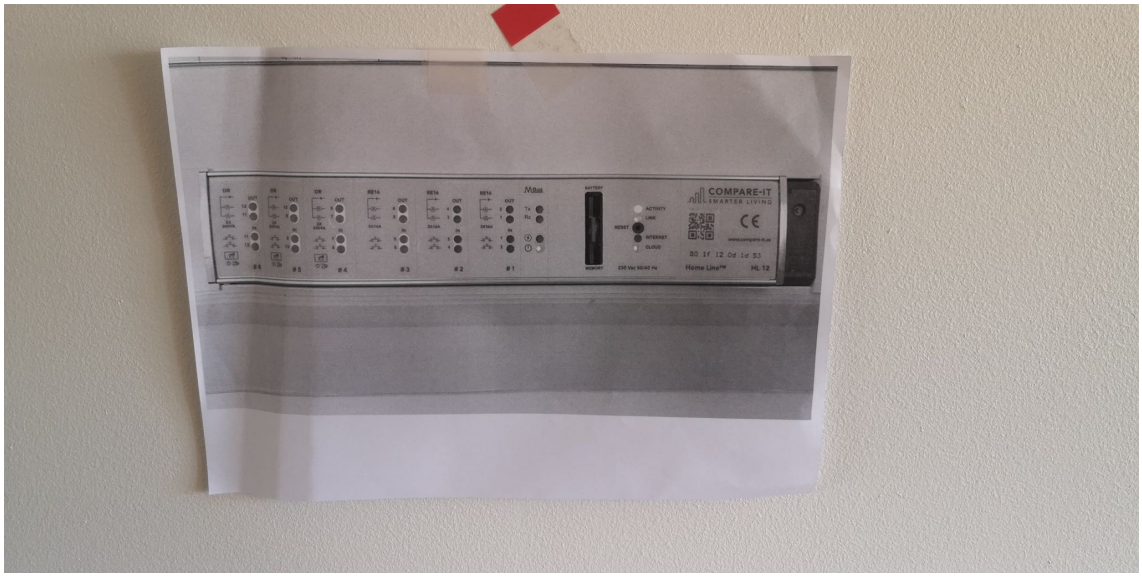
Figure 5.2: Floor plan of imaginary apartment used in final usability testing

Test Procedure

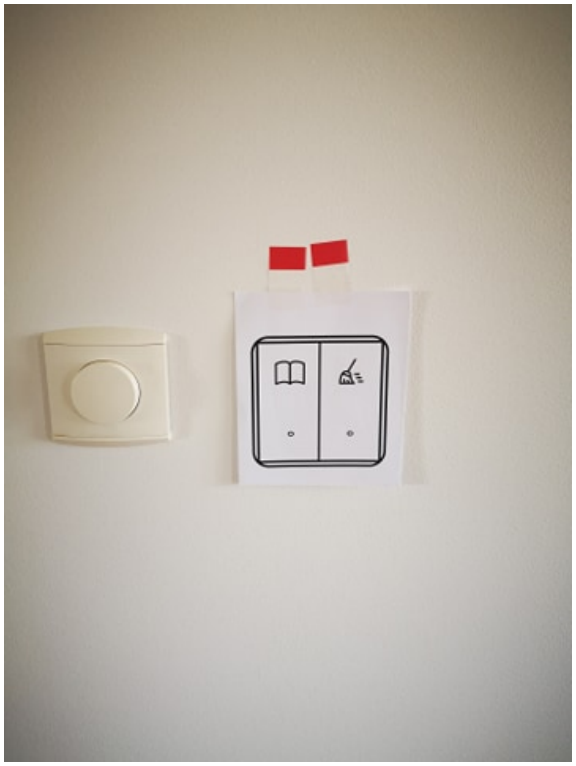
The test sessions started with an introduction of the premise and problems being covered in the setting of this master's thesis and why these tests were being done. The test moderator also explained that the product being tested is in fact an prototype and not a fully implemented application. The test participant were then introduced to the floor plan that would represent their apartment outfitted with smart home technologies, the hardware and the smart button that would be used later in the test cases. The test participants were encouraged to think like if they really were in the illustrated apartment and that everything that they would pretend to do was actually happening. After this, the test participants filled out the background questionnaire and then the actual test would begin. During the test cases the test moderator acted out any actions the test participants did in the prototype, by for example informing the test participants that a certain light was turned on or off. After the test cases were done, the test participants answered the post questionnaire and then finally the post interview questions.

5.2 Result - Final Usability Testing

This section will present the results from the final usability testing.



(a)



(b)

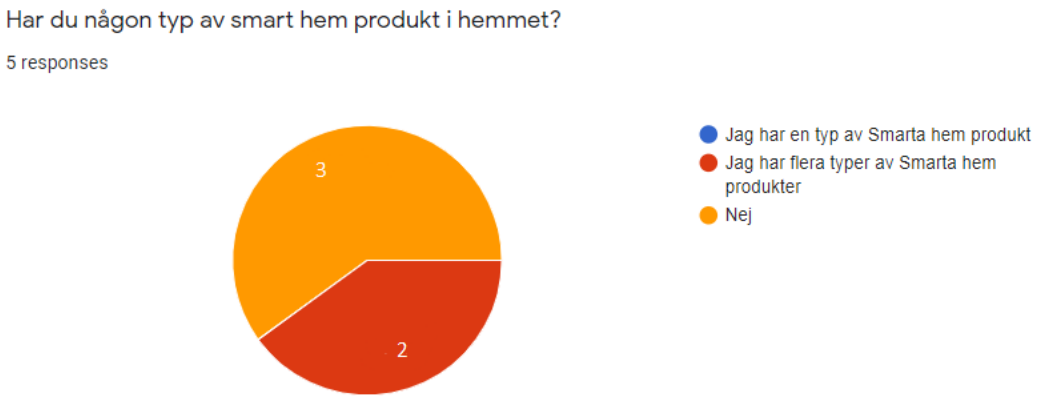
Figure 5.3: Photographic representations of hardware and smart buttons used during the final usability testing

Background Questionnaire

Just like the original testing, this test also consisted of a total of eight test participants. This time all the test participants were in the age span 20-30 with the average age being 25. Four were males and the other fours females. Five of the eight test participants considered them-

selves as technical persons while the other three thought of themselves as average. Eight out of eight participants lived in an apartment. Seven lived with another person while one lived alone. In Figure 5.4 data regarding prior use of smart home products can be seen.

(a) Usage of smart home products



(b) Ownership of smart home products

Figure 5.4: Prior use and ownership of smart home products

Test Cases

The results for all the different test participants can be seen in table 5.1. The table also includes **Best Case Scenario (BCS)**, which is the time that it would take for each task as if they were performed by a user with complete knowledge of the system.

Observations

Test Case 1 - Two test participants commented that the Homeline had a lot of information on it which made it difficult to extract the necessary information, both however had no trouble finding the QR-code. Eight out of eight participants did use the camera to scan the QR-code

Table 5.1: Results for the different test cases. All the time values are in the format mm:ss.

Test Case	Successes	Failures	Avg Time - Success	Avg Time - Fail	BCS Time
1	8	0	03:32	-	00:37
2	8	0	00:34	-	00:03
3	8	0	00:52	-	00:02
4	8	0	00:41	-	00:07
5	8	0	01:26	-	00:16
6	8	0	00:25	-	00:13
7	8	0	01:39	-	00:10

leaving the manual option unused.

Test Case 2 - Seven out of eight test participants solved the case by entering the bedroom to toggle a light. Two out of these seven participants clicked the button on the card firstly to realise that it turned on all lights instead of just one before going in to said room. One test participant created a scenario and added a single light to that scenario and then activated the scenario to turn on the light.

Test Case 3 - Five of the eight test participants clicked a scenario card to achieve the goal. Two out of these five had a first reaction to turn on all lights in two different rooms before clicking the scenario card after the TL reminded them that it should be done simultaneously. Two test participants chose to create a new room and added lights from different rooms in that room to then toggle all the lights within that newly created room to achieve the goal. One test participant created a new scenario and added lights from different rooms to then toggle that scenario card.

Test Case 4 - Since two test participants already achieved this goal in Test case 3 they are not included in this test case. The other six test participants executed the test case without any problems. However two test participants expressed a small confusion to if they had to add the physical Smart button to the room as well as lights and outlets.

Test Case 5 - Seven out of the eight test participants solved the test case without any problems. One text participant is unsure to where to start but solved the case without any problems once the TL gives a clue that scenarios could be a good way to start.

Test Case 6 - Eight out of eight test participants solved this test case without any issues.

Test Case 7 - Seven out of the eight test participants solved the test case without any major issues. However two out of the seven participant's first instinct was to go to the room Outdoor and remove the light from the button there, but later realises that the button is located in the Living room. One test participant had issues to where to find the button. After the TL gives a clue that the button is located in Living room the test participant quickly finishes the test case.

SUS-questionnaire

The results from the SUS that was answered after the test cases can be seen in Figure 5.5. The score was once again calculated with the method described in [19] and resulted in a score of 86, which is clearly above the benchmark value.

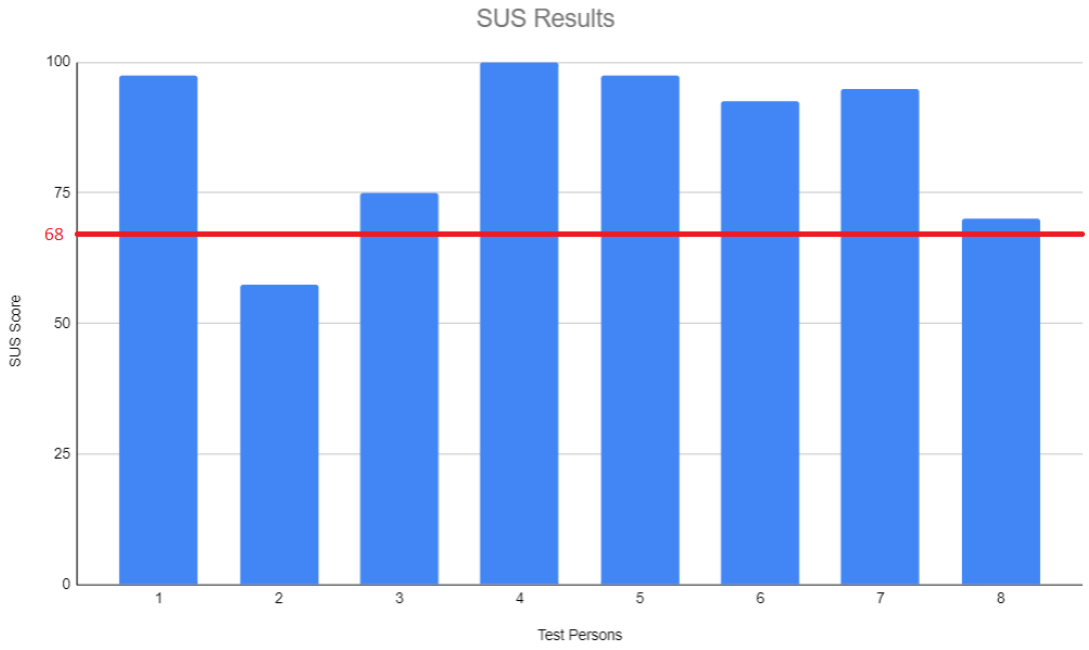


Figure 5.5: SUS Results for the Hi-Fi prototype. The red line indicates the benchmark value for an average experience

Post Interview

The answers that were acquired from the post interview can be found below:

1. *First of, what did you think about the mobile application?*
   Seven of the test participants commented that they thought that it was a clean and good looking app and that it felt intuitive and simple to use. One commented that they would like to have a view to see all the different active devices in one place. Another test participant expressed the desire to be able to connect more different types of devices to the system, like a robot vacuum cleaner, coffee maker etc.

2. *Would you say that the mobile application is well designed from a usability perspective?*
   Eight of the test participants thought that the application was well designed from a usability perspective. However, two test participants commented that it was not overly evident that you could click on the card of a room to enter it. Two test participants expressed that they felt that it was a bit confusing as to where to find the smart buttons for a room. One test participant commented that a floor plan of the apartment with all the devices would have been useful.

3. *How did it feel to work with rooms in the mobile application?*
   The answers on this question was quite wide spread, with the general impression that the test participants did not immediately grasp that they could enter a room via the room cards. One test participant commented that it would be better to call it Areas, as it would be more frequently used to add a sofa group for example, rather than an entire room. One test participant asked where new devices would appear if you install them. Another test participant mentioned that it was a bit hard to immediately understand that the smart buttons were connected to a specific room, but that it probably would be a one time confusion. One test participant expressed confusion regarding what an outlet is and commented that there were no information about outlets in the instructions or infographics. Lastly, one test participant asked what it was that they were turning on and off with the switches on the room cards.

4. *How did it feel to work with scenarios in the mobile application?*
   Three test participants expressed the need for further confirmation when they had created a scenario or added a timer to a scenario, something in the likes with *Save Scenario*. One test participant said that it felt scaled down in a good way and that there was no unknown or confusing icons that you had not seen before. One test participant felt that the base concept of scenario collides with the base concept of a room. Finally, one test participant commented that it might be hard to keep track and sort the scenarios if you have plenty and that it would be nice with some sorting functionality, perhaps according to most used.

5. *Was there something that was extra hard to understand or do?*
   Five test participants thought that it was a bit troublesome to find the physical smart buttons. One test participant felt a bit insecure if it was required to add outlets and what an outlet actually was.

6. *What did you think about the terminology?*
   Eight of the test participants thought that the terminology was good. One test participant wanted to switch the naming of rooms to areas. One test participant was not sure about what an outlet was.

7. *Any final thoughts or opinions?*
   Two test participants commented that they felt a bit insecure about what they were actually doing when they clicked on the "+"-icon in *Add Devices*. One test participant expressed the desire of a "turn of all outlets" in the event of a fire.

5.3 Analysis of Results Final Usability Testing

This section will include discussions and analysis of the results presented in the section above.

5.3.1 Onboarding

The overall outtake from the results regarding the onboarding process was that it was well received and that the infographics gave the users a informative and reliable first introduction to the prototype. However, the results also shows that two of the test participants still had some issues regarding the fact that they could enter a certain room by clicking on its card in the home screen, even though the infographics indicated this in one of its steps. This could simply be due to that the test participant did not pay attention during the infographics or forgot that specific functionality. To address this problem the infographic could display what happens if the user clicks on a room card rather than explaining it. An argument for the user forgetting about that specific functionality is that there is too much information in the infographics resulting in a user not remembering certain parts of it. One solution to avoid excess amounts of information via text could be to make the infographics interactive and guide the user more engagingly through the different functions in the application, step by step.

5.3.2 Rooms

The results regarding rooms as a concept in the prototype does not indicate any general problems as to how they are represented. There were a few concerns regarding the on and off button on a room card and if toggling it toggled all the devices in that room or just the lights. However this concern will always persist regardless of the functionality of said button. We consider this to be of a small concern since this will probably only be confusing until a user clicks the button for the first time. Another issue that is worth discussing is that it can be seen from the results that some test participants expressed confusion regarding the physical smart buttons and where to find them within the prototype, even though the smart buttons were marked on the floor plan available during the test. This could be related to the fact that the tests were not performed in any real apartments with 100% accurate conditions. Which could result in the test participants not always knowing what the results are from their actions since no feedback is given in the real life surroundings.

5.3.3 Scenarios

The major outtake from the results regarding scenarios are that they were well understood and that the test participants overall had no issues interacting with them from a practical and conceptual point of view.

5.3.4 Time Scheduling

The results does not indicate any problems regarding how the functionality regarding time scheduling of scenarios are handled within the prototype.

5.3.5 Terminology

The results show no need to change anything regarding terminology in the application. One concern was lifted that rooms could be thought of as zones and thus should change name. However this was not a general concern and is not considered a big issue.

5.3.6 General App Design

The results from the post interview and the observations indicates a general appreciation of the visual design of the prototype, and that the overall feedback received within the prototype were more than sufficient. This can also be motivated by the rather high SUS-score of 86, which clearly indicates a positive reception of the developed prototype amongst the test participants. However, there was some issues that can be seen from the results observed from test case 2. One test participant did not at all understand that it was possible to enter a room by clicking its card while another commented that they would not have understood how to enter a room if they had not seen the infographics earlier. This can point towards that improvements could be made regarding how evident it is that the users can click the room cards in order to navigate to a room specific view.

Another issue that three test participants expressed regarding the design of the prototype, observed from test case 3, was an uncertainty in whether or not that a scenario is being saved, or more specifically when it is being saved. Two test participants commented on the lack of a save button and that the home button felt more like a cancel button in that specific context. Two of these test participants expressed a hesitation but clicked the home button anyway, maybe due to lack of other choices.

Chapter 6
Discussion

In this chapter, various discussions regarding different the different processes and results will be presented.

6.1 Aborted Implementation Phase

As our main goal states in 1.2 our goal was to develop and implement an application with the end user in focus in relation to smart homes. However, due to various reasons during the work process the implementation part could not be properly executed and finished as planned. One of the reasons why this unfortunately was the outcome, was that one of the thesis's writers got sick with covid-19 with symptoms that prevented any work for two weeks. In addition to sickness, the Design phase took longer than expected which lead to us not having enough time in the Implementation phase. Thus implementing a mobile application that in the end would live up to the usability standards set in the Hi-Fi prototype turned out to be unfeasible, leading to the implementation being aborted after three weeks.

To avoid the shortage of time in the Implementation phase an evaluation could have been made after each phase to better schedule for future work and at the same time estimate if we were in phase with our original time schedule. For example, an evaluation could have been made after the Planning phase in which we could have evaluated and estimated the amount of time the final evaluation would take in regards to the work that was done in the original testing. This since a lot of the work done in the Planning phase is similar to the one in the Evaluation phase.

6.2 Design Phase

Our general opinion regarding the Design phase is that it went as planned. However a few alterations could have been made in order to further better the results and foster a more developed design process. One additional way of improving the design phase could have been to issue surveys regarding the different problems and features that exist in relation to smart homes as a concept. Such surveys could reach a lot more potential end users that could provide more concrete information as well as more opinions regarding different desirable features. Such surveys could include both questions from our background questionnaire and post interview questions, as well as additional potential inquires regarding smart homes.

During the Design phase we both had different opinions about certain design choices, leading to us sometimes working in parallel with said design choices to then, at the end of an iteration, scrap one alternative. To avoid spending unnecessary time on an alternative that would later be scrapped, a design choice could have been made earlier in the process by running these alternatives with people at Compare-IT in order to get a third point of view on the design choices.

6.3 Final Test

During the final usability testing, one goal was to strive for as equal conditions as in the original usability testing, to get results based on as fair circumstances as possible. This was achieved to a certain degree, mainly regarding the test cases, to what types of usability cases the test covered and the different concepts of smart home usage. As a result of the circumstances discussed in 6.1, the testing was only conducted by one of us and the recruitment of the test participants was also affected by the shortage of time.

Since only one of us could attend the tests, the tasks, that in the original test was performed by both of us, now had to be done single handily. Because of this, smaller details may have been missed. The shortage of time led to an inability to focus on diversifying the age of the test participants. Instead, the focus had to be to recruit the same amount of people as in the original test, without regards of the age span, as quickly as possible. This lead to the test participants only consisting of younger persons within the same age span. This may have resulted in that the actual results that the final test culminated in, might be slightly enhanced in a positive manner. This due to that older test participants would likely have a more conservative acceptance and show slightly less confidence in using a new type of system, as they often have had less continuous exposure to new types of technology in their everyday lives compared to a younger adult. Many older persons often show ambivalence and some form of opposition towards new forms of technology [6]. Also, studies have shown that people among the older generation (aged above 55) find more advanced manoeuvres, like double tapping and using soft keys (keys that are embedded in the screen) as well as adopt to new functionality, to be more troublesome than the younger generation who are more willing to use new functionality [24]. These factors likely supports the assumption that an older person would find more trouble using the same features as a younger person, and thus a more age diversified test demographic would probably have resulted in a slightly less positive results.

Another factor that may have change the outcome of the results are the different environments in which the test were conducted in, as well as the fidelity difference in the product that the test was performed on. In the first test the test participant got introduced to the Demonstration wall, see 3.1.2), while on the final test a floor plan was used, see 5.2. Using a physical wall with real lights may have helped the test participant to get a more immersive experience. This in combination with the test participant getting instant feedback (lights turning on and off) from clicking on the different buttons on the application in the original test may have resulted in a better experience than when doing the test using a prototype which lacks this type of feedback.

6.4 Original System vs Developed Prototype

The final prototype as a result has numerous differences compared to the original system.

6.4.1 Functionality & Design Differences

- **More coherent design** - As seen in the Figures in 4.2.2, the design of the developed prototype follows more unified and logical ways of interacting with system, compared to the original system. For example, the original system supported two different ways of interacting with and creating scenarios via the website and mobile application, while the developed prototype limits the user to one way of achieving the same goals.

- **More user friendly terminology** - Terms like *input* and *output* along with various other technical words has been replaced with terms more fitting to the context or have been simply avoided if possible. *Programming* was a term that was previously not very user friendly and could due to this discourage use of the functionality that is gathered under the term Programming. Instead of introducing a new term for this, the functionality has instead been incorporated in the new design in such a way that it does not require any new or changed naming.

- **All functionality available within the same user interface** - Previously, the user could interact with their smart home via both a website and a mobile application, with these offering the same types of functionality but with restrictions in what the users could do via the mobile application. The developed prototype gathers all the functionality within the same user interface.

- **Toggle functionality** - In the previous system there was a lack of functionality regarding toggling a light, scenarios and the lights within an entire room, as observed in the results from the tests on the original system, see 3.3.3, while the developed prototype offer this kind of functionality.

- **Better coupling to reality** - The developed prototype was designed with the goal of providing the user with a more familiar way of understanding what the different entities within the prototype represent and what they may contain. This is done by categorising all the different devices within the system via the room that they are physically

present within. Another way of improving the coupling to reality is the introduction of device specific icons, to help the users to quickly realise what a certain device is.

6.4.2 Difference in Results

In table 6.1 the different times for completing the test cases for both the developed prototype and the original system are presented. For the developed prototype, all test cases were completed with a lower average time compared to the original system. This indicates that the developed prototype supports more efficient ways of interacting with the different features within the smart home. Test Case 4 and Test Case 7 especially shows a considerable improvement regarding the time it takes to complete the task. In the original system, both tasks forced the user to use the website which indicates that merging the systems into one application, as done in the prototype, is one way of significantly improving the completion time for said tasks. The original system does not distinctly guide the user where to begin solving the particular task. The user has to navigate and evaluate numerous different views until they find where to solve the task. The developed prototype however, forces the user to start from the home screen and then lets the user quickly identify where to navigate to in order to proceed with said task. This is achieved through limiting the number of alternatives the user may do certain tasks compared to the original system.

Table 6.1: Differences regarding average times for completing the different test cases for both the developed prototype and the original system. All the time values are in the format mm:ss.

Test Case	Avg Time Success - Developed Prototype	Avg Time Success - Original System
1	02:21	03:32
2	00:34	01:00
3	00:52	01:29
4	00:41	03:33
5	01:26	02:42
6	00:25	01:40
7	01:39	05:43

Another observation from the test cases is that no test participant failed a test case for the developed prototype unlike for the original system, showing an improvement regarding the number of errors that occurs when a user interacts with the developed design. This in combination with the increased efficiency, as discussed above, indicates an overall higher usability for the developed prototype compared to the original system.

Another indication that the prototype is more user friendly is the difference in SUS-score for the different systems. The difference of the SUS-score of 42 for the original system and the SUS-score of 86 for the developed prototype indicates that the users are more willing to use the developed prototype in compared to the old system. As discussed in 6.3, the SUS-score for the developed prototype might be slightly exaggerated, but seeing as how it is more than double that of the score for the original system, we feel confident that this result still indicates an improvement.

Furthermore, the answers that the test participants provided during both post interviews after each test supports the hypothesis discussed above that the developed prototype is an improvement from usability perspective. From the post interview that was held after the tests on the original system, the following were common answers and reflections from the test participants about the system.

- Cumbersome to use
- Lack of functionality
- Hard to know exactly what they were doing and a general lack of confidence when using the system
- Difficulty to understand the terminology
- Not designed from with the end users in mind
- Unnecessarily complicated to re-configure certain functionality
- Found the programming tab to be especially hard
- Everything should be able to do using only a mobile application, and this should be easy to use.

This can be compared to the most frequent answers and comments that were received during the post interview that was held after the tests on the developed prototype:

- Clean design and easy to use
- Well designed from a usability perspective
- Somewhat troublesome to find the physical smart buttons
- Lack of confirmation when saving a scenario
- Not obvious that you can enter a room by clicking the room card.

With these reflections from the test participants regarding the two designs, it is again indicated that the problems that the critique concerning the original system has been solved in many aspects. However, the developed prototype also received some critique regarding certain features which indicates that there are still some problems that should be addressed. These new problems are however seemingly less critical than the ones observed from the results in the original system.

6.5 Future Work

While the developed prototype shows a clear improvement in many aspects regarding the interaction with a smart home, a number of potential new features and alternatives were elicited. These were either raised from testing done throughout the entire thesis or by exploring different design alternatives during the design phase.

6.5.1 Addressing Problems in Developed Prototype

As described in the previous section 6.4.2 some problems still exist in the developed prototype which should be addressed to further improve the design. One of these concerns regards how obvious it is for the users that you can enter a room by clicking its card in the home screen. The developed prototype should make it more evident that a room card consists of more functionality than just toggling the devices in the room. The problem of where to find the physical smart buttons could potentially be solved by doing further user studies of how functionality like this should be represented within an application. Lastly the lack of confirmation when saving a scenario should be addressed, this could be in a form of a banner that is made visible for a few seconds after creating a scenario (like the one for creating a room) or by introducing a save button in the scenario view.

6.5.2 Other Potential Features

Other potential features that emerged at some point during the studies that could be potentially be interesting and beneficial in the concept of interacting with smart homes were:

- **Interactive floor plan of the home** - One idea during the early Lo-Fi phase was that by illustrating the entire home of the users via an interactive floor plan within the user interface, any problems regarding the localisation and identifying the different interactive elements within the smart home could possibly be heavily reduced. This interactive floor plan could provide functionality for visualising different statuses of devices and also let the user interact with said devices, for example toggling a light could be done by just clicking on the desired light in the floor plan.

- **A view of all the active devices in the home** - A suggestion from one of the test participants was to have the feature of a view in which the user could see all the active devices in the entire home. This would enhance the cohesion in the application while reducing the amounts of clicks when turning off certain lights.

- **Be able to toggle the lights on a smart buttons from the application** - Today's design lets the user configure the smart buttons in the home without any functionality to control the button. A feature could be that a user should be able to toggle the lights on the physical smart button from the application itself.

- **Add scenarios to smart buttons** - There has been a few discussions whether or not the user should be able to add whole scenarios to a smart button or just individual devices. The design today lets the user add individual lights to a smart button, however a future feature could be to add groups of lights to a smart button (scenarios).

- **Calendar with scheduled scenarios** - During the Lo-Fi phase the potential feature of having a calendar icon somewhere in the home screen that would enable the users to see all the different scenarios that might have been scheduled for a certain day. This calendar would also let user remove any scheduled scenarios that they for any reason no longer felt the need for it to happen automatically during the day.

- **Capture this light scene** - A feature of being able to save a specific scene directly to a scenario was suggested during a test. The idea is that the user will be able to capture the scene as it is in that moment (the colour and brightness of the lights) and save that to a scenario right away. This would simplify the process of creating a scenario as well as providing the user to add impulsive scenarios.
- **Default mode** - Another feature suggested from the testing was a default mode in case the user has done many changes in certain areas of the application and wants to do a factory reset. This feature could be introduced in different parts of the application such that the user could decide what settings to keep and what settings to restore. For example a default mode could be introduced to rooms, scenarios and settings separately.

These features or ideas were however scrapped either due to them falling out of the scope of this thesis or simply due to them being discovered or elicited at a point in the process where it would not be feasible to introduce these new features without changing major parts of the already established design.

Chapter 7
Conclusion

The main goal of this master's thesis was to develop and implement an application with the end user in focus in relation to smart homes. As discussed in 6.1, the implementation part of the thesis had to be aborted and thus resulting in a part of the main goal not being fulfilled. However, the goal was heavily based on the development of a new design and the implementation phase of the work process does not in the end determine the fact if the developed design supports high accessibility and usability or not. Despite the omitted implementation, we feel that we still managed to produce a well designed prototype that in the end contributes to the area regarding of how an application in relation to smart homes could be designed and developed with the end users in mind. With that being said, the research questions can still be answered from the different results and discussions presented in this master's thesis.

What expectations does the end user have on the design of the application?

The results from this thesis indicates that the end users expect a single user interface in order to control their smart homes with a design that is easily understood and provides the necessary basic functionalities of interacting with the smart home in such a way that technical expertise does not hinder the user in any way.

What functions are desirable for the end user?

Functions and features that from this thesis seem to be the most desirable are:

- The possibility to turn off all the lights within the home. This feature would be especially useful when leaving the home.
- The ability to create and configure different scenarios that can combine different functionality from different devices in across the entire home and with the possibility to schedule or automate these scenarios as wished.

- Easily getting information regarding the status of devices, for example it should be simple and quick to see if a certain light was left on.

How should information and functionality be aggregated and abstracted in an application for smart homes?

The developed prototype is based on a more real life representation of the smart home compared to the original system, resulted in observed improvements, in many aspects. Because of this, the information and functionality should be aggregated and abstracted in such a way that the users can quickly and effortlessly identify the different features and entities in the application based on their own homes.

How does the developed application compare to the existing platform?

From the comparison done in 6.4, it is evident that the developed prototype shows clear improvements in the different aspects that were examined in this thesis.

Bibliography

[1] Adobe. Adobe xd. `https://www.adobe.com/se/products/xd.html`, Accessed: 2021-05-17.

[2] Muhammad Raisul Alam, Mamun Bin Ibne Reaz, and Mohd Alauddin Mohd Ali. A review of smart homes—past, present, and future. *IEEE transactions on systems, man, and cybernetics, part C (applications and reviews)*, 42(6):1190–1203, 2012.

[3] Johanna Bergman and Isabelle Johansson. The user experience perspective of internet of things developmenty. Master's thesis, Department of Design Sciences Faculty of Engineering | Lund University, 2017.

[4] John Brooke. Sus: a "quick and dirty'usability. *Usability evaluation in industry*, 189, 1996.

[5] Andrew Chen. New data shows losing 80% of mobile users is normal, and why the best apps do better. *URL: https://andrewchen. co/ new-data-shows-why-losing-80-of-your-mobile-users-is-normal-and-that-the-best-apps-do-much-better/[accessed 2019-02-03]*, 2015.

[6] Ke Chen and Alan HS Chan. A review of technology acceptance by older adults. *Gerontechnology*, 2011.

[7] compare it. Compare-it. `https://www.compare-it.se/`, Accessed: 2021-06-01.

[8] Liyanage C De Silva, Chamin Morikawa, and Iskandar M Petra. State of the art of smart homes. *Engineering Applications of Artificial Intelligence*, 25(7):1313–1321, 2012.

[9] Steven Dow, Blair MacIntyre, Jaemin Lee, Christopher Oezbek, Jay David Bolter, and Maribeth Gandy. Wizard of oz support throughout an iterative design process. *IEEE Pervasive Computing*, 4(4):18–26, 2005.

[10] Anne Galletta. *Mastering the semi-structured interview and beyond: From research design to analysis and publication*, volume 18. NYU press, 2013.

[11] Quality management systems — Requirements. Standard, International Organization for Standardization, Geneva, CH, September 2015.

[12] Ankur Joshi, Saket Kale, Satish Chandel, and D Kumar Pal. Likert scale: Explored and explained. *Current Journal of Applied Science and Technology*, pages 396–403, 2015.

[13] Anna Kaley. Match between the system and the real world: The 2nd usability heuristic explained. `https://www.nngroup.com/articles/match-system-real-world/`, Accessed: 2021-02-23.

[14] James R Lewis and Jeff Sauro. Item benchmarks for the system usability scale. *Journal of Usability Studies*, 13(3), 2018.

[15] Jakob Nielsen. 10 usability heuristics for user interface design. `https://www.nngroup.com/articles/ten-usability-heuristics/`, Accessed: 2021-02-23.

[16] Jakob Nielsen. Usability 101: Introduction to usability. `https://www.nngroup.com/articles/usability-101-introduction-to-usability`, Accessed: 2021-04-02.

[17] Jakob Nielsen. Iterative user-interface design. *Computer*, 26(11):32–41, 1993.

[18] Jeffrey Rubin and Dana Chisnell. *Handbook of usability testing: how to plan, design and conduct effective tests*. John Wiley & Sons, 2008.

[19] Jeff Sauro. Measuring usability with the system usability scale (sus). `https://measuringu.com/sus/`, Accessed: 2021-04-02.

[20] Daniel Tovesson. Control your home with augmented reality. Master's thesis, Department of Design Sciences Faculty of Engineering | Lund University, 2020.

[21] Usability.gov. Prototyping. `https://www.usability.gov/how-to-and-tools/methods/prototyping.html`, Accessed: 2021-04-02.

[22] Miriam Walker, Leila Takayama, and James A Landay. High-fidelity or low-fidelity, paper or computer? choosing attributes when testing web prototypes. In *Proceedings of the human factors and ergonomics society annual meeting*, volume 46, pages 661–665. SAGE Publications Sage CA: Los Angeles, CA, 2002.

[23] Feng Xia, Laurence T Yang, Lizhe Wang, and Alexey Vinel. Internet of things. *International journal of communication systems*, 25(9):1101, 2012.

[24] Jia Zhou, Pei-Luen Rau, and Gavriel Salvendy. Age-related difference in the use of mobile phones. *Universal Access in the Information Society*, 13, 11 2013.

Appendices

Appendix A

Background Questionnaire Initial Usability Testing

Inför test

Hej! Vad roligt att du vill vara med och testa Compare-ITs applikation och hemsida. Testet kommer att ta ungefär en timme. Innan vi börjar skulle vi uppskatta om du svarade på följande frågor.

* Required

1. Testnummer *

2. Ålder *

Mark only one oval.

- <20 år
- 20-30 år
- 30-40 år
- 40-50 år
- 50-60 år
- 60-70 år
- 70+ år

3. Kön *

Mark only one oval.

- Man
- Kvinna
- Annat alternativ
- Vill ej uppge

4. Ser du dig själv som en teknisk person? *

Mark only one oval.

- ◯ Ja
- ◯ Nej
- ◯ Medel
- ◯ Vet ej

5. Vad har du för boende? *

Mark only one oval.

- ◯ Villa
- ◯ Lägenhet
- ◯ Radhus
- ◯ Annat

6. Hur många personer bor i hushållet? *

Mark only one oval.

- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4 eller fler

7. Har du använt dig av en "Smarta hem produkt" tidigare? (Ex. Philips Hue, Ikea trådfri, Google home, Alexa ...) *

Mark only one oval.

- ◯ Ja *Skip to question 8*
- ◯ Nej *Skip to question 9*

8. Har du någon typ av smart hem produkt i hemmet?

Mark only one oval.

- Jag har en typ av Smarta hem produkt *Skip to question 9*
- Jag har flera typer av Smarta hem produkter *Skip to question 9*
- Nej *Skip to question 9*

INFORMERAT SAMTYCKE

Vi som genomför testet är studenter som gör vårt examensarbete här på Compare-IT. Syftet med testet är att kartlägga problem och undersöka användarvänligheten i en plattform för att styra ett Smart hem. Detta kommer att göras genom att du som deltagare kommer att genomföra ett antal uppgifter.

Under testet kommer vi att spela in skärmen på både dator och mobil som du kommer att interagera med. Vi kommer även att spela in ljud och bild från kameran som är monterad precis bredvid.

Testet är helt frivilligt att genomför och du kan närsomhelst välja att avbryta ditt deltagande utan att motivera varför.

Jag godkänner att jag blir inspelad och att min data används i studien syfte. Efter avslutat examensarbete kommer inspelat material raderas.

9. Jag godkänner ovanstående *

Mark only one oval.

- Ja
- Nej

Appendix B

System Usability Scale Initial Usability Testing

SUS-enkät

Du har nu fått testa dig av Compare-ITs applikation och webbsida för Smarta hem. För varje påstående, fyll i den rutan som bäst beskriver hur du upplevde applikation eller webbsida.

* Required

1. Testnummer *

2. Jag tror att jag skulle vilja använda det här systemet regelbundet. *

Mark only one oval.

	1	2	3	4	5	
Instämmer inte alls	◯	◯	◯	◯	◯	Instämmer helt

3. Jag tycker att systemet är mer komplicerad än det behöver vara. *

Mark only one oval.

	1	2	3	4	5	
Instämmer inte alls	◯	◯	◯	◯	◯	Instämmer helt

4. Jag tycker att systemet var enkelt att använda. *

Mark only one oval.

	1	2	3	4	5	
Instämmer inte alls	◯	◯	◯	◯	◯	Instämmer helt

5. Jag tror att jag skulle behöva personlig teknisk support för att kunna använda systemet. *

Mark only one oval.

	1	2	3	4	5	
Instämmer inte alls	◯	◯	◯	◯	◯	Instämmer helt

6. Jag tycker att de olika funktionerna i systemet fungerar väl tillsammans. *

Mark only one oval.

	1	2	3	4	5	
Instämmer inte alls	◯	◯	◯	◯	◯	Instämmer helt

7. Jag tycker att det finns många saker som inte är konsekventa i det här systemet. *

Mark only one oval.

	1	2	3	4	5	
Instämmer inte alls	◯	◯	◯	◯	◯	Instämmer helt

8. Jag tror att de flesta skulle kunna lära sig systemet ganska snabbt. *

Mark only one oval.

	1	2	3	4	5	
Instämmer inte alls	◯	◯	◯	◯	◯	Instämmer helt

9. Jag tycker att det här systemet var besvärligt att använda. *

Mark only one oval.

	1	2	3	4	5	
Instämmer inte alls	◯	◯	◯	◯	◯	Instämmer helt

10. Jag känner mig väldigt säker och trygg (på vad jag gör) när jag använder systemet. *

Mark only one oval.

	1	2	3	4	5	
Instämmer inte alls	◯	◯	◯	◯	◯	Instämmer helt

11. Jag behöver lära mig ganska mycket innan jag kan börja använda systemet. *

Mark only one oval.

	1	2	3	4	5	
Instämmer inte alls	◯	◯	◯	◯	◯	Instämmer helt

Appendix C

Background Questionnaire Final Usability Testing

Inför test

Hej! Vad roligt att du vill vara med och testa vår prototyp till en Smarta hem applikation. Testet kommer att ta ungefär 40 minuter. Innan vi börjar skulle vi uppskatta om du svarade på följande frågor.

* Required

1. Testnummer *

2. Ålder *

Mark only one oval.

- ◯ <20 år
- ◯ 20-30 år
- ◯ 30-40 år
- ◯ 40-50 år
- ◯ 50-60 år
- ◯ 60-70 år
- ◯ 70+ år

3. Kön *

Mark only one oval.

- ◯ Man
- ◯ Kvinna
- ◯ Annat alternativ
- ◯ Vill ej uppge

4. Ser du dig själv som en teknisk person? *

   Mark only one oval.

   - ◯ Ja
   - ◯ Nej
   - ◯ Medel
   - ◯ Vet ej

5. Vad har du för boende? *

   Mark only one oval.

   - ◯ Villa
   - ◯ Lägenhet
   - ◯ Radhus
   - ◯ Annat

6. Hur många personer bor i hushållet? *

   Mark only one oval.

   - ◯ 1
   - ◯ 2
   - ◯ 3
   - ◯ 4 eller fler

7. Har du använt dig av en "Smarta hem produkt" tidigare? (Ex. Philips Hue, Ikea trådfri, Google home, Alexa ...) *

   Mark only one oval.

   - ◯ Ja *Skip to question 8*
   - ◯ Nej *Skip to question 9*

8. Har du någon typ av smart hem produkt i hemmet?

Mark only one oval.

- Jag har en typ av Smarta hem produkt *Skip to question 9*
- Jag har flera typer av Smarta hem produkter *Skip to question 9*
- Nej *Skip to question 9*

INFORMERAT SAMTYCKE

Vi som genomför testet är studenter som gör vårt examensarbete här på Compare-IT. Syftet med testet är att kartlägga problem och undersöka användarvänligheten i en mobil-applikation för att styra ett Smart hem. Detta kommer att göras genom att du som deltagare kommer att genomföra ett antal uppgifter.

Under testet kommer vi att spela in skärmen på den mobil som du kommer att interagera med.

Testet är helt frivilligt att genomför och du kan närsomhelst välja att avbryta ditt deltagande utan att motivera varför.

Jag godkänner att jag blir inspelad och att min data används i studien syfte. Efter avslutat examensarbete kommer inspelat material raderas.

9. Jag godkänner ovanstående *

Mark only one oval.

- Ja
- Nej

Appendix D

System Usability Scale Final Usability Testing

SUS-enkät

Du har nu testat vår framtagna prototyp för att styra ett smart hem. För varje påstående, fyll i den rutan som bäst beskriver hur du upplevde applikationen.

* Required

1. Testnummer *

2. Jag tror att jag skulle vilja använda den här applikationen regelbundet. *

Mark only one oval.

	1	2	3	4	5	
Instämmer inte alls	◯	◯	◯	◯	◯	Instämmer helt

3. Jag tycker att applikationen är mer komplicerad än den behöver vara. *

Mark only one oval.

	1	2	3	4	5	
Instämmer inte alls	◯	◯	◯	◯	◯	Instämmer helt

4. Jag tycker att applikationen var enkel att använda. *

Mark only one oval.

	1	2	3	4	5	
Instämmer inte alls	◯	◯	◯	◯	◯	Instämmer helt

5. Jag tror att jag skulle behöva personlig teknisk support för att kunna använda applikationen. *

Mark only one oval.

	1	2	3	4	5	
Instämmer inte alls	◯	◯	◯	◯	◯	Instämmer helt

6. Jag tycker att de olika funktionerna i applikationen fungerar väl tillsammans. *

Mark only one oval.

	1	2	3	4	5	
Instämmer inte alls	◯	◯	◯	◯	◯	Instämmer helt

7. Jag tycker att det finns många saker som inte är konsekventa i den här applikationen. *

Mark only one oval.

	1	2	3	4	5	
Instämmer inte alls	◯	◯	◯	◯	◯	Instämmer helt

8. Jag tror att de flesta skulle kunna lära sig applikationen ganska snabbt. *

Mark only one oval.

	1	2	3	4	5	
Instämmer inte alls	◯	◯	◯	◯	◯	Instämmer helt

9. Jag tycker att den här applikationen var besvärlig att använda. *

Mark only one oval.

	1	2	3	4	5	
Instämmer inte alls	◯	◯	◯	◯	◯	Instämmer helt

10. Jag känner mig väldigt säker och trygg (på vad jag gör) när jag använder applikationen. *

Mark only one oval.

	1	2	3	4	5	
Instämmer inte alls	◯	◯	◯	◯	◯	Instämmer helt

11. Jag behöver lära mig ganska mycket innan jag kan börja använda applikationen. *

Mark only one oval.

	1	2	3	4	5	
Instämmer inte alls	◯	◯	◯	◯	◯	Instämmer helt