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Home, Smart Home: Informing Mobile User Interfaces for Smart Environments

A framework to support practitioners within the HCI community to inform mobile user interfaces for smart home environments

Master's thesis in Interaction Design and Technologies

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Abstract

The wave of the transformation of products and services into smart ones has triggered the rise of device interoperability and contributed to the growth of smart home technology turnover globally. In late years, companies within this industry are committing effort not only towards widening their product range - which may be reasonably considered as their core business - but pairing such smart devices with a mobile application, as well, enabling users to easily control their own smart environment. In this regard, both industry and research advocate the formalization of a framework to assist designers, researchers and practitioners from the HCI domain on informing state-of-the-art mobile user interfaces (or MUIs) within the home automation context.
Following a research through design approach, this master's thesis contributes to address the need articulated above: findings emerging from this work culminated in a set of 21 design guidelines - covering 5 key areas in the home automation context: user control, user feedback and situational awareness, spatial awareness, security and privacy in multi-user environments, and customization and flexibility. To justify the outcome of this result, the report describes the design process being adopted, composed of three major iterations - in which user research, together with ideation, prototyping and evaluation activities were carried out, recurring to interaction design methodology - and operated in collaboration with The Company, with the goal of designing a new MUI, taking shape and concretized in the form of an interactive, high-fidelity prototype. Potential future work, based on the results achieved in this project - hence both involving the set of design guidelines and the high-fidelity prototype - and on the possibility of a novel design ideation method, emerged throughout the design process, is discussed in the conclusion.

Keywords: home automation, smart environment, mobile user interface, interaction design.

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Amos Cappellaro, Maranello, September 2022

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Introduction

1.1 Aim

The wave of transformation of products and services into smart ones has triggered the rise of device interoperability and contributed to the growth of smart home technology turnover globally. Significant attention has been paid to home appliances, where smart technology has become intensively researched and practically applied [83]. The *Company* I am collaborating with for this thesis project is a tech company that develops products and services for smart lighting and home automation, and is putting a lot of effort within this domain. From a user perspective, such Company's mobile application is a core part of their product offering, as it enables users to directly control home appliances installed in their household; as The Company is widening their product portfolio, they will need to apply major changes to their *mobile user interface* (or *MUI*) to accommodate new product categories: to provide with some examples, along with lighting control, some of the most common ones that can be found in the market relate to appliance control, thermostat control, or live video surveillance [9]. Therefore, the main purpose of this thesis project is to understand such categories of products that are to be integrated in the future, design for a suitable user experience accordingly - through the implementation of a new, simple and fluid MUI - and formalize a design framework around it, in the form of design guidelines, guiding *Human-Computer Interaction* (or HCI) researchers that will need to inform MUI designs within the home automation context.

1.2 Research Question

This thesis, hence, will aim to answer the following research question:

What design techniques should be considered - in a home automation context - when informing a mobile user interface for multiple product categories in a smart environment?

Along with the supporting sub-questions:

What factors of user experience are affected by the introduction of new interface components in a smart environment application?

What solutions should be produced to address a framework of design recommendations, in order to make it actionable?

1.3 Stakeholders

This section will follow by identifying the major stakeholders of the project.

Chalmers University of Technology is the university I am writing my Master's thesis at. Chalmers provides the requirements and the guidelines which the thesis will have to fulfill in order to be accepted. Chalmers provides an examiner approving and grading the thesis along with an academic supervisor who will supervise the academic aspect and the learning outcomes of it. The *Master's Program in Interaction Design and Technologies* (or *MPIDE*) teaches a multitude of skills to bring an idea from needs and requirements through research and ideation into evaluation-ready interactive prototypes. The courses provide different approaches towards Interaction Design; in order to fulfill the requirement of involving significant specialisation within the thesis work in relation to *MPIDE*, this project will specifically apply skills earned from the courses *Graphical Interfaces (TDA493)*, *Mobile Computing: Design and Implementation (CLS055)*, *Human-Centred Design (TDA486)* and *Designing User Experiences (DAT157)*. Mikael Wiberg will be the examiner and Mafalda Samuelsson Gamboa will be the academic supervisor of this thesis.

The project that will count as project for my Master's thesis - and will be thoroughly described within this report document - has been conducted in collaboration with a company which - in compliance with a *Non-Disclosure Agreement* (or *NDA*) - will not be directly mentioned with its name, but will rather be referred in this report to as *The Company*. The Company I am working on this project at is a fast-growing Swedish tech company that develops products and services for smart lighting and home automation. It is currently one of the leading actors in the smart lighting control segment for the professional sector in Sweden and growing in Europe, and is heavily investing in opening up new product categories (as mentioned in Aim - Section 1.1 - examples of common categories within this industry relate to appliance control, thermostat control, and live video surveillance), propelling The Company into the smart home category in the future. I approached The Company and got in contact with the *Chief of Staff* and *Project Manager*, who introduced their initial vision for the thesis proposal to me: essentially, it will consist of designing a new version of their mobile application, primarily in accordance with the introduction of such new product categories. On further meetings with the *app team*, the proposal was discussed more in-depth, and the common vision for this thesis work was better elaborated, in a research perspective: on a bigger picture, the project will not just consist of designing the MUI for a new version of the app offered by The Company, as said in the first instance, but rather - as interest towards this direction was manifested - it will provide a formalization of a framework that can act as guide for *Human-Computer Interaction* practitioners, researchers and designers, which can be applied when it comes to inform a MUI design - within the home automation context - in need of updating or adding features, hence adding complexity and escalating the risk of affecting the user's mental effort.

Two main user groups of the products offered by The Company may be identified: *electricians*, whose main goal is to install and configure the products in both home and business contexts, and *end-users*, whose main goal is to control such products installed in their own environments. As agreed with The Company, users from these two user groups - with different levels of expertise and background - will be made at my disposal upon request, for the sake of the thesis' research and evaluation processes.

As this thesis project is aimed to provide a formalization of a framework to inform a MUI design - within the automation context - that needs to be enriched with additional features, considering complexity and user's mental effort as challenging factors, it is expected that such framework will turn out to be useful for other *practitioners*, *researchers* and *designers* within the *Human-Computer Interaction* field: more specifically, it is plausible to think that other interaction designers working in the home automation context will benefit the most from the formalized framework that is expected to be developed.

1.4 Delimitations

This project aims to fill the gap between HCI research and home automation environment: as the project will consist of designing a MUI that embeds features and controls to interact with smart home appliances, a framework will be derived, to guide other practitioners through the process of designing MUIs for a home automation context. However, as the wave of transformation of products and services into smart ones is contributing to the growth of smart home technology turnover globally, with the most various kinds of new smart devices getting introduced in an seemingly endless stream [66, 102], smart home environments are becoming more and more heterogeneous [111]; to avoid studying the whole variety of smart devices - quite overwhelming for the scope of this project -, focus will be only put on few product categories, especially on the ones that stakeholders of this project will deem to be worth exploring the most. As work for this project will be handled at The Company, participants for research - if not *in toto* - will mostly be recruited internally, as employees of The Company; this will still guarantee access to people with different levels of expertise (some non-users may also be found), different specialisations, and different backgrounds. Furthermore, user research - e.g. usability tests - will be conducted at The Company, in a laboratory setting, so aspects deriving from not performing research in a natural setting will need to be taken into account.

1.5 Expected Result

Out of this thesis project, in a pragmatic perspective, it is expected to be created a *state-of-the-art*, *high-fidelity* interactive prototype of the MUI for a redesigned mobile application, which should accommodate new features for an umbrella of new product categories within the home automation domain, placing the increase in complexity and the user's mental effort as central challenges to tackle during the design process. Assuming the final MUI will potentially be integrated and marketed in a future version of the app, factors of real world usability will be assessed through usability evaluation and user tests, focusing on the pragmatic attributes [50] of the product. Specific methods to evaluate the final prototype are included in Section 4.5. Accordingly, shifting towards a more research-related perspective, the ultimate result that is expected to be achieved out of this project is the formalization of a framework of design guidelines that will act as guide for other practitioners within the HCI field to apply when it comes to inform a mobile user interface design - within the home automation context - that deals with the need of adding features, hence adding complexity and affecting the user's mental effort. In a sense, the prototype that is going to be provided will act as an instance of the application of such framework.

2
Background

This chapter covers the background of this project, describing The Company - along with its market segment - this project will be carried out at, further elaborating on the research conducted within the home automation domain, and presents related work, relevant to this project.

2.1 The Company

As anticipated in the Introduction (see Chapter 1.3), this thesis project will be conducted in collaboration with a company that we will simply call *The Company*. The Company is a Nordic tech company and supplier of smart lighting solutions. With more than 10 years working with smart lighting control, The Company is now one of the leading actors for such segment in Sweden, with notable growth in Europe; currently, The Company started also investing in broadening their product portfolio, with the goal of expanding into the smart home category in the future. As of now, such Company's products fit the need of making domestic lighting smarter: the mission is to make smart lighting control simple and accessible to everyone, and to provide their customers with the best possible user experience, thought throughout the whole chain, from beginning to end. Profound care toward products and services, aiming to high quality and ease of use, is granted: the whole development process, in fact, fully happens in-house, while some products are even produced within an internal production line. According to [3]'s five classes of smart homes, technology currently offered by The Company matches the third class, allowing to convert homes into *connected homes*: i.e., containing intelligent, communicating objects that are remotely available for control, both within and beyond the home [3].

2.1.1 The Company's Products

As mentioned above, the current range of products offered by The Company mainly focuses on the smart lighting segment. Essentially, aside from a few particular exceptions, their products can be grouped into three major categories: *input buttons*, *smart plugs*, and the so-called *pucks*. Input buttons merely consist of wireless wall push switches or rotary buttons, to enable control of connected lights as an alternative to the app, and are usually installed on walls; smart plugs, as can be intuitively expected, consist of `ON/OFF` plugs embedding relay switching; the pucks, instead, are compact devices that actually make the magic happen, and mostly consist of dimmers or relays which - thanks to their compact format - provide flexibility during installation, as they fit behind a wall button, in the distribution box, or in a ceiling fitting. In a way, this addresses Weiser's view, among the first to envision ubiquitous smart technologies disappearing into the background [131]. Actually, all categories offer maximum versatility during installation, as none requires costly wiring but rather exploits The Company's wireless technology, resulting in added value for both the installer and the end-user. In fact, these products use cheap, energy efficient and reliable Bluetooth communication technology that, according to Asadullah and Raza, offers a high communication rate and great security, so it can be used to implement real-time systems and can use smartphones as receiver devices [9]. A quite powerful aspect to consider is the robust wireless mesh technology that can be achieved, so once multiple products offered by The Company are installed within the same area, they will all begin communicating with each other. One of The Company's products standing out from such categories, yet worth mentioning, is the gateway. Put it simply, the gateway offered by The Company brings all products installed in a domestic environment to a higher level: acting de facto as a bridge between such products and the Internet, it enables users to control them remotely, through the app.

2.1.2 The Company's App

Standard hardware input buttons, though, are not the only control available to manipulate lights. With services offered by The Company, a variety of ways to control lights is provided: one way, for instance, is voice control. However, the most immediate way of interaction one can think of happens through the app. Actually, the app caters way more features than just lighting control. As Eckl and MacWilliams claim, "different types of control devices should let the user select complex scenes, with unobtrusive assistance, besides traditional interaction such as turning on lights" [32]. The Company's app does just that: along with switches, buttons, and sliders to control lights, it allows one to configure scenes that can later be activated either from the app or regular input buttons. But not only that: the app lets the user automate lights through time functions, such as *astro schedules* - automatically turning on, for instance, outdoor lights when the sun sets - or *weekly schedules* - such as making a light slowly start fading in ten minutes before the alarm rings, on weekdays. Users can benefit also from other features in the app, like activating the so-called *vacation mode* - to let the system mimic the behavior of someone staying at home - or managing access for other users to one's environment, through *owner*, *user*, or *installer* roles.

2.2 Smart Homes

First evidence of a concept that we can now relate to as *smart home* began to surface in the 1990s [135]. According to the Smart Home Association, the smart home is

> *"the integration of technology and services through home networking for a better quality of living"* [113].

However, research literature offers a number of definitions to conceptualize smart homes, which mainly fall into two broad categories: one sets the focus onto the generic, physical building itself, and its connection with energy systems; the other, instead, shifts its focal point towards the very meaning of home, and what it can do for its occupants [25]. Within the latter, which can be reasonably considered as most compatible with this project, some pertinent definitions - collected by Marikyan et al. [83] - describe smart homes as “residences equipped with computing and information technology, which anticipate and respond to the needs of occupants, working to promote their comfort, convenience, security and entertainment through the management of technology within the home and connections to the world beyond” [3], as “residences equipped with a communications network, linking sensors, domestic appliances and devices, which can be remotely monitored, accessed or controlled and providing services that respond to the needs of its inhabitants” [11], or again as “the integration of different services within a home by employing a common communication system, assuring an economic, secure and comfortable operation of the home and including a high degree of intelligent functionality and flexibility” [81].

Aldrich, focusing on the functionality available to the user, proposes five hierarchical classes of smart homes [3], which can be summarized as follows:

1. *Homes containing intelligent objects*, i.e. stand-alone applications and objects which function in an intelligent manner;
2. *Homes containing intelligent, communicating objects*, so objects work intelligently in their own right but also exchange information between one another to increase functionality;
3. *Connected homes*, allowing interactive and remote control of the systems, as well as access to services and information, both within and beyond the home;
4. *Learning homes*, where users’ needs are anticipated by their patterns of activity being recorded so to exploit the accumulated data to control the technology accordingly;
5. *Attentive homes*, in which both activity and location of people and objects are constantly registered, so that the information can be used to control technology in anticipation of the occupants’ needs.

2.2.1 Challenges in Smart Environments

In light of Aldrich’s hierarchy, it is evident that the more advanced smart homes become, the more burdens and challenges they can inherently carry with them [3]. Edwards and Grinter examine a series of challenges for ubiquitous computing in the home setting, spanning across technical, social, and pragmatic domains: existing homes were not designed with the purpose of being smart; trade-offs among requirements for reliability, the desire for interoperability, and the fact that there will not be any formal systems administrator are often underestimated; the social impact of new technologies is hard to predict; and finally, through an overarching dilemma - *“how smart does the smart home have to be to provide utility to its occupant-owners?”* -, they invite designers to face the challenge of balancing the desire for innovative technological capabilities with the desire for a domestic, easy, and calming lifestyle [33].

One specific challenge that Roe highlights is *user acceptance*. Use and acceptance of technologies, in fact, depend on a prismatic set of factors: people, for instance, do not accept everything that is technology possible and available: at least, they may use technologies but may not have confidence in them; ambient assisted living concerns a heterogeneous group, so acceptance by users varies depending on functionality, utility, usability, as well as financial resources, security, and adequate design of the devices involved; moreover, *new* products should consider *old* habits of the users, and should definitely not impose themselves over users, but should rather stay user-determined - in a way that user intervention is possible, at any time - and even help users through appropriate, supportive information and training for usage; finally, technologies to be accepted in a new living environment should provide an additional aid to improve social life conditions, without the aim of replacing social interaction - as they merely can't - nor generate new risks [113]. Schomakers et al. found - by exploring how privacy and trust determine the willingness to use smart homes - that the major acceptance determinant is *perceived reliability*, as semi-automated systems are preferred over fully automatic smart home technologies [120].

Accordingly, quite big of a chunk in research investigated how the social aspect plays a critical role while interacting with a smart home ecosystem, often encroaching on trust, security, and privacy. Garg and Cui elicit the need of future smart home technologies to adapt their behaviour based on the social context of use, but also to offer flexible agency - that is, to support a calm or engaged technology - and to support conflict resolution by providing relevant information about others' preferences, values, and activities [40]. Families participating in a study, which aimed to explore possible new genuine needs for smart home automation, faced difficulties in identifying needs in general, except for social needs: one need, for example, would be to facilitate family members' agreement on joint household practices; along with other social needs, users sought to resolve and improve the handling of issues in family life that household members had to face every day [118]. Zheng et al. note how users' desires for convenience and connectedness dictate their privacy-related behaviors for dealing with external entities, and observe how users are unaware of some privacy risks, or at least - even though they trust smart device manufacturers to protect their privacy - they do not verify that these protections are in place [136]. Chalhoub et al. present evidence that designers of smart home devices do not systematically consider UX as a factor to address security or privacy concerns, so they propose user-centered design guidelines and recommendations to improve data protection in smart homes [21].

A rather specific branch of smart home research has developed, instead, around access control and the user's feeling of control. Davidoff et al. - through the argument that "smart home control ultimately provides control of devices, but families want more control of their lives" - suggest seven design principles to help smart home systems deliver that better sense of control. To summarize them, these principles focus on providing flexibility in the planning of activities and the formation of routines, along with support for breakdowns in them; they also suggest the need to accommodate conflicting goals and responsibilities among family members [26]. Mare et al., instead, evaluate seven popular smart home systems and identify underlying design choices around access control, security, and privacy, highlighting their implications for end-users, but also their related challenges and tensions for design choices: for instance, they recommend reducing privacy leaks via side-channels to address tensions like guest privacy or utility v. privacy with continuous sensing, or recommend location-based access policy for guests to address some access control tensions [82]. Tabassum et al. explore the needs not only of home residents, but also of secondary stakeholders who may be granted access to devices outside of the home. By understanding users' perspectives on privacy and trust in relation to sharing smart home devices beyond the home, they built a case for community-based access control of smart home devices [123]. Jang et al., instead, provide scenarios that highlight the need for flexible authorization control and seamless authentication in smart devices, in the form of design recommendations for smart device manufacturers to provide fine-grained access control and authentication [58].

2.2.2 Interaction Modalities in Smart Environments

Research shows that different modalities of interaction in smart environments have been explored and discussed. Two major categories of modalities emerge: mobile-based and gesture-based interactions. However, other modalities are also identified. Some examples from research will be presented here.

Hoffman and Novak tackle the topic in a quite theoretical way, and discuss interactivity from four perspectives: level of interaction, zone of interaction, path of interaction, and time of interaction. They classify actions of pressing and swiping the screen of a smartphone (motor-goals) as low level instrumental actions, executed to accomplish higher-order instrumental actions where the smartphone is used to program the home's lighting system (do-goals), which in turn may lead to non-instrumental, experimental, and playful actions (be-goals). Then, two zones of interaction need to be considered in the smart home, i.e. *direct* and *ambient*: ambient interaction, in particular, has an important role to play in territorializing the identity of smart homes, as it can build trust and acts as a background, passive interaction of a user with a device. The model of paths is based on level and zone of interaction, however it may evolve to territorialize the smart home's identity and user experience in different ways; finally, user experience in the present incorporates not just a list of capacities, but also contingent relationships among interactions that can evolve over time [53].

Coming to a more practical perspective, research suggests that everyday objects and devices at home can be networked to give inhabitants new means to control them, so Koskela and Väänänen-Vainio-Mattila evaluated three UIs (a PC, a media terminal and a mobile phone) for smart home environments, and observed how mobile phones are well suited for instant control, which turned out to be the primary and most frequently used UI during the evaluation [68]; also, the mobile phone proved to act, after usability and acceptability tests, as an ideal "remote control" UI for smart home functions, and tested to be an attractive UI when instant control of both within-home and over-the-distance functions were needed [69]. Other researchers, also evoke the idea of the smartphone becoming a universal remote control - regarded as a fixed embedded part of the system rather than as a personal device - and highlight the benefits of having such medium to control and operate multiple smart home devices from the same screen [23]. With the argument that touch-screen devices are expensive and fragile, Fitriyah et al. prototyped a button-based remote control for smart homes, equipped with a simple LCD screen to keep the amount of buttons low and give visual feedback to users [35]. It is important to also consider other, more passive modalities of interaction with smart homes, still within the smartphone medium: Voit et al. claim that notifications are a core mechanism of smart environments, and warn about distraction, the higher cognitive load, and the task interruptions that they cause. Therefore, they discuss about the problems notifications would have in terms of scalability, as sensors in smart homes that could trigger them could increase dramatically. However, their study shows that smartphones are generally rated the best as preferred notification location [129].

Another portion of research pushes towards more novel modalities of interaction, such as gesture-based interaction. A gesture is “any physical movement that a digital system can sense and respond to without the aid of a traditional pointing device such as a mouse or stylus. A wave, a head nod, a touch, a toe tap, and even a raised eyebrow can be a gesture” [115]. According to Zhao et al., smart homes are getting equipped with more and more advanced technology, which makes them more intuitive and provides a solid foundation to support gesture-based interfaces [135]. Some researchers still consider mobile phones as the perfect user interface for interacting with smart devices [71]. This time, however, they are deemed as useful tools from a gesture-based interaction perspective: Kühnel et al. suggest a set of three-dimensional gestures, and use traditional user interfaces (e.g. a MUI) as an additional interface, to allow complicated actions that are performed less often [71]. Peters et al. approach the concept of an intuitive controller by exploit magnetometers, gyroscopes and accelerometers in mobile phones to let the user point to target objects and complete specific gestures, like pointing to the top of a window and completing a *down*-gesture to lower the blinds [106]. Other valid mediums to enable gesture-based interactions are wearable devices: Verweij et al. use motion sensors embedded in smartwatches for motion matching input, so users track smart home devices as moving targets with their arms [127]. One further device used in research to explore gesture-based interaction in smart environments is Microsoft Kinect [59, 128].

Another form of novel design for a home control interface comes from Luria et al., who developed a social robot that can be commanded via tangible icons and giving feedback through expressive gestures. As result of their study, they raise questions about voice control as a smart-home interface, and suggest that embody social robots could provide for an engaging interface with high situation awareness, but also that their usability remains a considerable design challenge [80].

2.2.3 Smart Home Software Frameworks

Smart home devices usually come with their own apps: that is the case, for instance, for The Company’s app (see Subsection 2.1.2). However, leading players in designing smartphone operating systems - e.g. iOS by Apple or Android by Google - offer native software frameworks as well, letting users control different kinds of smart home devices, of different brands, all in one place; two major examples of those will now be introduced.

2.2.3.1 Apple HomeKit

Apple HomeKit is an integration technology framework that allows users to easily and securely control their HomeKit accessories from any of their Apple devices. In other words, it brings together the user's home, the wide range of reviewed and approved HomeKit-enabled accessories, to name a few: air conditioners and purifiers, lights, doorbells, thermostats, locks, windows, security sensors, and switches, and the user's own ideas about how their home should be automated [34]. The Home app groups accessories by room, so they can be easily controlled anywhere within or beyond the house, but also allows them to be controlled through Siri voice assistant. Moreover, Home app lets the user setting scenes, which enable multiple accessories to work in combination, all with a single command [7].

2.2.3.2 Google Home

Google Home is an integration technology that allows users to set up, manage and control Google Nest thermostat, Google Wifi router, and other Chromecast devices, as well as third-party compatible devices - such as lights, cameras or thermostats - all from the Google Home app. The app - designed to show the status of a user's home - provides shortcuts for the things a user may do most and allows to create routines, whereas a feed section highlights all important events happened in the home. The app also gathers all active audio and video streams in one place, so to easily change the volume, or quickly change which speakers they're playing from. Just like Apple Home, Google Home app also allows to have voice-based interaction with smart devices, through Google Assistant [43].

2.3 Designing Mobile User Interfaces

If we put together an array of example applications from handheld-format devices, we may observe that their interfaces present similarities in terms of UI components and layouts: in fact, some popular, basic layout patterns include constructs such as *lists*, *grids*, *bars* or *drawers*, while newer structural idioms might be *carousels*, *swimlanes* and *cards* [24]. Cooper et al. focus on various facets of user interaction with mobile user interfaces and outline a series of design principles and guidelines to be applied in the design process. Mobile applications have - by their very *on-the-go* and highly context-driven nature - a transient stance, so it is crucial for them to be easy to learn and provide effective affordances for gestures available; in addition to that, mobile applications are usually optimized for browsing rather than for data input, in order to help preempt a user's need to build search queries. However, *searching* may still be considered as a key user activity, as it is used to find anything, whether it's an e-mail, a song or video, or a place nearby [24]. Cooper et al., then, urge to design constructs like tool bars, control panels and menu items in a way that they are properly scaled for finger use. Moreover, it is worth mentioning Cooper et al.'s analysis about the controversy of drawers, especially since The Company's app (see Subsection 2.1.2) - the app under scrutiny within this project - is heavily based on drawers, as shown in Figure 2.1. Drawers allow to navigate in a more immersive way, and make the whole interface cleaner, with more room for content: "for an app with a set of complex features, this can be a godsend". Nonetheless, they hide an entire nav hierarchy behind a single icon button; for this reason, some in the HCI community claim that this use of drawers hampers user engagement, and therefore fiercely advocate for drawers to be abandoned entirely [24].

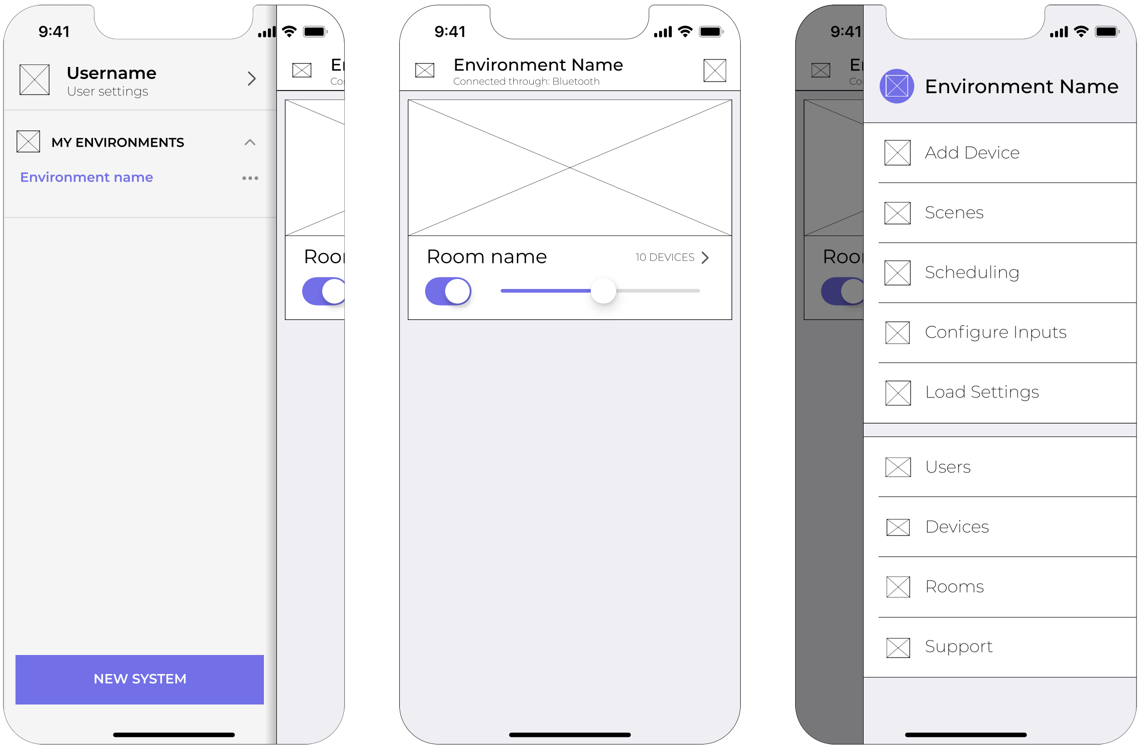


Figure 2.1: The Company's app utilizes the *drawer* idiom both on the left and on the right of the main home screen. Both are accessible by tapping on the icons on the top left and top right corners (relatively, the *hamburger* and the *cogwheel*) of the main home screen, or by simply swiping left or right.

Designing mobile user interfaces (or MUIs), though, involves a wide spectrum of other aspects, as well: as it will be further discussed, it does not involve UI components only. Kraft and Hurtienne suggest how transition animations can affect user orientation in a mobile user interface: they found, in fact, that animations support building more accurate mental models of the app's structure; thus, lightweight orientation animations can have large potential benefits at little cost. Not only that, animations were also found to enhance gesture-based interaction [70]. When it comes to designing a mobile user interface, actually, it is important to keep in consideration how to best exploit multi-touch screens, through the various gestures at disposal: in fact, Cooper et al. consider gestures at the heart of mobile experience. Beauchesne et al. explore how users react to certain gestures - e.g. *swipe*, *scroll*, *tap* - for certain use cases, and suggest guidelines on that, with the argument that some gestures are better aligned with certain use cases as they require less cognitive effort than others [13]. Laubheimer discusses drag-and-drop interactions on mobile user interfaces: after premising that such interaction may be hard to implement on touchscreens, as they lack hover states, he argues that draggable objects should have at least 1cm x 1cm of unused space for dragging, in order to avoid the *fat-finger problem*. Also, it is important to distinguish between taps, swiping gestures, and intentional *grabs* by using a delay in time of a few milliseconds; moreover, one way to provide feedback is to use haptic *bumps*, which indicates that an object has been grabbed or has been grabbed over a drop zone [73].

2.3.1 Interface Design Guidelines

In 2021, the only Apple's App Store counted over 1.8 million apps available for download [6]. However, most of the apps populating online application stores are not developed by the platforms hosting them - such as Apple or Google -, but rather come from other companies, or passionate developers and designers. That is why such platforms outlined guidelines, offering application developers and designers a set of recommendations, with the aim of improving the experience for their users by making interfaces intuitive, learnable and consistent. Furthermore, the guides usually enumerate specific policies, which may be based either on usability studies, or on conventions chosen by the platforms. Two traditional guidelines are Apple's *Human Interface Guidelines* and Google's *Material Design*.

2.3.1.1 Human Interface Guidelines

Human Interface Guidelines is a framework developed by Apple that provides designers with in-depth information and UI resources in the form of design templates, with the goal of creating intuitive and beautiful experiences, resulting in great, state-of-the-art apps that seamlessly integrate with Apple platforms, i.e. *macOS*, *iOS*, *watchOS* and *tvOS*. It offers a comprehensive perspective on how to best implement UI elements - such as icons, bars, views or controls - and provides detailed guides on aspects like application architecture, user interaction, system capabilities and visual design [8].

2.3.1.2 Material Design

Material Design is an adaptable system of guidelines, components, and tools that support well-established practices of user interface design created by Google to help designers and developers build digital experiences for *Android*, *iOS*, *Flutter*, and the web. Material Design inspired by the physical world and its textures, including how they reflect light and cast shadows, reimagining the mediums of paper and ink. Components offered by Material Design are interactive building blocks for creating a user interface, and include a built-in states system to communicate focus, selection, activation, error, hover, press, drag, and disabled states [44].

2.4 Related Work

Park et al. propose a systematic approach to developing comprehensive *style guides* for mobile user interfaces. Together with that, they present a case study to validate the approach, applying the combination of general usability principles, namely improving ease of use, UI components, and guideline properties to developing guidelines. A style guide is a document in which common recommendations are summarized to improve the consistency of product design and to promote good UI practices [122]; therefore, it can provide benefits, such as improving visual and functional consistency within an application [39]. This study will be beneficial for this project not only for the formalization of the framework, but also for the usability principles for UI components they identified. Zhao et al., with the argument that the development of HCI and its impact on the user interface play an increasingly significant role in the building of an effective smart home, propose two guidelines - i.e., *visualize the function* and *provide efficient feedback* - to design efficient and effective user interfaces that are to be used in smart environments [135]. Although through a study conducted with old-generation mobile phones, Koskela et al. provide practical requirements - e.g., *as users want a remote control that is as simple as possible, the interface should require only 2 or 3 buttons* - for UIs to control smart home devices that may prove beneficial for this project, to a certain extent. Roe proposes *adaptive intelligent interfaces* as a valid compromise to the extremely large number of complex choices smart homes may provide, and suggests how they can be designed by means of artificial intelligence methods and techniques; Roe adds that spatial dependency is fundamental in interfaces for smart homes, so that features depend on the position of the user [113]. In a more practical perspective, instead, Zhong et al. present HouseGenie, a direct-manipulation interface of universal monitor and controller for smart environments, which provides with several mechanisms and features to address the basic interaction issues of home universal monitoring and control. Once evaluating their interface, they found that representations of *mixed models* - with *icon-oriented* and *list-oriented* views combined - was preferred; furthermore, thanks to the feedback they were given, HouseGenie got designed around three main views: overview, list view and scenarios [137]. Now, focusing on the evaluation phase of a design process, Darby clearly advocates for studies in the wild, which give insight into how people adopted technology in their homes to meet their needs. That opposes trying to capture the user experience in laboratories, where it is missed out on the complexity of home life, and where practices are negotiated between residents, or even visitors [25].

2.5 Research Opportunity

Quite a lot of literature has been produced on the topics of smart environments and the design of mobile user interfaces. It is evident, however, that only little research has been conducted on these topics interlaced one with each other; or rather, studies mostly focus on the technical implementation of mobile applications to control smart environments, but very few of them mainly focus the discourse in a HCI perspective. Zhao et al. advocate for building quality smart home systems not only upon advanced smart devices, but also upon "excellent HCI design", and a "general guide addressing how to design user interfaces for smart devices that are targeted for use in the smart home environment should be created" [135]. Thus, this work will aim to fill this gap, by providing a framework with guidelines to help practitioners inform state-of-the-art mobile user interfaces to control and interact with a variety of smart devices in a smart environment. Since the project will focus on building up an intuitive and easy-to-use mobile user interface from an already existing one, I believe this work has potential to become particularly valuable in the present and future eras of smart homes, as they will include a large and constantly growing number of networked devices that communicate with each other to coordinate activities [130]. I furthermore expect that the outcome of this project will be of inspiration and will give real guidance - through an actionable design framework - for designers that are challenged by the same activity faced here.

3
Theory

In this Chapter, theories and challenges within the interaction design field, related to the design research and work of this thesis project, are presented.

3.1 Interaction Design

Interaction Design, often abbreviated as IxD, is an overarching term that includes methods, theories, and approaches used within the practice of designing interactive products to support the way people communicate and interact in their daily and working lives Preece et al.; in fact, the word *Interaction* represents the field of Human-Computer Interaction. Many different terms have been juxtaposed to Interaction Design to emphasize different aspects of what is being design, such as user interface, user experience or user-centred design. With a more general vision, Winograd originally described it as “designing spaces for human communication and interaction” [134].

3.2 Wicked Problem

Usually, design problems turn out to be difficult to formulate and difficult to solve, due to their complex nature and their roots in society. Such problems are described as wicked: according to Rittel and Webber, who first coined this term, *wicked problems* are problems without any clear boundary or definition, to an extent they’re not trivial to solve [112]. Buchanan later translated this concept under a more *design thinking* perspective: “the wicked-problems approach suggests that there is a fundamental indeterminacy in all but the most trivial design problems, while the indeterminacy implies that there are no definitive conditions or limits to design problems” [18].

3.2.1 Design Processes

There are many fields of design, such as graphic design, architectural design, industrial design, and software design [108]. Each of these disciplines has its own approach to design. However, they share some commonalities: for instance, practice within all these fields aiming to solve such wicked problems can be split into different sub-activities, or stages, which form the whole design process. Four basic stages of a design process, for instance, are *discovering user requirements*, *designing alternatives*, *prototyping* and *evaluating* [108]. However, to better describe the different stages characterizing a design process, an umbrella of models took hold within both design research and industry. One is the *Double Diamond* model, developed by the Design Council, and articulated in four stages: *discover*, *define*, *develop* and *deliver* [28]. Another well-established, five-stage process model comes from the Hasso Plattner Institute of Design at Stanford: as the thesis will adopt this model, Chapter 4 will be shaped accordingly, discussing each of the five stages more in detail. Another model worth mentioning, formulated by Google Ventures, was specifically developed with the aim of supporting design sprints - i.e., quick, five-day iterations - and follows six phases: *understand*, *define*, *sketch*, *decide*, *prototype*, and *validate* [45]. All these models refer back - as can arguably be viewed as reinterpretations through mappings of divergent and convergent stages - to Jones' Model, acting as a common denominator. Jones in fact first conceptualized design practice as a three-stage process: *'breaking the problem into pieces'*, *'putting the pieces together in a new way'* and *'testing to discover the consequences of putting the new arrangement into practice'* [60]. These three stages are more commonly known as *divergence* - to find alternatives -, *transformation* - to refine and understand alternatives - and *convergence* - to choose alternatives through selection or synthesis -. One relevant aspect to mention is how Jones insists on the idea that "the mind must be free to jump about in any sequence, at any time, from one aspect of the problem, or its solution, to another, as intuitively as possible" [60]; this iterative and flexible paradigm behind design processes is inherently adopted and recommended by the different models introduced above.

3.2.2 Research Through Design

This thesis will apply a *Research through Design* (RtD) approach. Research through Design is an approach to conducting research through the application of methods and processes borrowed from design practice; in Frayling's words, this is "taking a problem outside design and using design to address it" [37]. Hanington and Martin view it as a legitimate research activity, examining the tools and processes, bridging theory and building knowledge to enhance design practices [48]. Its produced outputs - primarily taking the form of artefacts and systems [41] - become design exemplars, providing an appropriate conduit for knowledge and findings to easily transfer towards research and practice communities [138]. In this case, such approach will manifest as soon as a framework for practitioners within the HCI community will be produced in the project.

3.2.3 User-Centred Design

Historically, the development of computer systems has been primarily a technology-driven phenomenon, with the misbelief that "users can adapt" to whatever developers would build. User-centred design advocates that a more promising and enduring approach is to model users' natural behavior to begin with so that interfaces can be more intuitive, easier to learn, and freeer of performance of errors [101]. *User-Centred Design* is a term - originated in Donald Norman's research lab at the University of California San Diego in the 1980s - to describe design processes in which end-users influence how a design takes shape: in other words, it is crucial to involve users one way or another [1], by means of the wide spectrum of tools and methods available. Preece et al. identify three principles that are generally accepted as the basis for a user-centered approach: *early focus on users and tasks*, studying users' cognitive and behavioural characteristics, and the nature of their tasks; *empirical measurement*, by observing and analyzing performance of users; and *iterative design*, repeating cycles of design-test-measure-redesign as often as necessary. These principles were adopted from Gould and Lewis's paper on *Designing for Usability*, who believed that they would lead to a "useful and easy-to-use computer system" [46]. Recently, the term *Human-Centred Design* (HCD) is being preferred over User-Centred Design: according to the Standard ISO 9241:210, in fact, HCD - defined as the "approach to systems design and development that aims to make interactive systems more usable by focusing on the use of the system and applying human factors/ergonomics and usability knowledge and techniques" - is used to better empathize that a design addresses might impact a number of stakeholders, and not just those typically considered as users [57]. However, both terms are often used synonymously. Norman himself - among the first to coin the concept of User-Centred Design - now favours the term Human-Centred Design instead, as can be noticed in his argument that such approach should be abandoned in favor of *Activity-Centred Design* [98, 99].

3.2.4 Activity Theory and Activity-Centred Design

As briefly anticipated in Section 3.2.3, Norman embraces Activity-Centred Design over Human-Centred Design, arguing that ACD is actually very much like HCD - to the point that a deep understanding of people is still a part of ACD - but focusing on activities rather than people might bring benefits. Still, we don't need to discard all the knowledge learned from HCD, but rather build upon it using an ACD attitude, i.e. the mindset of the designer [99]. According to Williams, ACD presents a dramatic shift from HCD, in that "ACD asks not what tasks or activities the user must perform with the application but what tasks or activities must be enabled by the system" [133]. Activity Theory defines a conceptual framework that originates from the sociocultural tradition in Russian psychology, as the most authoritative exposition [64] of activity theory comes from Aleksey Leontev's *Activity, Consciousness, and Personality* [76]. The first attempt to introduce activity theory within the field of Human-Computer Interaction was made by Susanne Bødker, proposing activity theory "as formulated by Leontiev as a theoretical foundation" for HCI [15], since the need to consider human use of technology within a wider context of human interaction with the world has emerged: an interaction mediated by technology [64]. Activity theory requires the scope of analysis to be extended from tasks to a meaningful context of a subject's interaction with the world, so that the boundary of the "objective world" is not limited by the user interface [64]: people interact with the world "through the interface" [15]. Therefore, according to Activity Theory, "user-system" interactions are too narrow to be counted as genuine activities - such as keeping in touch with a friend - and it is important to consider the objects in the world with which subjects are interacting via technology [64]. Consequently, a new *Activity-Centred Design* (ACD) approach emerges, serving as an alternative to other approaches that ignore some aspects of real activities - such as sequences or interruptions - focus specifically on producing page-by-page analyses, like scenarios or personas - deemed “cute but design-empty” by Norman [98].

3.2.5 Frameworks to Support Design Work

As already discussed in Section 1.5, this project is aimed to produce - out of a high-fidelity interactive prototype - a formalization of a framework, with the ambition of it acting as guide for other designers and researchers within the HCI field to apply when it comes to inform a MUI design within the automation context. In order to formalize such framework, implications along the process will inevitably be generated. Generating implications for design, or translating empirical findings into actionable ideas that inform design, is a repeated but critical challenge in design [119]. Sas et al. synthesize different types of design implications into a participant-derived taxonomy to guide their generation: more in detail, their work will be substantially beneficial for this study, as it provides “theoretical and practical implications of practice-informed design knowledge for HCI researchers designing and building prototypes”, where examples of knowledge informed by practice primarily include *design concepts* and *design heuristics*, but also *research-through-design* [139], *patterns* [4] and *design deliberations around issues* [112]. Regardless of what type is informing design knowledge, implications for design should be valid, original, generative, inspiring and actionable [119].

3.3 Usability and User Experience

In this Section, the notions of Usability and User Experience will be better elaborated through scholarly literature. Some clarity around the terms Usability and User Experience needs to be done, since they are often used as synonyms. Despite both revolve around the Interaction Design semantics, they refer to two different concepts. According to Roto et al., “usability is an aspect contributing to the overall user experience”, and “while usability factors were largely related to performance and smooth interaction, new user experience factors relate to affect, interpretation and meaning” [114].

3.3.1 Usability

The international Standard ISO 9241-210:2019 on Ergonomics on Human-System Interaction, issued by the *International Organization for Standardization* (or ISO), defines the term *usability* as

> *“the extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use”* [57].

There is a common misconception that usability refers entirely to the notion of “easy to use” [57]. When providing his own definition of usability, Nielsen indeed associates five attributes with it: *learnability*, *efficiency*, *memorability*, *errors* and *satisfaction* [93]. As the aim of this thesis project will focus on preventing complexity in the design of a mobile GUI in a home automation context, usability plays a pivotal role along the whole design process. Research proposes that usability is, in fact, a central issue, particularly for mobile phone design because users need to access functionalities via limited user interfaces, so simplicity and interactivity are identified as key determinants and preconditions for positive mobile phone usability [75]. Relevant literature provides frameworks and tools to measure and quantify visual complexity on graphical interfaces through the use of metrics, such as *visual clutter*, *symmetry*, and *color variability*, based on screenshots of the interface as input [85, 86], or on interaction data, specifically on mobile applications [110].

3.3.2 User Experience

The term *User Experience* (UX) is backed up by several different definitions and views. The International Organization for Standardization defines it - again within their Standard ISO 9241-210:2019 on *Ergonomics of Human-System Interaction* - as follows:

> *"[User experience is] a user's perceptions and responses that result from the use or anticipated use of a system, product or service"* [57].

Among other most accredited resources, Preece et al. define it as a concept that refers to "how a product behaves and is used by people in the real world, including their overall impression of how good it is to use, right down to the sensual effect small details have on them" [108]; to not forget the quality of experience a person has when interacting with a specific design [74]. Nielsen and Norman define it as encompassing "all aspects of the end-user's interaction with the company, its services and its products" [97]. Roto et al. also propose three different views on UX - as a *phenomenon*, as a *field of study*, or as a *practice* - and outline four time spans of UX that refer to the experience with an artifact before, during or after interaction events, i.e. *anticipated*, *momentary*, *episodic* and *cumulative* [114]. For the scope of this project, the most meaningful time spans to consider will arguably be represented by momentary UX and cumulative UX.

User Experience is also characterized by a number of factors. According to Morville's *Honeycomb Model*, User Experience is articulated by seven facets: *useful*, in the way that a design owns a purpose; *usable*, since it's vital to achieve ease of use; *desirable*, giving an emotional aspect to a design; *findable*, in the sense that users can navigate through a design and locate objects; *accessible*, so that users with disabilities are not excluded from a design; *credible*, focusing on the design elements that influence whether users trust what's being told to them; *valuable*, to contribute to customer satisfaction [90].

3.3.3 Methods for Studying Usability and User Experience

A wide spectrum of methods can be used for studying Usability and User Experience. However, their suitability in our study depends on what are the real answers that we need; in fact, these methods can be split into two major categories of research: *qualitative* and *quantitative*. Qualitative research focuses on the nature of something [108] and answers *why*, helping us understand both attitudes and behaviors [42], while quantitative research answers *how much* and *how many* [42], to ascertain the magnitude of something [108] or to determine the priority of a problem [89], helping us to put statistical significance behind our experiences [42]. But these two categories of research hide more differences: when it comes to outcomes, findings in qualitative research are based on researcher's impressions and interpretations, while in quantitative are statistically meaningful results; a handful of participants in qualitative research - Moran's rule of thumb is five to eight users per user group [89] - is enough, whereas in quantitative research you need many, so to support meaningful results; methods in qualitative research are quite flexible, so they can be structured or unstructured, while in quantitative research, methods are well-defined, in strictly controlled conditions [42]. Popular qualitative methods include *user interviews*, *qualitative usability testing*, *field studies* [89], *focus groups* and *diary studies* [42]; popular quantitative methods, instead, include *analytics*, *A/B testing*, *surveys* and *quantitative usability testing* [89], but also *card sorting*, *tree testing*, or even *eye-tracking* [42].

One particular reason to use quantitative research methods is that they're applicable for comparative purposes: with *A/B testing*, for instance, it is possible to compare alternative design options for a specific layout and use data to inform the designer's decision. A major benefit, in fact, is that quantitative research allows us to determine whether the difference between two numbers is statistically significant [89]. Another useful method for comparative studies is *Benchmarking*, which will be elaborated more in-depth in Section 4.1.4.

The best strategy is to use a variety of methods [89]. However, relying on their hands-on experience, Cooper et al. strongly support qualitative research over quantitative research, with the argument that human behaviors are too complex to be understood through quantitative data only; put it another way, they deem that without a robust body of primary qualitative research, providing answers to the why of those behaviors, quantitative results may raise more questions than they answer [24].

In order to study Usability and User Experience and apply many of the methods introduced here, we need a medium to base such studies on: here is where prototypes come into play. Prototypes are "tools for traversing a design space where all possible design alternatives and their rationales can be explored", so to enable designers "communicate the rationales of their design decisions" [78] - or, in other words, to demonstrate a concept in early design [14] - to allow stakeholders explore their suitability and interact with them [108], or even test [14] the design solution they incorporate. Prototypes may come with different levels of *fidelity*, referring to how closely it matches the *look-and-feel* of the final system. Fidelity can vary depending on interactivity, visuals, content, and commands [104]. Prototypes can be discerned into two major levels of fidelity: *low-fidelity prototypes* and *high-fidelity prototypes*. Low-fidelity prototypes are more focused on the broad underlying design ideas and take less time to produce [14]: if these are to be tested, they put less pressure on users, who may better understand that what is really being tested is the design and not them, so that they feel less obliged to be successful [104]. High-fidelity prototypes, that are more similar in look-and-feel to the anticipated final product, are useful for detailed evaluation of the main design elements, and are generally developed when ideas are beginning to firm up [14]; for the sake of testing, they're also supposed to have a realistic and faster system response, as a too long of a lag between user's action and the system response can break the users' flow [104].

4
Methodology

This Chapter is aimed to collect and elaborate on the different methods that are taken into consideration for the sake of this Master's thesis project. A suitable model for this project comes from the *Hasso-Plattner Institute of Design at Stanford* (also known as *d.school*), consisting of a five-stage design process model. These five stages - outlined as *Empathize*, *Define*, *Ideate*, *Prototype* and *Test* [51] - will determine the different sections in this Chapter, with the set of methods listed accordingly. Overall, as several other design processes do, this model inherits a User-Centred Design approach, implying an iterative nature; therefore, it may be possible to iterate both by cycling through the process, or by iterating within the same stage, achieving the benefit of narrowing the scope.

4.1 Empathize

In the Empathize stage, the designer is expected to set aside their own assumptions about the world and gain an empathetic understanding within the context of the problem they're trying to solve. Through user-research, it is their effort to put themself in the shoes of the users they're designing for, to understand the way users do things and why, their physical and emotional needs, and what is meaningful to them [51]. Research gets done in an exploratory manner, in the way that it should be an immersive experience for the designer, inspiring creative momentum and empathy [48].

4.1.1 Literature Review

Literature reviews are intended to distill information from published sources, capturing the essence of previous research and, thus, potentially informing the current project [48]. They help establishing the context of a project and understanding gaps in the field [125]. As Hanington and Martin suggest, it may be useful to organize the material by research categories [48].

4.1.2 Interviews

Interviews are a well established method to gather qualitative information about a specific topic through direct dialogue [79], considered as *the crux for inspiration*, as it allows the designer to unlock all types of insights and understanding that can never be acquired by sitting behind a desk [55]. Preece et al. identified four different types of interviews: unstructured, structured, semi-structured and group interviews [108]. For this project, a suitable type of interview to use is the semi-structured interview, which is meant to be broadly replicable [108], and combines features and qualities of both unstructured and structured interviews: unstructured interviews offer the possibility of being more conversational and comfortable for participants [48], and hence to probe, in order to gain more reasoned, articulated answers and insights; structured interviews, on the other hand, follow a more rigorous format, with pre-planned questions only, so that are easier to control in terms of questions and timekeeping, but also easier to analyze [48] afterwards. One form of interviews worth mentioning for this project is *expert interviews*. In essence, expert interviews very much follow the same structure as regular interviews. However, they differ in a way that participants are specifically recruited to be experts within the subject topic of the interview: a major benefit of recruiting experts is that key insights into relevant context, perspectives, and innovations can be picked up more easily, as they often give a system-level view of a project [55]. Interviews, within this phase, are especially used to inform journey maps, feature ideas or even workflow ideas, but can also supplement observations with description of tools, processes, bottlenecks, and how users perceive them [105]. However, interviews are profoundly helpful not only for research, i.e., in this Empathize phase: they can offer, in fact, valuable results when used within the evaluation of a design as well (see Subsection 4.5.3).

4.1.3 Questionnaires

Questionnaires are a research instrument to collect self-report information - both quantitative or qualitative - from people about their characteristics, thoughts or perceptions, typically in written form. Despite their ease in being produced, Hanington and Martin warn about the importance of tackling the right question wording and response options, sequencing, length and layout: the way a question is constructed will play, in fact, a key role in the quality of the answer and analysis. It is also suggested to triangulate (see Subsection 4.2.5) questionnaires with other methods [48]. Just as with interviews, questionnaires are helpful in both the Empathize and Test phases of a design process (see Subsection 4.5.6).

4.1.4 Competitor Benchmarking

When it comes to redesign a product, it is generally intended to influence its user experience, with the aim of improving it. Generally, benchmarking enables to measure the extent of that improvement, evaluating a product's user experience by using metrics to gauge its relative performance against a meaningful standard [62]. Moran defines benchmarking as an iterative practice, as designers can track their progress over time, redesign through redesign, by running studies with the same established methodology; it is also argued that comparison can be made, for instance, with an earlier version of a product, but also with a competitor, or with an industry standard [88]. According to Shetty, in competitor benchmarking a product's performance is measured against that of *best-in-class companies* to determine how to achieve performance levels [121]. Competitor benchmarking is about taking an in-depth look at competing products so that a comparison can be made between them [5]; the knowledge collected, deriving from such comparison, will be beneficial to designers, as it will highlight what products exist, what their strengths and weaknesses are and hence will be of inspiration to designers to make more informed decisions in a design project, knowing how to differentiate from the competition. Allen and Chudley argue this method - commonly being allocated one or two days in project plans to conduct one - can fit early phases of a design process, and can go hand in hand with other methods - like usability testing and expert reviews - to determine the current state of a product. Since this project will involve an already existing product - a mobile application - it will be included within the analysis as one of the products that is benchmarked, so as to provide a measure of its state which can then be compared against a future version of itself [5]. Similarly, Hanington and Martin talk about Competitive Testing, which is the process of conducting research to evaluate the usability and learnability of a competitor's products from the end user's point of view [48].

4.1.5 Wireflows and Annotated Interfaces

Wireflows are a combination of wireframes and flowcharts to document user workflows and complex interactions for mobile applications [72]: an arrow is used to indicate *hotspots* of a specific interface component where the user may take action - e.g. *tapping on a button* - and points to another interface component or view, to represent what happens as a result of the interaction. For this project, - even though often applied as a collaboration and ideation technique - this tool will be used mainly to map out and understand the current version of the mobile application under analysis, and will include the Annotated Interfaces practice to keep track of any specific design feature or interaction problem.

4.2 Define

In the Define stage, it is the designer's responsibility to bring clarity and focus to the design space [51] through the definition of a problem statement, by laying out the knowledge acquired in the Empathize stage, making sense of the information gathered, and synthesizing the emerging insights.

4.2.1 Thematic Analysis

Thematic Analysis is a method for identifying, analyzing, and interpreting patterns of meaning - meant as *themes* - within qualitative data [22]. More formally, a theme is something important about the data in relation to the study goal. Themes emerging from the set of qualitative data may relate to a variety of aspects: some examples may include behavior, a user group, events or places [108]. Nowell et al. point out how thematic analysis provides a highly flexible approach, due to its core theoretical freedom [100]. An example demonstrating this flexibility is the way themes can be identified: they can, in fact, emerge inductively from raw data or be generated deductively from theory and prior research [100]. Through an inductive approach, the themes identified are strongly linked to the data themselves by conducting a process of coding the data without trying to fit them into a preexisting coding frame [16]. Clarke and Braun hence consider this form of analysis as *data-driven*, or *bottom-up* [22]; through the coding process, this approach allows one to evolve a specific research question [16]. In a deductive approach, instead, the analysis usually tends to provide a more detailed analysis of some aspect of the data, rather than some rich description of the data overall: Clarke and Braun call this the *theory-driven*, *top-down* Clarke and Braun, or *analyst-driven* [16] approach; here, you can code for a rather more specific research question [16]. Clarke and Braun also highlight the fact that thematic analyses provide accessible and systematic procedures for generating *codes* and *themes*, from the collected data: here, codes are meant as the smallest units of analysis, capturing interesting features of the data relevant to the research; in a way, then, we can view codes as building blocks for themes, which are larger patterns of meaning, and underpinned by a central, shared core idea [22]. According to Preece et al., thematic analysis is suitable to be used in combination with affinity diagrams (see Subsection 4.2.2), as the identified themes may then be grouped by being visually structured and hierarchically organized [108].

4.2.2 Affinity Diagramming

Affinity Diagramming is a common technique for exploring data, identifying themes, and looking for an overall narrative is to create an affinity diagram. The approach seeks to organize individual ideas and insights into a hierarchy showing common structures and themes [108]. The LUMA Institute, referring to this method as Affinity Clustering, defines it as a graphic technique for sorting items according to similarity, into logical groups. Once items are sorted based on perceived similarity, patterns begin to emerge, letting designers draw insights and new ideas [79] that would otherwise not be obvious to define.

4.2.3 User Stories

Out of the information gathered through research, user stories can be created to capture what a design is intended to do: in fact, they may be viewed as brief scenarios that determine the requirements the design will have to satisfy. User stories may also be used to capture usability and user experience goals [108]. The appropriate structure for user stories is as follows:

As a ***<role>****, I want* ***<behavior>*** *so that* ***<benefit>****.* [108]

Cooper et al. define user stories as informally phrased requirements which, similarly to scenarios, do not describe the user's entire flow at a big-picture level or describe what the user's end goal is [24].

4.2.4 Point of View

Point of View (PoV) is a method suitable to define the design challenge to address a problem statement: it builds and elaborates on a deeper understanding of users, together with their needs and the most essential insights about them, collected in the Empathize phase (Section 4.1). PoV is meant to provide a wide enough scope for designers to start thinking about solutions that go beyond the status quo [38]. This method would logically extend to the *How Might We* method (see Subsection 4.3.2).

4.2.5 Triangulation

Triangulation is a method that aims at the convergence of multiple methods on the same research question, to corroborate evidence from several different angles [48]. In other words, it helps improving design decisions by looking at the problem from multiple points of view: combine multiple types of data or data from several methods of investigation [132]. According to Jupp's classification of triangulations, this project will most likely concern the *methodological* type of triangulation.

4.3 Ideate

In the Ideate stage, the designer generates ideas with the goal of reaching possible design solutions: mentally, it represents a process of *going wide* in terms of concepts and outcomes [51], and trying to creatively *think outside the box* and view the problem from different, alternative perspectives. Many authors consider methods like *Sketching* (4.3.3), or even *Storyboards* as low-fidelity prototypes [108]. The reason why such methods are listed within this Section - rather than in Prototype (see Section 4.4), as one may assume - is that they're more common throughout early ideation processes [48], being used more to generate ideas rather than to test them, as anticipated in Section 3.3.3.

4.3.1 Brainstorming

Brainstorming is a well established and widely used ideation method in design. Preece et al. define it as a technique to generate, refine, and develop alternative designs [108]. In general, a brainstorming session - which Kelley calls *brainstormer* [65] - is conducted in group, using Post-It notes to write ideas down, but some variations of it exist, i.e. *Brainwriting 3-6-5* or *Brainsketching*; regardless of which format is opted for, it is suggested to not run sessions only among designers, but also with stakeholders of a project [55]. Kelley - who describes brainstorming as an opportunity to *blue sky* ideas early in a project or to solve tricky problems, cropped up later on - also outline a series of *secrets* for better a brainstorming: briefly summarized, we have sharpening the focus into a well-honed problem statement, starting by playing some fast-paced word game to the team into a more outgoing mode, do not critiquing or debating ideas, numbering ideas, and exploiting spatial memory, being visual with sketches or mind maps [65]. Gale encourages the use of collaborative approaches such as brainstorming to collect ideas to develop guidelines [39], which Park et al. deem to be more efficient than literature review. On the other hand, they also argue that brainstorming is very subjective and its quality depends on the expertise of the members, so systematic procedures and specific techniques are required [103].

4.3.2 How Might We

Once problems are identified, it is often useful to reframe and translate insight statements such as How Might We questions to turn the challenges users face into opportunities for design. This format offers the chance to formulate answers in a variety of ways [55], so it suggests directions towards innovative ideas or solutions. How Might We may be considered as a natural continuation, a follow-up method from the *Point of View* method (see Subsection 4.2.4).

4.3.3 Sketching

Another pillar ideation method is sketching. Despite many people find it difficult to engage in this practice, being inhibited by the quality of their drawing, sketching must be considered not about drawing, but rather about design [108], so that everyone can benefit from thinking visually [55]. Sketches can be considered as low-fidelity prototypes, so they don't strictly need to be anything more elaborated than just boxes, stick figures or stars on paper; if an interface is to be design, icons or dialog boxes can be sketched [108]. It is important to have them done, shared, and learned quickly [55]. Buxton lists an array of attributes that sketches manifest: they are - for instance - *quick*, *inexpensive*, *disposable*, *plentiful*, and intentionally *ambiguous*. Buxton also visualizes them in a loop conversation with the mind, meaning that if the act of creating a sketch is triggered by current knowledge, reading a sketch would instead create new knowledge [19], offering opportunities for new ideas to spark. Sketching may also be referred to as *Rapid Prototyping* [55] or *Rough & Ready Prototyping* [79].

4.3.4 Storyboard

Storyboards are low-fidelity prototypes consisting of a series of sketches, representing a meaningful sequence of events [79], showing how a user experiences a rough idea in action or progresses through a task interacting with the design solution under development [108], to envision its intended usage. Storyboards are used to consider different design alternatives in the early phases of the design process, but can also help build empathy for end-users [48].

4.3.5 Extreme Characters

Djajadiningrat et al. introduce this technique to the research and design community as a valid alternative to *scenarios*, which are often used to design with a particular target group in mind, through *personas*: in their argument, scenarios may be very detailed in terms of lifestyle, but ignore the full spectrum of human emotions, and only address those recognized as socially or culturally desirable, offering shallow and *out-of-touch* characters. On the contrary, instead, “extreme characters steer away from the usual designing for a prototypical, emotionally shallow character from a target group” and actually are to design for characters that have exaggerated emotional attitudes. The extreme characters, then, help designers to achieve richness at the actions and role levels [30]. Moreover, by bringing this method to the process and considering them as our target group, we may see extreme characters - thanks to their peculiar requirements - as a springboard that will help us to give rise to new, interesting ideas to be pushed forward, and to put the technology we are working with in a new light [54]. IDEO.org presents this method in a perspective of inclusiveness, hence of complementariness between extremes and mainstreams: ideas that get triggered by extremes will nearly certainly work for the majority of all users, but, most importantly, considering people at the “extreme ends of a product or service” can spark the designer’s creativity by exposing them to use cases, hacks, and design opportunities that could have never been imagined otherwise [55].

4.3.6 Moodboard

Moodboards are visualizations of a topic, or of a concept, through a collection of representative images. Images can be setting the mood for a product, or displaying example elements from other existing products. Therefore, moodboards are often used to capture the desired feel of such a new product; this is informed by any data gathering or evaluation activities [108].

4.3.7 Focus Group

Focus groups are a form of group interview composed of a trained interviewer and a number of interviewees, normally ranging between three and ten [108], who can provide deep insight into themes, patterns and trends: ideally, this happens when a peer setting is achieved, that is, where the fear of being judged is diminished [48]. In that case, focus groups allow diverse issues to be raised that might otherwise be missed.

4.4 Prototype

In the Prototype stage, artifacts are iteratively generated to help the designer experiment and get to the final solution. It is common practice to begin by producing scaled-down, low-fidelity prototypes that are quick and cheap but can elicit useful feedback [51], so to save the best working solutions and discard the remainder: by iterating, such low-fidelity prototypes get more and more refined until high-fidelity prototypes are created, ready to be tested and evaluated.

4.4.1 Wireframe

Wireframes are a set of documents that highlight the structure, the content, and the controls - constructed at varying levels of abstraction - of interface design solutions [108]. Usually, wireframes are hand drawn or electronic, but in either case they exclusively consist structural, layout elements - e.g. lines and text -, ignoring other visual design elements, such as images, icons or colours. In relation to prototypes, we may say that all wireframes are low-fidelity prototypes, suitable for quick feedback about a design direction [61], but also for illustrating user flows. Wireframes usually embody the step between sketches and *mock-ups*, meant as higher-fidelity representations of a design in terms of look and feel, yet not functional nor interactive.

4.4.2 High-Fidelity Prototype

Main differences between low-fidelity and high-fidelity prototypes have been previously introduced in Section 3.3.3. In essence, high-fidelity prototypes are more refined, often representing the appearance of the final product in look and feel, and sometimes even basic functionality. They become particularly helpful in later phases of the design process, such as during testing, so participants can provide a response based on aesthetics, form, interaction, and usability [48]. In a way, then, we may view high-fidelity prototypes as working, interactive mock-ups.

4.4.3 Wizard of Oz

Wizard of Oz is a low-fidelity prototyping method, often used when dealing with software-based prototypes: normally, the user interacts with the software as though interacting with the product. In fact, however, a human operator simulates the software response to the user [108]. In other words, participants are led to believe they interacting with a working prototype of a system, while in reality a researcher is acting, unseen, as a proxy for the system from behind the scenes [48]. For this project, this method will become of notable help to simulate how smart home appliance prototypes in the outside world will react to changes made through the controls in the MUI high-fidelity prototype, while being tested for evaluation.

4.5 Test

In the Test stage, the designer solicits feedback for the prototypes produced and gets another opportunity to understand their users and possibly redefine one or more further problems. Here it is crucial to ask the right questions: instead of asking whether or not people like the solutions, it is important to continue ask *Why?* [51], and focus on what the designer can learn about the person or improve about the design.

4.5.1 Heuristic Evaluation

A heuristic is known as a rule of thumb, or a generally accurate guideline based on experimental knowledge of how something works best [79]. Heuristic Evaluations are, thus, methods to evaluate a design by means of sets of such heuristics. Hanington and Martin define it as an informal usability inspection method that asks evaluators to assess an interface against a set of agreed-upon best practices, or usability rules of thumb [48]. Unlike usability tests, heuristic evaluations enlist members of a team to inspect an interface to detect baseline usability problems, so that they can be fixed before actual and more effective usability tests can be conducted [48]. A cornerstone set of heuristics for the evaluation of user interfaces was first provided by Nielsen and Molich [96, 92]: such a set of ten heuristics, empirically derived from the analysis of 249 usability problems [91], include *visibility of system status*, *match between system and the real world*, *user control and freedom*, *consistency and standards*, *error prevention*, *recognition rather than recall*, *flexibility and efficiency of use*, *aesthetic and minimalist design*, *help users recognize, diagnose, and recover from errors*, *help and documentation*. However, many other researchers and practitioners have converted design guidelines into heuristics that are then applied in heuristic evaluation [108]. For example, LUMA Institute provide their own set of ten rules of thumb for good design [79].

4.5.2 Usability Testing

Usability Testing is an evaluative method that aims to find empirical evidence on how to improve the usability of an interface, focusing on people and how they walk through the steps of a given task, and providing insights into the mindset and working methods of real users [95]. Usability testing, in fact, involves users, as they will participate and perform the tests. This method should help teams identify the parts of an interface that most regularly frustrate and confuse people so that they can be prioritized, fixed, and retested prior to launch [48]. Regarding the recruitment of participants in a usability test, Nielsen suggests five to eight participants as the ideal amount [94]. Usability tests can be performed under different environmental settings, but they are usually performed in laboratories or in temporarily assigned controlled environments, enabling designers to control what users do [108]. According to Baravalle and Lanfranchi, though, it may be difficult to recruit participants for tests performed in a laboratory, as some people cannot participate due to illness, disabilities, or the test itself being time-consuming; on the other hand, they suggest performing *in loco* tests (or tests performed in a natural setting [108]), enabling participants to perform the test in a real-world environment [12], i.e. the participant's home or workplace, where they will feel more comfortable performing the test. Usability tests typically follow the format of the *Think-Aloud Protocol* (discussed more in depth in Subsection 4.5.4). Furthermore, Hanington and Martin argue that the key to successful usability testing is to require the attendance of developers and project stakeholders at research events, where they can weigh in on usability problems firsthand.

4.5.3 Interviews

Together with a rather thorough description of this method, Subsection 4.1.2 anticipated how interviews can also be beneficial when it comes to evaluating a design. Pernice suggests, indeed, that interviews would be suitable to be conducted at the end of a usability test, to collect verbal responses related to observed behaviors; it is really stressed, though, to defer the interview after the behavioral observation segment of the usability study, otherwise participants would be primed to pay special attention to whatever features or issues included in a question [105].

4.5.4 Think-Aloud Protocol

Think-Aloud Protocol, one of the most common evaluative methods in the usability methods, is a method that requires participants, through its tried-and-true approach, to verbalize what they are doing and thinking as they complete a task during a test, revealing aspects of an interface that are delighting, confusing, or frustrating [48]. According to the LUMA Institute, who refer to this method as think-aloud testing, suggests that this style of evaluation does not just ask for a *play-by-play*, but rather *thought-by-thought* account of an experience [79]. For this project, according to Hanington and Martin's definition, a *concurrent procedure* will be followed, as participants will work through tasks while articulating what they are doing, thinking, and feeling [48].

4.5.5 Cognitive Walkthrough

The cognitive walkthrough is a usability inspection method used to evaluate a system's relative ease-of-use in situations where preparatory instruction or training of the system is unlikely to occur. In these situations, the user must engage with an interface to know what to do, without the need of owning any preexisting knowledge of the system. Cognitive walkthroughs offer a systematic way to identify steps of the interaction that move user closer or further from their goal, so it is possible to evaluate whether each step is more likely to fail or succeed in helping make the next correct decision; obviously, systems that meet these expectations are usually more usuable and learnable [48]. This approach can in fact be considered as an alternative to heuristic evaluation (see Subsection 4.5.1) for predicting users' problems without performing user testing [108].

4.5.6 Questionnaires

As mentioned in Subsection 4.1.3, questionnaires become of particular help not only when trying to empathize with users, but also during the Test phase of a design process, when it comes to evaluating a design solution and collect users' opinions. Here, it is very important to maintain questions as neutral as possible so as not to influence users, but at the same time, ideal answers should be strong answers: in that case, *Likert scales* are highly recommended [48]. One straightforward example of the Likert scale is *System Usability Scale* (SUS), served for assessing usability of a system, originally developed by Brooke for Digital Equipment Corporation, who first defined it as a *quick and dirty* usability scale. This scale answers the need to quantify and measure feedback from subjective assessments of usability; with options ranging from “Strongly Disagree” to “Strongly Agree”, it is considered an effective way of benchmarking a given design against later iterations [79]. Another suitable example is NASA Task Load Index (TLX), a Likert 7-point scale that allows one to perform subjective workload assessments on operator working with various human-machine interface systems. Thanks to NASA TLX, an overall workload score based on a weighted average of ratings on *mental demand*, *physical demand*, *temporal demand*, *performance*, *effort*, and *frustration* can be derived [49].

5

Design Process

This Chapter describes the entire process conducted throughout the project, and focuses on presenting outcomes and events that sequentially occurred over the direction of three main design iterations, including the different design methods applied. Figure 5.1 illustrates how the different iterations were conducted throughout the entire project: as one may observe, this visualization highlights how the five-stage design process model adopted was followed more as a guide, rather than as a constraining factor to be strictly followed during the project.

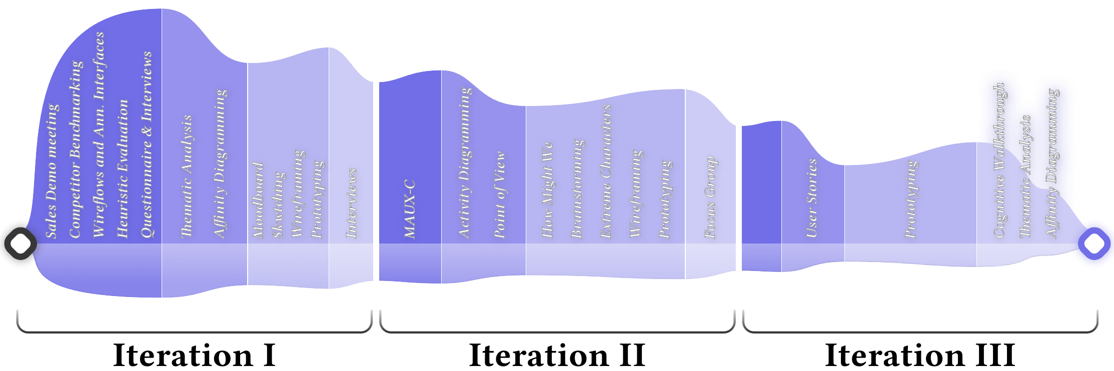


Figure 5.1: Visualization of the entire project's design process: in a *double diamond* perspective, this visualization shows how subsequent design iterations helped converging towards a final design solution.

5.1 Iteration I

In this Section, the first iteration in the project - heavily focused on research, as shown in Figure 5.2 - is analyzed.

5.1.1 Empathize

After carefully reviewing and studying relevant literature about home automation within the Human-Computer Interaction domain and theory on designing mobile user interfaces (or MUIs) in the form of frameworks and guidelines - to acquire some general background on the field –, it was about time to start familiarizing both with The Company's current product offering (see Section 2.1.1) – mainly focused on the smart lighting segment, and consisting of input buttons, smart plugs, pucks, and the

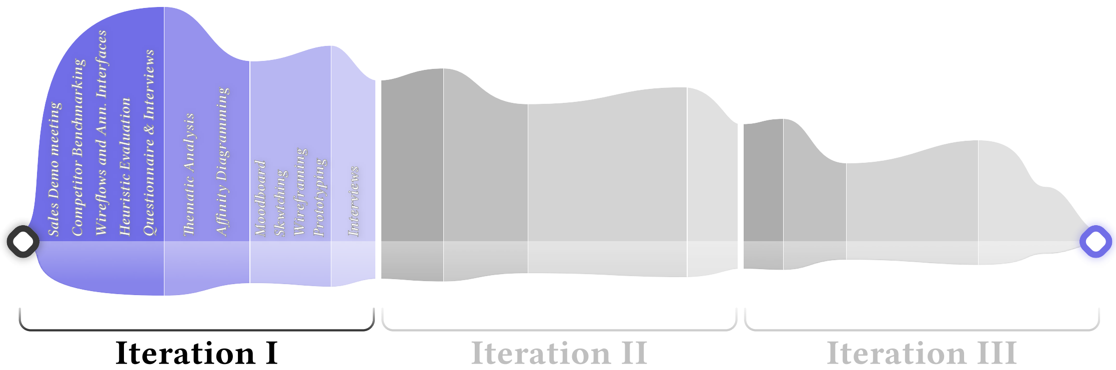


Figure 5.2: Visualization of the first iteration within the entire project's design process.

gateway – and with The Company's app (see Section 2.1.2), offering users to set up, manage or even control devices in their own environments connected over Bluetooth or the Internet. Such phase of familiarization with The Company's ecosystem was accomplished by getting involved through different angles.

Sales Demo meeting

At the beginning of the project, The Company offered an initial Sales Demo meeting; there, I got introduced to an overview on the whole Company's current product portfolio by a representative from the Sales team. Each single device was meticulously presented, getting into very technical details, at times. For instance, some of the lights being offered are capable of varying in colour temperature that – measured in Kelvin – usually ranges between 2700K to 6000K: the lower the number, the warmer the while light appears, whereas a higher Kelvin will make the light appear cooler. Otherwise, another example of technical information ties to the different voltage some of The Company's devices would have, depending on its destination country and/or market; or, again, the fact that input buttons - i.e. The Company's wireless wall *push switches* and *rotary buttons* - have a life cycle of about 15 years, as they're battery-powered and make use of Bluetooth technology.
Beyond such information, to cover and dig deeper on the most important use cases and views of the app, a quite exhaustive app walk-through was given by the Sales rep. It was shown, for instance:

- how to set up a *system* - i.e. the environment in which devices will be installed - from scratch, how to browse through them, if owning multiple ones, and how to invite other users to a system as *owner*, *user* or *installer*;
- how to add, control, edit, access advanced settings or remove devices in a system;
- how to add, edit or delete rooms in a system;
- how to set up scenes - i.e. specific mappings for one or more devices grouped together - in a system;
- how to configure input buttons and pair them with lights and/or scenes;
- how to create scheduled events, either based on custom absolute times or

depending on the daily-varying sunrise and sunset times[1];
- how to enable (and disable) a specific mode to automatically turn off or dimming - i.e. changing the brightness level - selected lights, mimicking the behavior of someone being home[2].

Overall, from an interaction design stand point, the major takeaways regarding the whole product ecosystem can be summarized as it follows:
- lights may embed either just the `ON` and `OFF` states or be dimmed to intermediate levels, and can be controlled both through the app or physical input buttons;
- lights may come either with a fixed or a variable colour temperature that can be controlled through the app;
- overall simplicity for electricians setting up and pairing devices with the app - or even supporting clients remotely: to give an example, unlike competitors' pucks - needing electricians to physically manipulate screws to adjust properties, such as dim speed -, The Company's pucks offer the big advantage to make adjustments on the puck right from the app;
- overall simplicity for end-users controlling and managing devices installed in their own environments via the app: for example, as a complement to the controls available in the app, users may set up integrations with smart home software frameworks (see Section 2.2.3), such as Google Home, to enable voice controls.

(a) Rotary button **(b)** Toggle switch **(c)** Rocker button

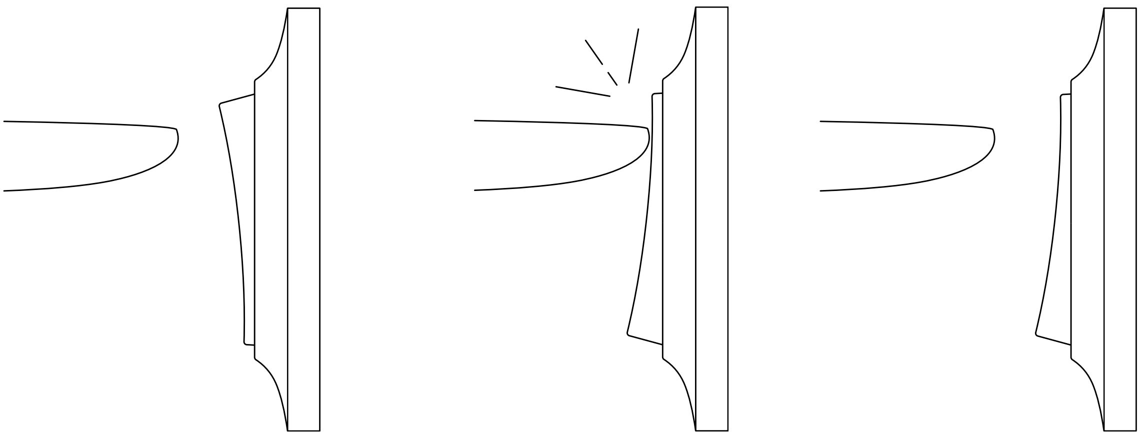
Figure 5.3: Instances of traditional *rotary buttons*, *toggle switch* and *rocker button switches*.

By definition, 'traditional' versions of these toggle and rocker button switches only present two states - i.e. `ON` and `OFF` - so they can either be pushed on the upper or on the lower part of their surface, and always indicate their current setting (see Figure 5.4). As Saffer observes, switches often make such setting easier to be determined at a glance, on physical devices [116].

Thus, if such buttons were to be bounded to a home automation app, a tension emerges on a consistency level: no matter how many times a light will be turned

[1] to have this feature up and running, a geographic location needs to be assigned to the system on the app

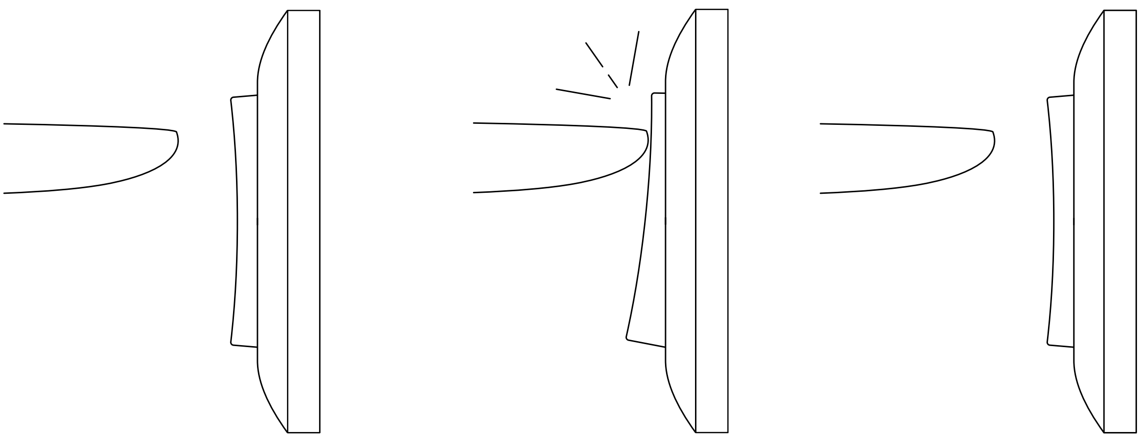
[2] this feature is likely needed when being away from home: in that case, a gateway needs to be installed in the system, so to establish a connection with the system over the Internet



(a) Before interaction **(b)** On interaction **(c)** After interaction

Figure 5.4: Illustration showing state of a *traditional* button switch before, on and after interaction for the example use case of turning on a light.

`ON` or `OFF` through the app, the physical corresponding switch will only have 50% chance to coherently represent the right state, as it will not update accordingly to the changes in the app. The 'smart' button switch offered by The Company, designed with home automation in mind, solves this problem by just adding what we may define as third, *idle* state, as neither the `ON` nor the `OFF` states are maintained once the button is pressed and released (see Figure 5.5).



(a) Before interaction **(b)** On interaction **(c)** After interaction

Figure 5.5: Illustration showing state of a *smart* button switch before, on and after interaction for the example use case of turning on a light.

To explain this contrast between traditional and 'smart' button switches in a different way, we may adopt physics and engineering terminology to describe concepts of *plasticity* and *elasticity* in *deformation*: if deformation is our microinteraction of turning `ON` or `OFF` a light, we may see traditional button switches as enduring a plastic deformation, as the final position does not recover to the original one upon unloading - i.e. when the user releases their finger - and is therefore permanent; whereas 'smart' button switches experience an elastic deformation, so their original position is recovered immediately upon unloading [31], preventing inconsistency between the state represented in the button switch and the one represented in the app.

	IKEA Home Smart	Philips Hue
Scenes	+ *All off* button − can access only first three scenes listed in Home view	+ possible to see what scene is active + pre-labelled scenes + offers scenes gallery (useful for colour lights) − not directly accessible from *Home* view + belong to *Rooms* or *Zones*
Scheduling	+ pre-labelled schedules (e.g. *rise and shine*, *away from home*) + sunrise and sunset integrated as available time options + *ON/OFF* pre-labelled schedule	+ pre-labelled schedules (e.g. *wake up*, *go to sleep*) + location-based (e.g. *coming/leaving home*) + sunrise and sunset integrated as available time options + provides randomized time options
Areas	− too general, doesn't provide pre-labelled environments	+ provides different concepts of areas (e.g. *zones*, *entertainment area*) + pre-labelled environments (e.g. *living room*, *kitchen*, etc.)
Environments	− no way to switch between environments, need to disconnect from one in order to connect to another	+ user can switch between environments they're in
General	+ doesn't need account + provides different ways to reach certain views (e.g. *shortcuts*) + provides collapsible dropdown lists/objects + group's dim slider represents average dim from individual lights − useless, obstructive splash screen (e.g. *Connecting to your gateway...*) − needs user's phone being connected to same WiFi network in order to work	+ doesn't need account + provides different ways to reach certain views (e.g. *shortcuts*) + left/right-hand mode to change light setting controls + provides collapsible dropdown lists/objects − replaced iOS widgets with shortcuts
Interactions	+ allows *swipe* shortcut gesture for *Go back* interaction	+ allows swipe shortcut gesture for *Go back* interaction + allows *Drag & Drop* interaction to order/sort objects + tap to turn on/off lights, slide up/down to dim (button becomes a slider)

Table 5.1: Major key points emerged during Competitor Benchmarking.

Competitor Benchmarking

The Company gently offered to provide me with products to try amid the whole period of the project: not only products from the company itself, but also products from two major competitors within their market segment - IKEA and Philips - so

to take an in-depth look at their apps, respectively *IKEA Home Smart* and *Philips Hue*, and ultimately compare them, trying to find and highlight who's doing better in whatever aspect of the app, what are their strengths and weaknesses, hence what can be taken as inspiration - or to differentiate from -, for a future version of The Company's app user interface, that might also be compared with such apps, eventually. Apps such as *Apple Home* and *Google Home* - belonging to the *Smart Home Software Frameworks* sphere (see Section 2.2.3), usually integrated in mobiles to act as a bridge between their operating system and third-party products - were also briefly tried out and tested: however, due to their nature being conceptually different from apps directly offered by third-parties, they were not really included within the more accurate analysis conducted for The Company's, IKEA Home Smart and Philips Hue apps. While experiencing such products in my daily life - in both my domestic and work environments - over a time span of about two weeks, various emerging, interaction-related facets of the apps were marked down. Below, Table 5.1 synthetizes major key points from the apps by IKEA and Philips in comparison to The Company's one, listed with a positive or negative symbol when interpreted as strength or weakness points.
At the end of such exercise, average ratings of the three apps under scrutiny - The Company's, IKEA Home Smart and Philips Hue - were taken from the two major application stores, compared with each other and summarized on Table 5.2.

	The Company's	IKEA Home Smart	Philips Hue
Apple App Store *as of February 20th, 2022*	4.3/5 ★★★★☆ 309 reviews	4.2/5 ★★★★☆ 2,709 reviews	4.5/5 ★★★★½ 40,599 reviews
Google Play Store *as of March 7th, 2022*	4.3/5 ★★★★☆ 432 reviews	3.7/5 ★★★½☆ 21,679 reviews	4.4/5 ★★★★½ 92,115 reviews

Table 5.2: Average ratings taken from the main applications stores - Apple App Store and Google Play Store: *The Company* app's ratings were acquired from the Swedish stores, whereas *IKEA Home Smart*'s and *Philips Hue*'s were acquired from the American stores.

Moreover, a table on *Google Sheets* was framed to note down and compare, among the three apps under scrutiny, whether a certain activity could be performed starting from a specific section of the app and, if so, what would be the amount of microinteractions needed to carry out such activity or to reach a specific view. This included a comparison between the names given to the sections the apps are composed of, whenever a section of an app was relatable to a section of the others. To provide with some example, an excerpt of the table is shown on Table 5.3. Here, *one-interaction* tasks - such as turning a light on - are included in the count; for *multiple-tap* tasks, instead, the count stops at the first microinteraction that allows to continue performing the task: for instance, if we are to rename a light, the count will stop once the user taps on the *Rename* button, before the actual activity of renaming takes place.

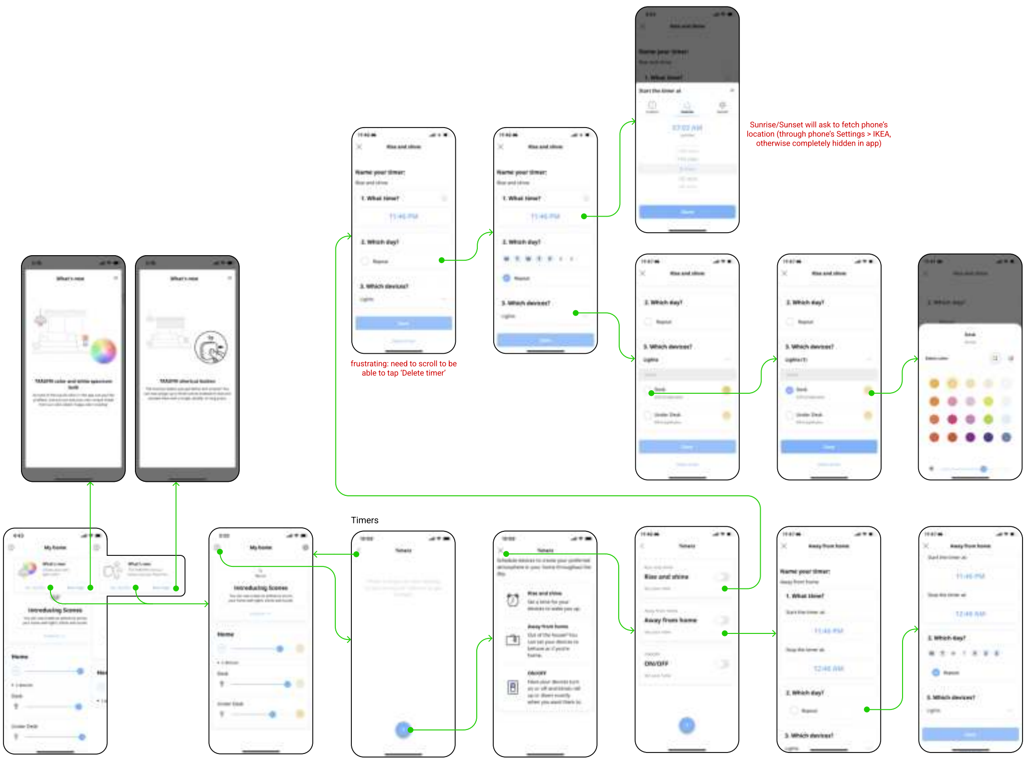
	The Company's	IKEA Home Smart	Philips Hue
Home	*(overview of rooms)*	**My home**	**Home**
turn on/off rooms	1t	1t	1t
order rooms	1dd	4t	1dd
access devices in rooms	1t	1t	1t
order/sort devices in rooms	3t	3t + 1dd	1t + 1dd
turn everything off	N/A	1t	1t
Settings	**Settings + User Sett...**	**Settings**	**Settings**
add devices	2t or 1s + 1t	2t	2t
devices	2t or 1s + 1t	3t	2t
change email / password	3t or 1s + 2t	N/A (no account needed)	N/A (no account needed)
change language	3t or 1s + 2t	2t	N/A
privacy policy / terms of use	4t or 1s + 3t	3t	3t
Scenes	**Scenes**	**Scenes**	**Automations**
activate	1t	≥ 1t	2t
create	3t or 1s + 2t	2t	3t
remove	4t or 1s + 3t	3t	4t
rename	5t or 1s + 4t	4t	4t
Scheduling	**Scheduling**	**Timers**	**Automations**
create schedule event	3t or 1s + 2t	2t	3t
delete schedule event	4t or 1s + 3t	3t	3t
rename	4t or 1s + 3t	N/A	3t
repeat	4t or 1s + 3t	3t	3t
Areas	**Rooms**	**Groups**	**Rooms + Zones**
create	3t or 1s + 2t	4t	3t
delete	5t or 1s + 4t	5t	3t
rename	4t or 1s + 3t	5t	N/A
order/sort	1dd	4t + 1dd	2t or 1dd
assign area typology	4t or 1s + 3t	N/A	4t
change picture	5t or 1s + 4t	N/A	N/A

Table 5.3: The amount of interactions needed to reach a specific view or to perform a specific activity in the apps. Key: tap = *t*; drag & drop = *dd*; swipe = *s*.

Wireflows and Annotated Interfaces

In parallel with the competitor benchmarking activity, described above, wireflows covering the main use cases of the apps under scrutiny - The Company's app, IKEA Home Smart and Philips Hue - were developed on *Figma*. This activity, mainly consisting of taking great amounts of screenshots of the different apps and rearranging them in a meaningful sense, illustrating the information architecture of the apps, helped me getting a general overview of the apps being analyzed, but also helped going back to specific views whenever I needed to during the project, without the hassle of looking for a specific screen by actually browsing through the app. In certain cases, interfaces in wireflows were complemented with annotations, elaborating on some specific steps that needed to be explained or on interactions that resulted in frustrating experiences. Figure 5.6 depicts the instance of wireflows being produced for the IKEA Home Smart app.

(a) Overview of IKEA Home Smart's wireflow



(b) Detail of IKEA Home Smart's wireflow

Figure 5.6: **(a)** Overview and **(b)** detail of the example wireflow, with eventual annotations, of the IKEA Home Smart app, analyzed under competitor benchmarking.

Heuristic Evaluation

After getting in the boots of users for a couple of weeks, thanks to the performing of competitor benchmarking, an evaluation method - Nielsen's heuristic evaluation (see Section 4.5.1) - was conducted. According to the five-stage process model being used in this project, we may intuitively imagine that such method, due to its evaluative attribute, should be most appropriate to use within the final stage, i.e. *Test*. However, as the project revolves around an already existing product - i.e. The Company's app - and as it was assumed important to first understand and analyze it before actually starting to iteratively design upon it, the heuristic evaluation was considered appropriate to conduct at this point. More specifically, the evaluation was conducted on my own, based on the app's wireflows.

Out of the heuristic evaluation we may observe how the current version of The Company's app is already doing pretty well in terms of usability, as could be assumed by quite encouraging ratings given by users on Google's and Apple's app stores (see Table 5.1). Yet, some minutiae may be found.

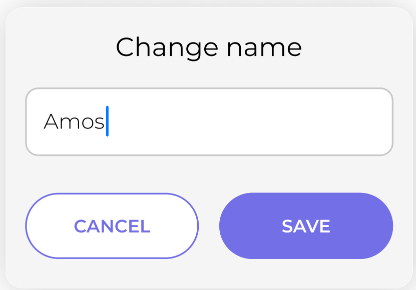
One aspect that may be examined relates to the heuristic of *match between system and the real world*: if we think about The Company's overall ecosystem of products offered, each product model is systematically named through monikers, usually getting in the form of 3-letter abbreviations, followed by a two-figure number; this makes it hard to understand, especially for newbies, what product a moniker refers to. One way to solve this, then, is to complement such moniker - which identifies the exact model of a product - with some descriptive words, actually describing what product we're talking about. Reasonably, with the introduction of new products in the future, this problem will risk becoming more and more relevant, getting users more confused; however, this may be considered as a peripheral matter for the scope of the project, as it's not closely related to the app user interface under scrutiny.

Going more in-depth in the app, instead, if we get to consider the Nielsen's first heuristic about *visibility of system status*, we can't really determine whether a scene is activated or not just by the app; this feature is available, for instance, on the Philips Hue app. Moreover, according to the heuristic of *user control and freedom*, there's not really an *Undo* button: however, being in the context of controlling devices in smart environments, this may be assumed to be not as relevant, since users may simply get to a previous system status by just pressing on a toggle switch or re-adjusting a slider. In fact, by triangulating such assumption with the analysis coming from the competitor benchmarking, we may observe how other apps don't contemplate such possible interaction as well.

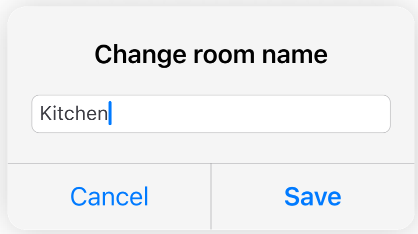
Most of the attention, though, should be paid to the heuristic of *consistency and standards*. One, first aspect relates to the positioning of buttons in the *Remote Control* view, within the *Gateway* settings section. Here, in fact, a redundant *"Close"* button is shown on the bottom right, whereas any other view in the app correctly shows such button in the navigation bar, on the top left - as Apple's Human Interfaces Guidelines regulate[3] (see Section 2.3.1.1) for actions like 'closing' or 'going back'. What makes the *"Close"* button on the bottom right especially redundant

[3]Apple's Human Interface Guidelines were taken as reference, as the whole project revolves around designing for iOS

is the fact that a *Back* arrow is correctly positioned in the navigation bar, performing the exact same action, if tapped. Another standard, according to Apple's Human Interface Guidelines, recommends to *"offer shortcut gestures to supplement interface-based navigation and actions"*: for instance, it is quite common to let users swipe right to navigate back. Such shortcut gesture is supported only in the home screen, as anticipated in Figure 2.1, so the app does not support the same shortcut gesture to navigate back, for instance. We may, then, observe a visual inconsistency of interactive dialogs among different sections of the app: if the user wants, for instance, to change their name, a dialog looking like the one in Figure 5.7a appears, visually consistent with the rest of The Company's style; if the user opts for renaming a room, instead, a native iOS dialog - what Apple defines this idiom as Alert - appears, illustrated in Figure 5.7b.



(a) Dialog visually consistent with The Company's style



(b) Native iOS Alert idiom

Figure 5.7: Dialogs throughout the app are sometimes visually inconsistent with each other.

Another aspect relates to the microcopy: throughout the different views in the app, for example, we may find options for removing instances of an item, be it a device, a scene or a room. Sometimes, the verb describing the action of removing is actually *"Remove"*, whereas some other times we may find *"Delete"*; to provide with another example of reparable microcopy, we may consider the *"Turn on"* and *"Turn off"* terms used when scheduling an event, asking for two specific times for such schedule event to begin and stop working. These terms may get quite ambiguous, especially for situations where the user would like to set up an event to keep devices `OFF` between two times. A solution to this would be replacing those terms with more appropriate ones, i.e. *"Start at"* and *"End at"*, just as it happens both on IKEA Home Smart and on Philips Hue. Also in the scheduling section, devices that really cannot be described as *"lights"* - i.e. a water kettle plugged to a smart plug - are expressed as such. One further aspect to consider is the advanced setting offered to set the minimum dim level of a light: here, the app provides two buttons, one for increasing and one for decreasing the percentage value. Just as it works anywhere else in the app, it would arguably make sense to have a slider, as being a more common interface idiom for such interaction.

Shifting towards the *flexibility and efficiency of use* heuristic, one major feature lacking in The Company's app is shortcuts. The app, in fact, does not enable users to access devices' settings directly from the rooms visualized in a list within what we may call *home view*, like Philips Hue does, for instance: devices listed in the home view, in fact, can only be controlled through toggle switches and eventual dimming sliders, but cannot be tapped to directly access their settings, i.e. to change their names, the room they're assigned to, to get device details, to restart, or even to remove them. Another somewhat relatable aspect to this heuristic is the amount of *granularity* conceded to dimming sliders and the haptic feedback they provide: dimming sliders can, in fact, be changed by even a single percentage unit. Despite the arguably nice-to-feel haptic feedback happening on each single percentage being slid, we may argue that it doesn't really bring value to the interaction; what if, instead, we would enable the same haptic feedback anytime we reach rounded percentage values (e.g. 10%, 20%, 30% etc.)? That would allow users, while interacting with the slider, to be aware of the approximate percentage to which a light is being dimmed, allowing them to focus on the actual light dim in the environment without having to look at the phone. For example, if a slider is initially set to the minimum and the user, by increasing it, feels a stronger haptic feedback for three times, they will know the dim is now set to a percentage value somewhere between 30% and 40%; what they really care is the final result in the room, so that's where they may want to put their focus on.

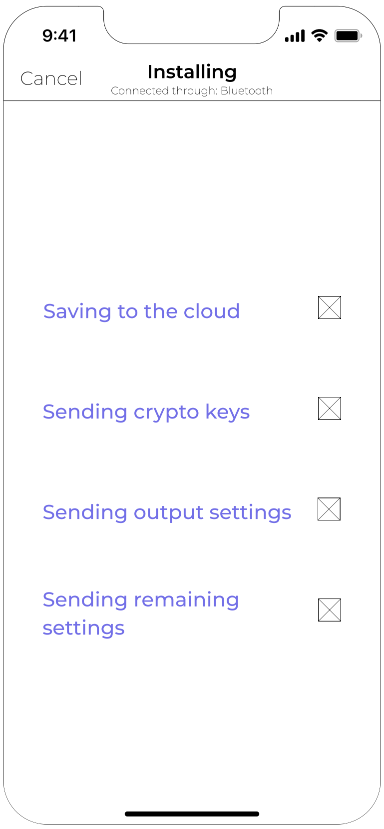


Figure 5.8: Final installation steps while installing a new device in a smart environment.

Finally, one consideration may be done around the *aesthetic and minimalist design* heuristic: some transition screens, in fact, may be considered not as relevant. To provide with an example, Figure 5.8 illustrates a screen showing the configuration steps being completed. We may say, in a way, that such steps can just happen in the background, hence completely skipped out from the interface As The Company's app is used both by end-users and installers, though, it may be argued that such screen would be essential for installers to have.

User Research

One essential step in a design process is of course *user research*, necessary for having a better understanding of people in the contexts in which they live or work. The term refers to the data collection and analysis activities necessary to characterize users, their tasks and the context of use before the actual product development begins, and is suggested to be conducted at the beginning of a project, or even before it begins [108]. Interviews and questionnaires were planned to be conducted for user research; before that, though, participants needed to be recruited. Therefore, an initial recruiting questionnaire was prepared and sent out to different teams within The Company (see Appendix B): such questionnaire was aimed to ask people not only to take part in research questionnaires and interviews to kick-off the project, but also in possible participatory activities and final usability tests. In the end, eight people - all users of The Company's app and all working in different teams within The Company - volunteered to participate in such activities spread throughout the project: Table 5.4 summarizes some of participants information gathered with the recruiting questionnaire.

Participant	Platform	Expertise *(1 to 5)*	User Category
Participant #1 ***(P01)***	Android	Expert *(5/5)*	End-user
Participant #2 ***(P02)***	Android	Intermediate *(3/5)*	End-user
Participant #3 ***(P03)***	iOS	Proficient *(4/5)*	End-user
Participant #4 ***(P04)***	Android	Proficient *(4/5)*	End-user
Participant #5 ***(P05)***	iOS	Expert *(5/5)*	End-user & installer
Participant #6 ***(P06)***	Android	Intermediate *(3/5)*	End-user
Participant #7 ***(P07)***	Android	Proficient *(4/5)*	End-user
Participant #8 ***(P08)***	Android & iOS	Expert *(5/5)*	End-user & installer

Table 5.4: Participants' general information gathered through the recruiting questionnaire. The *Platform* column indicates what operating system they're most familiar with, whereas the *Expertise* column illustrates what they deem is their expertise level when using smart home apps on smartphones.

User Research - Questionnaire

Once participants were recruited, a first research questionnaire - prepared on *Google Forms* - was sent out (see Appendix C): the questionnaire mainly included general

questions about The Company's app and their experience with it, but also whether they ever used other home automation apps, such as IKEA Home Smart or Philips Hue. For instance, it was asked what they liked most and least about The Company's app, which feature they used the most, for which goals and whether their goals were fulfilled by using the app; other questions included whether there were features that felt as needed but missing, whether they experienced any situation in which the app has been particularly useful in the last weeks, and what their thoughts were about the app in terms of strength and weakness points. A few questions focused on how they would rate various aspects of the app, such as navigation, overall experience, overall interface and intuitiveness. To conclude, the ten System Usability Scale (SUS) sentences [17] were also proposed: such sentences, though, are formulated in a way that is most appropriate asking right at the end of an evaluation study, such as a usability test; therefore, all ten sentences were reformulated keeping into account the nature of the questionnaire. For example, if the third sentence was originally *"I thought the system was easy to use"*, it would now become *"I think the app is easy to use"*. The reformulated sentences are included in Appendix C, as well.
If we now consider results from questions with a more quantitative perspective, out of eight people filling out the questionnaire, we may report an average rating for the navigation of the app of about 4.13 (out of 5), 4 (out of 5) for the overall experience, 4.25 (out of 5) for the overall interface and 4.5 (out of 5) for the intuitiveness of the app. When asked what features are most frequently used - apart from simply turning on or off a light - *scenes* is the feature being mentioned the most (6 occurrences); the list then follows with *dimming* (5 occurrences), *schedules* and *integrations* (4 occurrences), and *widgets* (3 occurrences). According to the System Usability Scale, instead, here are the resulting scores coming from each of the participants: 97.5 from *P01*, 55 from *P02*, 67.5 from *P03*, 82.5 from *P04*, 80 from *P05*, 80 from *P06*, 77.5 from *P07* and 80 from *P08*, for an average score of 77.5; if we consider 68 as average SUS score in research [126], we may outline a quite positive result determining The Company's app usability. This demonstrates how good the product under analysis within this project is already from the beginning: in a way, then, we may allege how important is within the project to maintain all the qualities the app embodies, rather than trying improving them. However, even though SUS is said to be fitting small sample sizes and yet achieve reliable results [126], according to Usability.gov, it is quite appropriate to warn about the small sample size used to get more quantitative metrics; as briefly discussed in Section 3.3.3, quantitative methods usually require significant amounts of participants in order to obtain reliable results. Answers of a more qualitative nature will instead be discussed together with results coming from the follow-up interviews.

User Research - Interviews

To complement with the first questions being asked in the research questionnaire, in fact, follow-up interview sessions were planned with all eight participants, to be conducted individually and in-person, each during about 45 minutes. Right before conducting the session, an informed consent form was sent to participants - available in Appendix D) over *Google Forms*, anticipating what the interview would be about, that it would be recorded (audio only) for automatic transcription, and the data collected would be used for research purposes, without disclosing the participant's identity, only and would be stored for a definite amount of time, before it would be permanently deleted. A more elaborated discussion of considerations about the informed consent is provided in Section 7.4. Interviews were planned to be conducted in a semi-structured way, so a set of questions was prepared beforehand - yet being free to ask probe questions all along the session -, available in Appendix E. Initial questions focused on asking when the participant started using The Company's app, how long it took for them to learn how to effortlessly work with its interface, and how often they would use it throughout the day. More in-depth questions, then, investigated the participant's usage of specific features, such as widgets, scenes, integrations with software frameworks (e.g. Google Home, see 2.2.3), and scheduling events, and for what activities such usage would be performed; other questions were focused, instead, on possible user needs, such as the grouping of devices or rooms, or a shortcut scene that would turn on or off every device in the environment. To conclude, questions about aspects emerging from the heuristic evaluations were asked, as well. To get a general overview on how the users' mental model would work while navigating through the app, a very brief usability test was included in the interview, e.g. asking to rename a light positioned in a specific room; that also resulted in being a nice opportunity to give participants a taste of what the final usability tests on the prototype would be about.

Once interview sessions were conducted, automatic transcriptions - provided by a service called *Otter.ai* - were refined and ultimately analyzed through a thematic analysis, together with qualitative answers coming from the initial questionnaire. Major takeaways from this analysis will be presented in the next, *Define* section (see Section 5.1.2).

5.1.2 Define

As soon as the first bits of knowledge and understanding on The Company's products and app were acquired, it was time to move on towards a synthesis of the emerging insights - coming from the information gathered - with the purpose of making a sense out of them.

Thematic Analysis

Following a natural process, user research - composed of the questionnaire and an interview with participants - was followed by a thematic analysis, performed on the digital tool *Miro*, trying to uncover themes in the data by exploring similarities and relationships between the different chunks of data. After having transcripts being entirely read through, relevant and insightful parts were highlighted: in the phase of highlighting such sections, codes suggesting different recurring themes started to emerge already, so the highlighting activity continued by using various colours, depending on the themes that were believed as emerging, written down on virtual sticky notes. After that, answers in the transcripts were reorganized and grouped together by question; to remember what transcript any of the answers came from - hence which participant gave that answer - a note of the participant number was made on each answer. To provide with a glance to an overview of the board, Figure 5.9 is presented below.

Figure 5.9: Overview of thematic analysis' process of coding and regrouping questions being answered by participants.

Affinity Diagram

The ideal method to follow a thematic analysis is definitely affinity diagramming. As anticipated in *Methodology* (see Chapter 4), in fact, affinity diagrams are suitable to be used in combination with thematic analyses, as the identified themes may then be grouped by being visually structured and hierarchically organized. Figure 5.10 portrays the resulting affinity diagram, summarizing the the main themes and insights identified in the thematic analysis (see Section 5.1.1).

Qualities was arguably the first emerging theme: by virtue of earlier questions in the interviews, participants expressed their thoughts and impressions about their personal experience with The Company's app, mostly of positive sort. The app, indeed, was perceived as intuitive, easy to use, with a self-explanatory user interface to make the user feel in control and perform simple basic tasks; on top of that, the app was felt as quick to learn, requiring just little cognitive effort, and versatile as it afforded customization, to some extent.

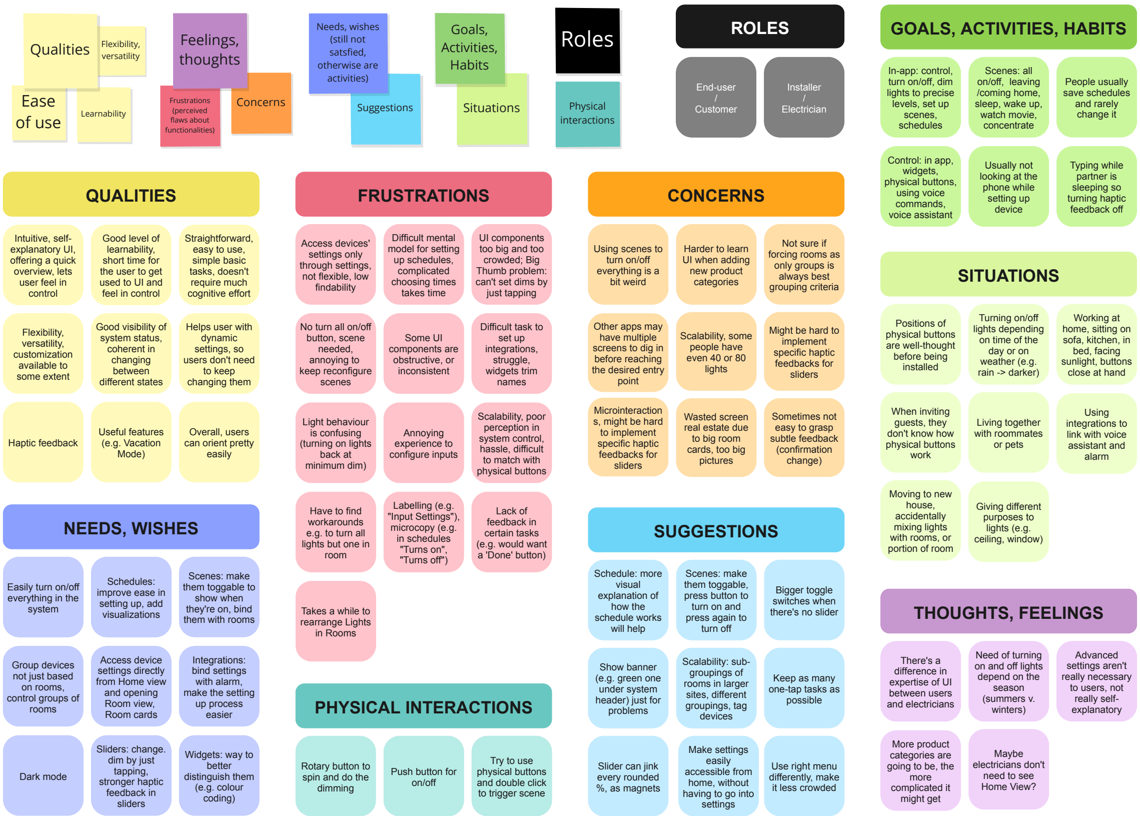


Figure 5.10: The affinity diagram resulting from the thematic analysis activity.

> *"It's easy to understand what's going on in my apartment and it requires little time to do what you want"* (P01)
>
> *"I think the basic parts were really straightforward [in the beginning], like how to turn lights on and off"* (P04)
>
> *"The interface was pretty self-explanatory"* (P05)
>
> *"I like that you can choose pictures for rooms, and it suggests names and stuff, which is very handy"* (P06)

Apparently, though, it wasn't just all fun and games as it seemed, as another major theme found during analysis is *Frustrations*: here, participants complained about various aspects of the app. To provide with a few examples, devices are felt as not easy to find in the app, especially if belonging to an environment with a considerable amount of devices, and their settings can only be accessed through settings; setting up integrations and schedules are felt as complicated and tricky tasks; some UI components may be either too big or too small, making the app crowded and resulting in the *big thumb* problem, whereas others may even be obstructive; it takes time to rearrange devices in rooms; also, as an environment scales up, the perception in system control gets poorer and poorer. Just as observed in the heuristic evaluation, some frustrations emerged when considering the mere interaction aspect with the app, and more specifically the lack of specific shortcut gestures, such as the swipe-right gesture to let users navigate back in menus: in fact, when asking them how they would do that, letting users accomplish themselves the task of navigating back, the main answer would be ‘I would press on *Back*’; however, while observing, they would unconsciously try out shortcut gestures, as they’re used to work with in other mobile apps, and realize that afterwards.

“The app makes you kind of go through more stuff than needed. [...] I’ve accidentally clicked on load settings when I was like trying to look into something else. [...] It’s annoying having to go back and reconfigure a goodbye, you always need to add new products. [...] If I want to put a scene, this accidentally goes up... [taps on home button]” (P03)

“I have like 80 devices, it’s a nightmare to try to get them in the app. I kind of avoid using scenes because of that.[...] It’s very hard to tap on the edges [of the slider] to jump back and forth, can only slide” (P05)

‘I think you need a person to help you set up schedules... I think it’s very tricky. [...] If you change load types, the app deletes scenes linked to it, depending on what load type you pick” (P08)

“I think I’m not so used to it [to swipe right to go Back], since I’m usually not going to any menus, but yes that’s... Uh yeah I do! I do try to swipe back! I didn’t think about that...” (P03)

Concerns is another theme, as participants manifested when being asked what their thoughts would be in regard of possible design solutions or possible directions the app may take in the future: for instance, particular sensitivity was demonstrated towards scalability - i.e. managing a large amount of devices in a smart environment -, towards learnability of a UI when adding new product categories, or even the risk of them affecting the size of room cards; other concerns dealt with downside effects of possibly having toggeable scenes, how devices can be grouped, or even with possible implementation issues when thinking about haptic feedback on sliders.

“It might be hard to implement specific haptic feedback for sliders” (P01)

“I’m afraid the UI will be harder to learn once we will add the new products. [...] I’m not sure how much people will know that you can long press [a button] to have 2% increases.[...] I think... too much wasted space for images in room instances” (P04)

A further theme was generically named *Thoughts & Feelings*, as some thoughts were just of general nature: these included the assumption of end-users and installers having different expertise of the UI, that some of the advanced settings aren’t really necessary to end-users, or that the activity of turning `ON` or `OFF` lights depends on the season. Two other - rather overlapping - rising themes were *Needs & Wishes* and *Suggestions*, as participants imagined how various sections of the app could take form: for instance, it was suggested to have some more visual explanation of how a defined scheduled event would work, to add a default `"All ON/OFF"` scene, to keep as many one-tap tasks as possible, to make device settings available directly from the home view, or to allow for grouping of rooms and assigning tags to devices. On the side of needs and wishes, instead, participants would simply like to have a dark mode, or have an enhanced integration with tools such as Google Home, so to link settings to the alarm.

"Grouping rooms might be useful, especially in larger sites maybe" (P01)

"A more visual explanation of schedules would help" (P02)

"Choosing the times for schedule events is not so smooth and it takes time, so I ended up giving up. Ideally I would like to link it to my Android alarm app" (P03)

"It would actually make sense to have a preset scene that says 'all off' or something like that" (P04)

"Some kind of functional groups might be good. Maybe it's like... if you have different things tagged in different ways that's basically the same thing as having groups, but you can tag 'window lamp' as 'ambient'." (P07)

Two other emerging themes were identified: the insightful *Goals & Activities* and *Situations*. Here, participants reported both activities that could be achieved by interacting with the app or directly with the smart environment (e.g. using voice commands), but also activities in their daily life. We may find, for instance, controlling devices, so turning them on and off or dimming lights, but also setting up scenes, schedules, or looking for a device; common scenes are labelled as *all 100%*, *leaving home*, *coming home*, *going to bed*, *wake up*, *watching a movie*, *concentrating* and *hoovering*. A more interesting activity relates to how users, while setting up a device, usually don't look at the phone even though they're interacting with it. Common situations, instead, include working at home, sitting on the sofa, eating in the kitchen, or having physical buttons at the ready. It is then worth to mention the need of turning on a light, actually depending on on the time of the day and on the weather. More interesting situations, however, may happen when living in a multi-user environment, such as living together with roommates or pets, or when moving to a new house, so devices may be accidentally be mixed and do not match with the old rooms saved in the app. Again, further relevant situations may verify when guests are invited at home, and they don't know how the physical buttons work.

"I usually don't look at my phone while I'm dimming [through the slider], I look at the lights" (P01)

"I recently moved and I took some of the products with me and mixed them so then they were in the wrong labelled room" (P03)

"I turn off everything when I leave or when I go to bed, otherwise I set a cozy light to sit on the sofa and watch movies" (P04)

"I schedule lights with the astronomical clock feature, depending on how dark it becomes... you know, there is some difference between summers and winters" (P05)

"I wanted a cozy yellow and warm light, so then I could save it as a concentration scene, or for other activities like hoovering or something" (P06)

"I have a plan for when we're moving to a new house and we're gonna have lots of products" (P07)

Finally, two more "peripheral" themes may be identified: *Roles* and *Physical Interactions*. Quite obviously, the roles indicate the two major categories of user, i.e. end-users and installers. Physical interactions relate to interactions accomplished with The Company's wall input buttons hardware, also presented earlier, i.e. the dimming a light by rotating a rotary button, or turning it `ON` or `OFF` with a push button switch through a single click or triggering a scene through a double click.

5.1.3 Ideate

Once the first stages of Iteration I's process were concluded, aimed to grasp some insightful knowledge about users' thoughts on The Company's app, the *Ideate* stage followed, trying to materialize such acquired knowledge into visual means.

Moodboard

To kick-off the Ideate stage in the process, the creation of a moodboard was deemed as fitting, in order to get myself - within the role of the designer - in the right mood towards designing for smart environments. The output of the moodboard, visible on Figure 5.11, gathers images and themes relevant to the domain of home automation systems as well as to the development of MUIs: it shows off, for instance, frames from Apple keynote events - depicting usual home activities and common interactions between users and smart home appliances, such as lights, thermostats, blinders, door locks or even smart speakers, enabling voice control. Other images represent common MUIs, such as Philips Hue or Apple Home, but also the so-called *thumb zones*, indicating the different portions of a mobile's screen real estate that are easy v. difficult to reach, or even a graph, illustrating the various kinds of scenes a user may want to have at disposal in a daily routine fashion.

Sketching

Once everything was set to begin sketching and projecting ideas into paper, a meeting was called, in order for me to get familiar with one specific product category - that the The Company is expected to commercialize in the future - and get started by focusing on the design of possible UI solutions, such as controls or the installation flow, to accommodate such category. At this meeting, an engineer working on this product gave an overview presentation to me and three other app team members. Products within this category cannot be directly presented, due to NDA limitations (see Section 7.3), thus any observation or discussion in this report that will revolve around such category will refer to *Category X*'s products; however, these products can be easily discussed if we relate them to dimming lights, as their behaviour gets pretty similar when it comes to control them on the app. In fact, just like dimming lights, such products do own two main end-states - that we may consider as `ON` and `OFF` - but do also give the possibility to set them to any intermediate state in between. Users would also have a say in deciding to which point the two end-states should be, while setting up this product: for instance, keeping the comparison with dimming lights, a user may want to set the `OFF` state to a dim level of 3%, and `ON` to a dim level of 90%. There is, although, a substantial difference in the com-

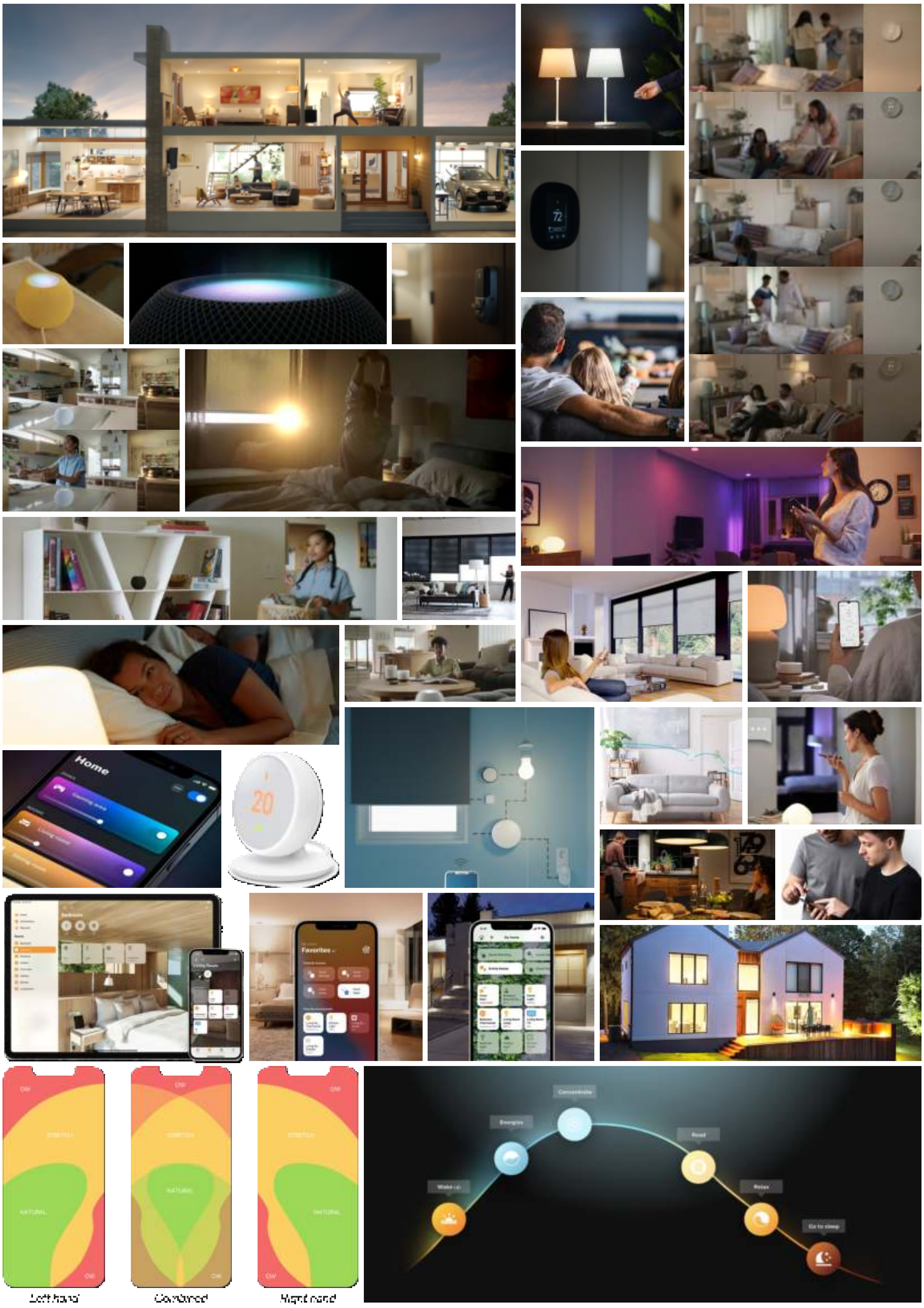


Figure 5.11: The moodboard, realized to kick-off the *Ideate* stage of Iteration I's process.

parison between a dimming light and the product under scrutiny: to discuss such difference, the concept of *latency* needs to be brought up: Mishra et al. - who also keep this aspect into account, within the home automation context - define latency as “the total delay from user interaction to physical action or change” [87]. In other words, from a general point of view, latency is the time span occurring between an event being triggered and the final outcome that it causes. Thus, going back to our comparison, while a dimming light’s latency between two dim levels is practically negligible, Category X product’s latency becomes easily appreciable, as it is in the order of magnitude of seconds. Therefore, it is crucial to somehow visualize such discrepancy in the interface, for the sake of the user’s situational awareness: in particular, keeping the ongoing paragon, it is of primary importance to show both the *target* dim level the user would just set, and the *current* level, reaching the target level over time. To solve this, default *sliders* are not enough, as they only reflect the current state of the property they control: however, if we think about adding a supplementary semi-transparent colour filling the *track* - defined by Material Design (see Section 2.3.1.2) as the part of the slider showing the range that is available for a user to select from - we may have, as result, two colours for the same track, indicating both the current and target states, with the *thumb* element - or the position indicator that can be moved along the track - attached to the floating end of the colour representing the target state. Figure 5.12 shows an early sketch of this concept, that we may call *standard slider*.

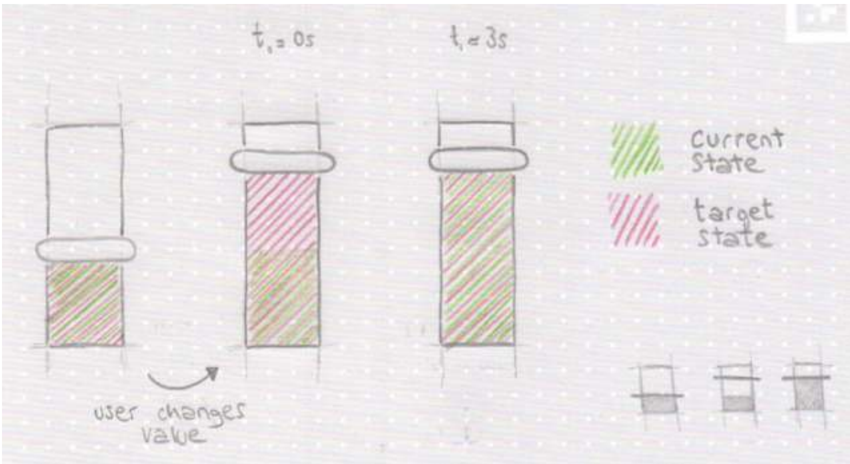


Figure 5.12: The *standard* slider sketched to display both a *current* and a *target* state.

Another portion of sketches was produced when it came to think about the installation flow for Category X’s product. In particular, most of the effort was put into the controls to set up such product: as anticipated above, users may set custom levels for end-states. For example, if this was a dimming light, users may set the end-states `ON` and `OFF` differently from default levels of 100% and 0%. In this regard, various controls were laid out: one was the slider that has just been discussed heretofore, as in Figure 5.12. A second possible solution, portrayed in Figure 5.13, suggested by the people who got to introduce me to the new product category, would consist of a mere button that we may call *flip-flop button*, as it would keep switching and alternate between two states anytime it is pressed: basically, if the first press will trigger an increase in the dim level, while the second will instead trigger a decrease. As it can be assumed, *long-press* gestures can only make this interaction work, with time being the only variable letting the user get to a specific dim level, depending on how long the button is being pressed. In a way, we could imagine this solution as a generic mobile phone's physical volume buttons being merged together into one.

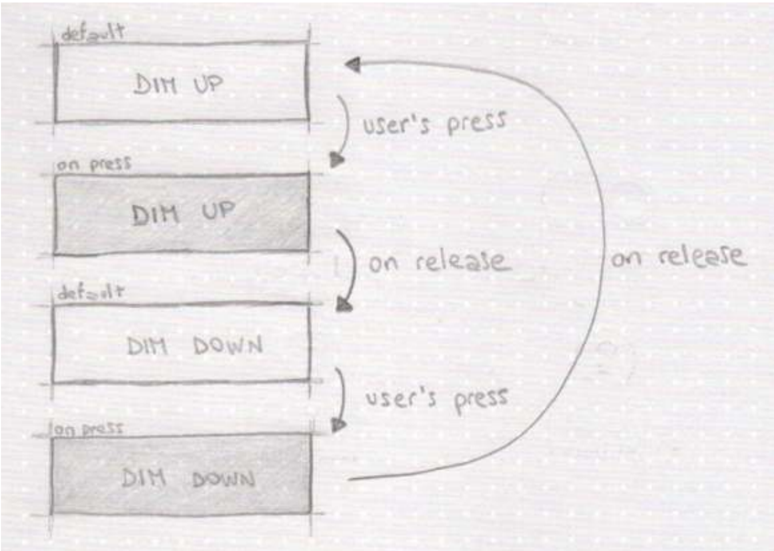


Figure 5.13: Sketches of the *flip-flop button*.

One further solution came alive thanks to the intuition of reinterpreting interface elements - such as the *throttle lever* (also known as *thrust lever*) that can be found in an aircraft's cockpit (see Figure 5.14a), but also Google Earth's *zoom slider* (see Figure 5.14b) - as well as reflecting upon one of the situations offered by one of the participants during the initial user research, i.e. "I usually don't look at my phone while I'm dimming, I look at the lights": in this case, the participant was referring to this interaction as to control a light; such observation, though, could gain even more relevance as you may want to keep your main focus on the actual product in the environments especially in the use case of setting up a product. In addition to that, previous ideas didn't take into consideration a product's feature that would enable users move through different dim levels at different speeds, so that could be exploited somehow.
As a result, a *joystick* slider took form, proposed in Figure 5.15. The idea behind this solution is that users would be then enabled to move through different intermediate states - or dim levels - at different speeds, by just dragging the thumb element: the farther it is pulled from its original, *relaxed* position, the quicker the product will change its dim level and approach either end. Obviously, the dim change will stop as soon as either one of the two ends has been reached, or the user releases the thumb: in this latter case, the thumb element will reach its starting position, right in the middle of the track; this animation may be viewed as a gravity interaction, or as the thumb being attracted by a magnet towards the exact center of the track. If we get to compare this *joystick* slider with the *standard* slider presented first, we may say that the joystick slider provides the user with the ability to reach and

(a) Example of an aircraft's throttle lever

(b) Google Earth's set of controls

Figure 5.14: Sources of inspiration for the *joystick slider* solution.

set a level depending on its relative starting position; the standard slider, instead, provides the user with the ability to reach and set a level depending on its absolute starting position. Moreover, this joystick slider solution offers both the advantage of not being constrained to look at the phone while interacting with it, but also the advantage to use different speeds to reach a specific state or level.

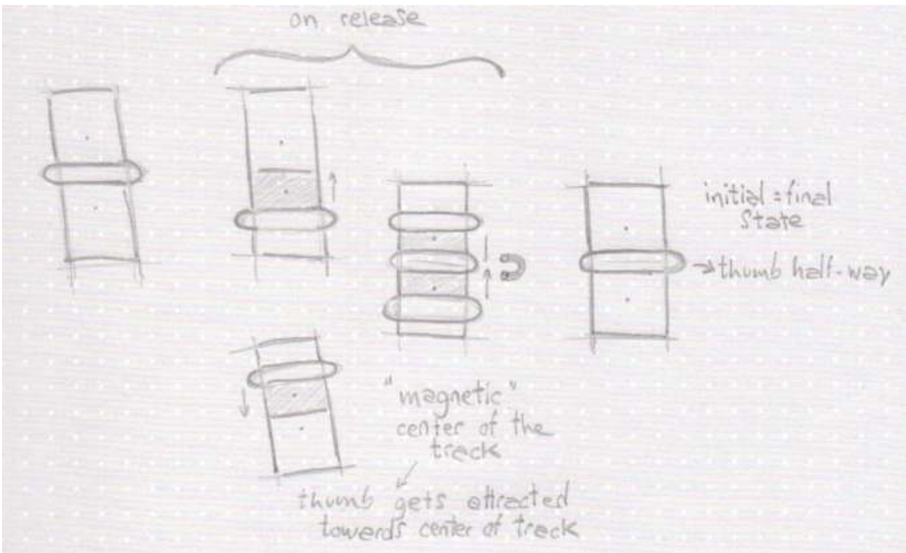


Figure 5.15: Initial sketches of the *joystick* slider.

Focus Group

Shortly after, a follow-up meeting was organized to discuss more in-depth how the new product - being introduced above - could fit into The Company app's UI. During this meeting - that turned out to be conducted in a sort of *focus group* fashion - two engineers provided deep insights into the product's functionality, whereas The Company's CEO, The Company's CTO, two app team members and myself joined to get feedback to each other and possibly raise some challenges for the design of a new MUI. For instance, the role of controls in the current app's room cards, positioned in the home view (visible in Figure 2.1), was discussed. Switches and sliders in a room card, in fact, would control all the devices belonging to that room. Accordingly, a problem can be raised: what would happen if products of different categories were to be installed within the same room? Indeed, there might be the risk that controls in room cards would somewhat lose their meaning. Given the nature of the new product category being considered, it was argued that it would not be appropriate nor coherent to use the same controls in a room card if such new products were to be installed in a room together with lights, for example, despite their quite similar behaviour. One way being discussed to solve this problem was separating and having ad-hoc controls for each product category: simple switches, then, could be replaced with buttons that would include an icon, indicating both the current state and product category it would represent (see Figure 5.16).

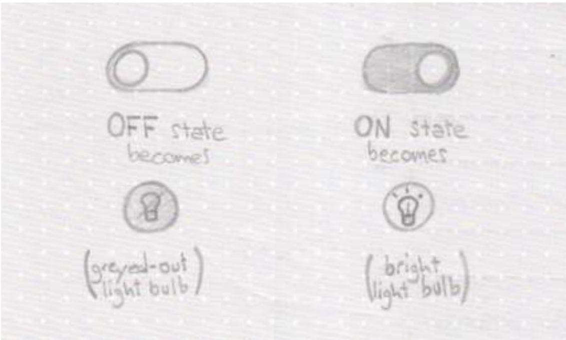


Figure 5.16: Visualization indicating the possible shift from standard switches to toggle buttons including an icon.

A subsequent point of discussion was whether this new product would need both a toggle switch and a slider in a room card; it was concluded that a button would be enough, with the argument that users will be likely to just want to reach either end-states way more often than it would happen with dimming lights, where the fine tuning aspect of controlling becomes more relevant. Yet, users should still be able to set the product to an intermediate level between the two end-states, if they wanted to. It was thought during the meeting, then, that a good compromise to reach the slider element would be by long-pressing the button representing the product: albeit not being as intuitive to discover, it was assumed that a long press might be more easily explored by expert users, arguably overlapping the same category of users who may end up desiring to fine tune the product through a slider. Obviously, this hypothesis would need to be validated. The meeting also unveiled the chance to show off some of the early sketches presented above. Among the sketches presented, it emerged that the standard slider (see Figure 5.12) and the joystick slider (see Figure 5.15) were the most viable solutions: the standard slider, for instance, was said to be ideal to control the product, once installed, whereas the joystick slider would particularly fit into the configuration and installation flow of the product, as it was claimed to be useful if the user wanted to adjust the product to a very precise state or level. However, it was concluded that both controls sketched should be prototyped and tested, together with a draft of the different interfaces that would inform steps in the overall installation flow.

5.1.4 Prototype

In order to concretize and to give a sense to the first chunks of knowledge gained through research and ideation, it came the moment to kick-off the Prototype stage, by projecting such knowledge into visual, digital artifacts, such as wireframes, mock-ups and prototypes.

Wireframing and Prototyping

As first visual outputs, a few wireframes and prototypes were created, starting from the app's home view - i.e. the list of rooms appearing as soon as a user opens the app - and the room cards in it. Even before that, actually, some work around the app's layout grid was conducted, resulting in Figure 5.17. Going back to the home view and room cards, or early prototypes more in general, focus was aimed towards how multiple product categories could fit together, such as lights, thermostats, and Category X, for instance.

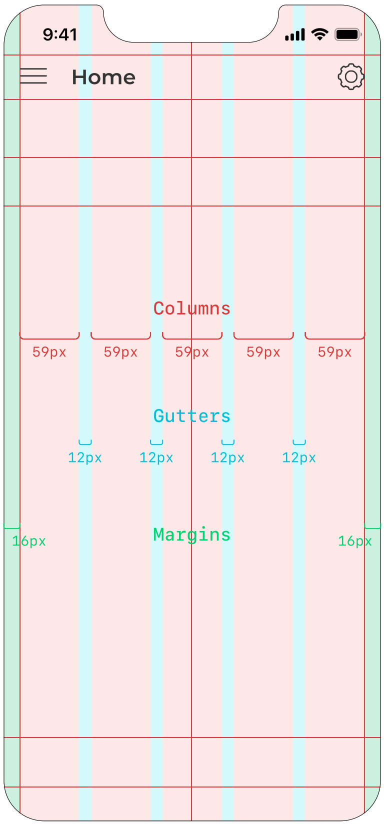


Figure 5.17: Brief representation of the layout grid used as reference during the following prototyping activity.

As visible in Figure 5.18, an attempt of tab bar was included, with the idea of allowing users have various portions of their smart environments - i.e. zones - better disposed in the app, hence splitting a single, possible endless, list of rooms, into multiple, shorter ones. In the same Figure, one of the room card's variants - resulted by trying out different solutions and layouts, as in Figure 5.19 - were included only for the first element of the room lists.

Figure 5.18: Two examples of *home view* mock-ups produced during the first iteration.

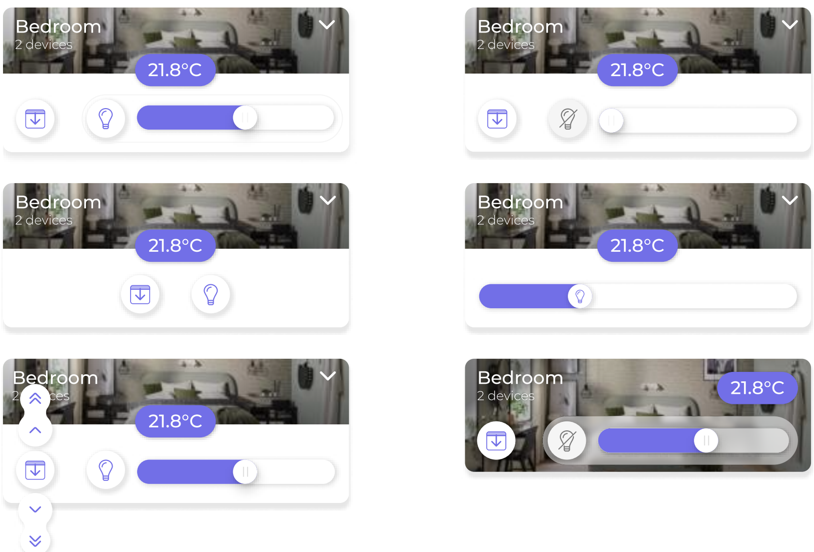


Figure 5.19: Mock-ups for different *room card* layouts and solutions.

Talking specifically about Category X's products, a handful of mock-ups were created to visualize how possible ad-hoc controller solutions would look: an example of them is shown in Figure 5.20, raising back the standard slider concept presented in Figure 5.12. Moreover, an early and simplified version of installation flow for Category X's products was prototyped: two different controlling alternatives, worth including, were proposed in the flow to perform the same action - i.e. setting up minimum and maximum customized values for a device's property: the first alternative, shown in Figure 5.21a, adopts the *flip-flop button* concept, first presented in Figure 5.13; the second alternative in Figure 5.21b, instead, portrays the joystick slider approach, originally shown in Figure 5.15. All these mock-ups would be then turned into interactive prototypes, in order to get a better feeling on how such controllers would actually work.

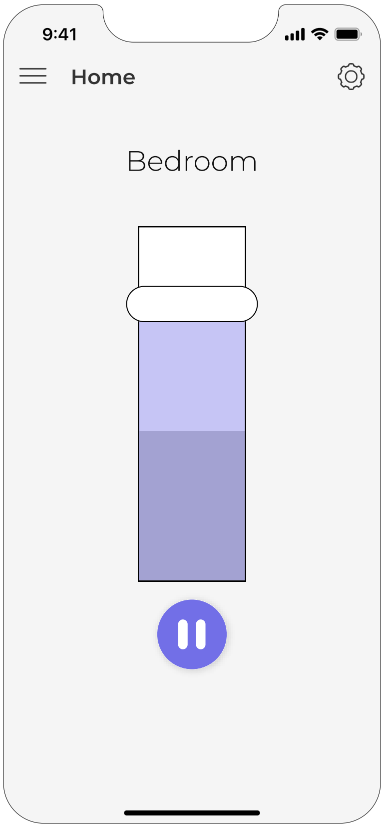
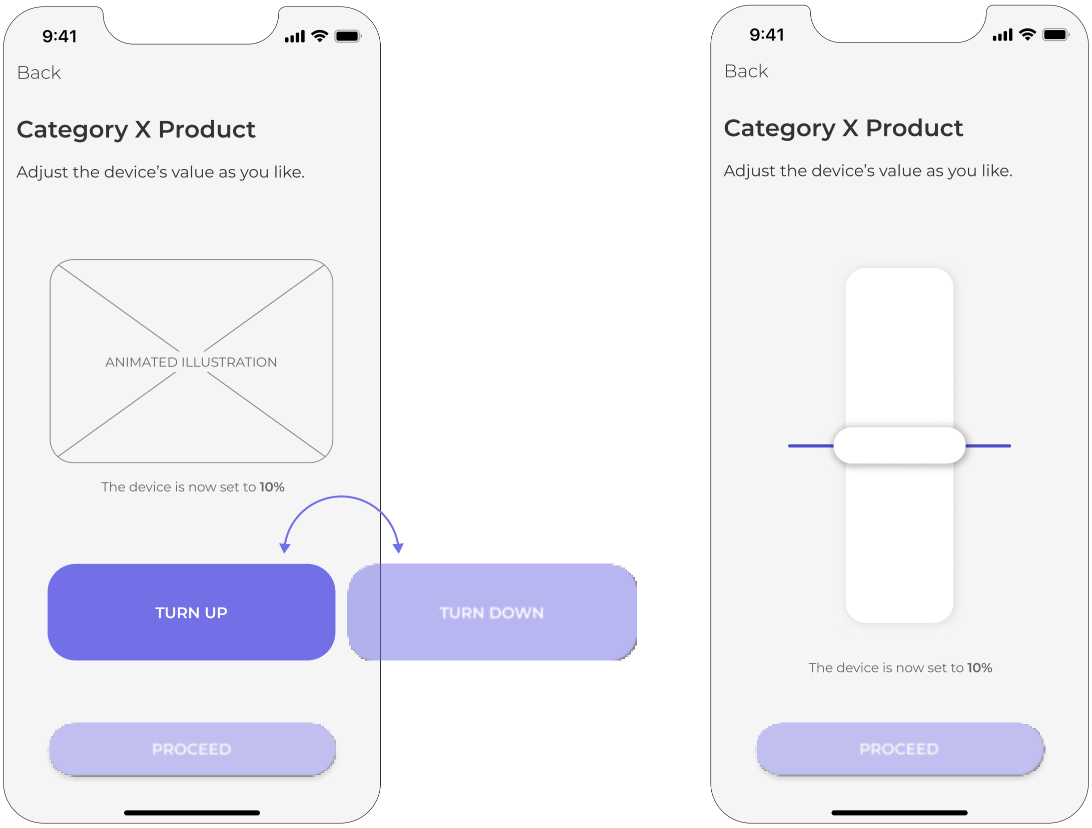


Figure 5.20: Mock-up of the *standard slider* controller concept.

As it will be further discussed in Section 5.1.5, the wireframes, mock-ups and prototypes produced during the execution of this stage would then be evaluated by interviewing and asking for some feedback to the research participants at disposal.

5.1.5 Test

In order to wrap Iteration I up, a brief *Test* stage was planned, allowing to assess some early ideas and prototypes produced, based on the insights collected initially from research participants.



(a) The *flip-flop button* alternative

(b) The *joystick slider* alternative

Figure 5.21: Two different controlling alternatives for setting up Category X's products within the installation flow.

Interviews

A second round of interviews with participants - the ones initially recruited for user research - was called, with the main purpose of getting feedback on the first assembled mock-ups. This series of interviews would take place inside one of The Company's meeting rooms - hence in what may be considered as a lab - and each session would take up to 30 minutes. In the first part, following a semi-structured logic, few questions about future products being offered by The Company, such as the one being described above in Section 5.1.3, were proposed: for example, participants were asked whether they would own any products that could relate to the one introduced, regardless of having them 'smart' or not, and - in that case - what are their usual habits when manipulating those products, and how they would interpret the `ON` and `OFF` terms in relation to them, besides intermediate states. In regard to the last question, quite discordant answers were given, letting contrasting user's mental models emerge: indeed, while three out of the eight participants believed it would be appropriate to ideally assign the `ON` label to one of the two product's end-states, the rest (five participant) supposed the exact opposite. Here comes a noticeable, distinctive characteristic between dimming lights and this product,

correlated until now for the sake of the product's explanation: it would be reasonably intuitive for everyone to state that the `ON` and `OFF` labels on dimming lights are strictly tied to the light intensity - i.e. trivially, `OFF` represents an emitted light intensity that equals a 0% dim level, whereas `ON` represents an emitted light intensity that equals or exceed a 1% dim level. That's not quite the same for the product under analysis, so this explains how dissimilar such product is from dimming lights, despite their akin behaviour. This fact supports the argument of replacing standard switches with buttons including an icon (see Figure 5.16), as brought up during the focus group.
The second and final part of the interviews, instead, was aimed at showing off and getting feedback on the wireframes and mock-ups produced in the Prototype stage - some of which are shown in Section 5.1.4 - to accommodate the new product category being discussed through Iteration I. Wireframes of the various steps constituting the installation flow were showed first: when it came to ask which control - between the *standard slider* (Figure 5.20), the *flip-flop button* (Figure 5.21a) and the *joystick slider* (Figure 5.21b) - would be most appropriate including in the installation flow, the *joystick slider* got evidently preferred over the others; also, despite the flow being generally coherent and recognizable, some participants pointed out the lack of few steps, that should always be included when installing any of The Company's product: a straightforward example is the step asking to assign the product being installed to a room in the system.

5.2 Iteration II

In this Section, the second iteration in the project - aimed at reinforcing understanding within the domain but mainly focused on wireframing and prototyping, as shown in Figure 5.22 - is analyzed.

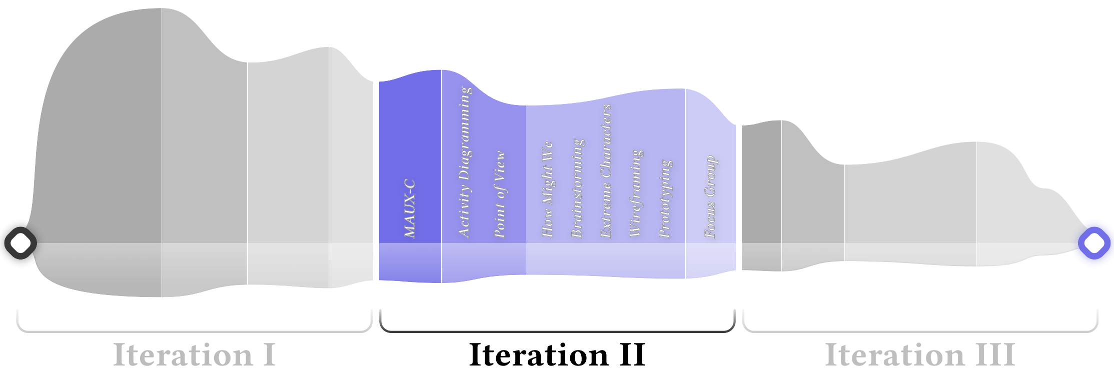


Figure 5.22: Visualization of the second iteration within the entire project's design process.

5.2.1 Empathize

MAUX-C Evaluation Tool

With the attempt of trying gathering some more knowledge about users' opinions

Principle	P01	P02	P03	P04	P05	P06	P07	P08	Amos
Usable									
1. Is at least one of the following true? a. The app offers a tour, tutorial, or provide support within the app b. It takes less than 5 minutes to learn how the app functions c. The app has a "frequently asked questions" section	✓		✓	✓	✓	✓			✓
2. Is the look and feel of the app consistent throughout?	✓	✓	✓	✓	✓	✓	✓		✓
3. Does the layout of the app appear organized?	✓	✓	✓	✓	✓	✓	✓	✓	✓
4. Are the visual cues of functions clear? (e.g. it is obvious when a button should be tapped, visual cues are used consistently)	✓	✓	✓	✓	✓	✓	✓	✓	✓
5. Is the content clear and concise?	✓	✓	✓	✓	✓	✓	✓	✓	✓
6. Can the app be personalized?			✓		✓		✓	✓	
7. Are the available features to share content easy to use and appropriate for the context?		✓						✓	
8. Is one of the following is true? a. All pages loaded quickly with no delay b. There was a delay and an indication acknowledged the delay	✓	✓	✓	✓	✓	✓	✓	✓	✓
9. Does the app accept user feedback?	✓				✓				✓
Usability	77.78%	66.67%	77.78%	66.67%	88.89%	66.67%	66.67%	66.67%	77.78%
Useful									
10. Does the app or app store description identify its purpose?	✓	✓			✓	✓	✓	✓	✓
11. Does the content in the app meet your expectations based on the identified purpose?	✓	✓	✓	✓	✓	✓	✓	✓	✓
12. Does the apps brand appear to have key indicators of authenticity and suited for the targeted audience?	✓	✓	✓	✓	✓		✓	✓	✓
13. Is the content well written and relevant to the target audience's needs and interests?	✓	✓	✓	✓	✓	✓	✓	✓	✓
Usefulness	100%	100%	75%	75%	100%	75%	100%	100%	100%
Desirable									
14. Is the design consistent with recently made apps and websites? (i.e. the app does not appear dated)	✓	✓	✓	✓	✓	✓	✓	✓	✓
15. Does the app provide a description of the origin or creator? (i.e. a section similar to: about us, about our story, our mission, who we are, etc.)	✓	✓		✓	✓				
16. Does the app create positive memories? (e.g. an engaging story)		✓	✓	✓	✓		✓	✓	✓
17. Would you describe the app as fun, surprising, impressive, impactful, captivating, or clever?		✓	✓		✓	✓	✓	✓	✓
18. Does the app use high quality photography, video, animations, and/or graphics?	✓		✓	✓	✓	✓	✓	✓	✓
Desirability	60%	80%	80%	80%	100%	60%	80%	80%	80%
Findable									
19. Without reading everything, does the important content obviously stand out?	✓	✓	✓	✓	✓	✓	✓	✓	✓
20. Are the apps navigation options simple and clear? (if uncommon navigation options, do they include a short teaser to describe what the option is?)	✓	✓		✓	✓	✓	✓	✓	✓
21. Does the app make use of current or emerging features on the platform?						✓			
22. Does the app have a search function and is relevant information retrieved when searching for a specific term or phrase?		✓		✓			✓		
23. Does the app retain a record of what you have done within the app? (e.g. recent search history, sections visited)								✓	
24. Does the app save content/place when you are interrupted from the session (e.g. if interrupted by a text or call the app will resume exactly where you were before)		✓		✓			✓	✓	✓
25. Were you able to achieve your primary goal within the app without being redirected to a full website?	✓	✓	✓	✓	✓	✓	✓	✓	✓
26. Is the contact information available and easy to find?	✓	✓	✓	✓	✓	✓	✓	✓	✓
27. There were no errors found within the app (e.g. typos, broken links)	✓	✓	✓	✓	✓	✓			✓
Findability	55.56%	77.78%	44.44%	77.78%	55.56%	66.67%	66.67%	66.67%	66.67%
Accessible									
28. Does the app use plain language?	✓	✓	✓	✓	✓	✓	✓	✓	✓
29. Does the app use pictures or symbols for links to convey function?	✓	✓	✓	✓	✓	✓	✓		✓
30. Can text be resizable?	✓							✓	
31. Can you zoom on the content within the app?									
32. Does the text and content appear distinct from the background and easy to read?	✓	✓	✓	✓	✓	✓	✓	✓	✓
33. Is there sufficient room around buttons and/or links to easily touch?	✓	✓	✓	✓	✓	✓	✓	✓	✓
34. Can the layout adapt to screen orientation? (i.e. layout remains consistent in portrait or landscape orientation)		✓		✓	✓			✓	
35. Is one of the following true? a. There is no flashing content within the app b. There is flashing content, but it occurs less than 3 times in a one second period	✓	✓	✓	✓	✓	✓	✓	✓	✓
36. Is the app accessible to people who are hard of hearing?	✓	✓	✓	✓	✓			✓	✓
Accessibility	77.78%	77.78%	66.67%	77.78%	77.78%	55.56%	55.56%	77.78%	66.67%
Credible									
37. Is at least one of the following true? a. The app is offered by a legitimate source (e.g. reputable institution, commercial business, government, university) b. The author or organization that takes responsibility for the app's content and distribution has credentials that are listed and verifiable	✓	✓	✓	✓	✓	✓	✓	✓	✓
38. Does the source of the content (author, etc.) show experience and expertise on the app content?	✓	✓	✓	✓	✓	✓	✓	✓	✓
39. Has the app been endorsed by a trusted third party?		✓			✓			✓	✓
40. Within the app, does the app generally provide content that appears unbiased?	✓	✓	✓	✓	✓	✓	✓	✓	✓
41. Does the app include a privacy statement/policy?	✓	✓	✓	✓	✓			✓	✓
42. Is it clear how the development and maintenance of this app is funded?	✓	✓			✓			✓	✓
43. Is the content that requires reference to an external source linked to the appropriate source? (e.g. citations, embedded link to original website)	✓	✓	✓	✓					
44. Does the app identify when the content was last updated?	✓	✓		✓	✓	✓	✓	✓	
45. Does the app link to external unbiased sources? (e.g. review sites, social media)		✓							
Credibility	77.78%	100%	55.56%	66.67%	77.78%	44.44%	44.44%	77.78%	77.78%
Total MAUX-C	73.33%	82.22%	64.44%	73.33%	80%	60%	64.44%	75.56%	75.56%

Table 5.5: Summary of the results gathered from the questionnaire based on MAUX-C evaluation tool.

on The Company's app, participants recruited on Iteration I (see Table 5.4) were invited to fill in a new questionnaire, proposing Richardson et al.'s *Mobile Application User Experience Checklist* (or *MAUX-C*) in its entirety (see Appendix F to access the entire checklist in detail): Richardson et al. define MAUX-C as an evidence-informed, user-friendly tool that measures the overall UX quality of mobile applications [109], mainly aimed at complementing other evaluation tools, such as heuristic evaluation. This tool could, in fact, complement the heuristic evaluation conducted during Iteration I, so to triangulate results in a redundancy perspective (see Section 5.1.1). Table 5.5 summarizes the results gathered from a sample of nine people who filled the questionnaire - i.e. the eight recruited participants plus myself, as I was also gaining experience in using The Company's app. By calculating the average percentage from all nine submissions, we may see how the overall UX quality of The Company's mobile application already starts at a quite respectable level (72.10%), with the highest average percentage in the *Usefulness* key area, of 91.67%, and the lowest average percentage in *Findability* (64.20%). This demonstrates how a possible area of improvement in the app relates to making objects, options and other resources easier to find in the app; otherwise, The Company's app seems to already set a pretty high bar in other factors of UX.

5.2.2 Define

Conclusions from Iteration I led to the need of better defining both how some sections of the app would work - such as the different steps included in an installation flow, which my early wireframes partly lacked - and the users' points of view, to gain a deeper understanding of users' needs and most essential insights.

Activity Diagrams

In order to avoid repeating the mistake of missing some of the app's screens, especially within well-established user flows in the app, the creation of activity diagrams was deemed an essential exercise to have a clear overview of the app's most used processes. Obviously, given the wide number of features and functionalities included in the app, one may develop a multitude of activity diagrams; however, only the diagrams that were deemed as most helpful and significant towards supporting the project's design process were produced. Figures 5.23 and 5.24 show, respectively, the flow to install a generic device and the flow to install The Company's input buttons, e.g. push switches or rotary buttons. Finally, Figures 5.25 and 5.26 illustrate, respectively, the activity of managing scenes - such as creating or editing one - and the activity of managing scheduled events.

Point of View

By picking back up the results coming from Iteration I's affinity diagram, the Point of View method was considered to define the design challenges that arise once the problem statement is to be addressed; in other words, PoV was applied to better grasp user needs and to synthetize their insights. Here follows the set of bullet points:

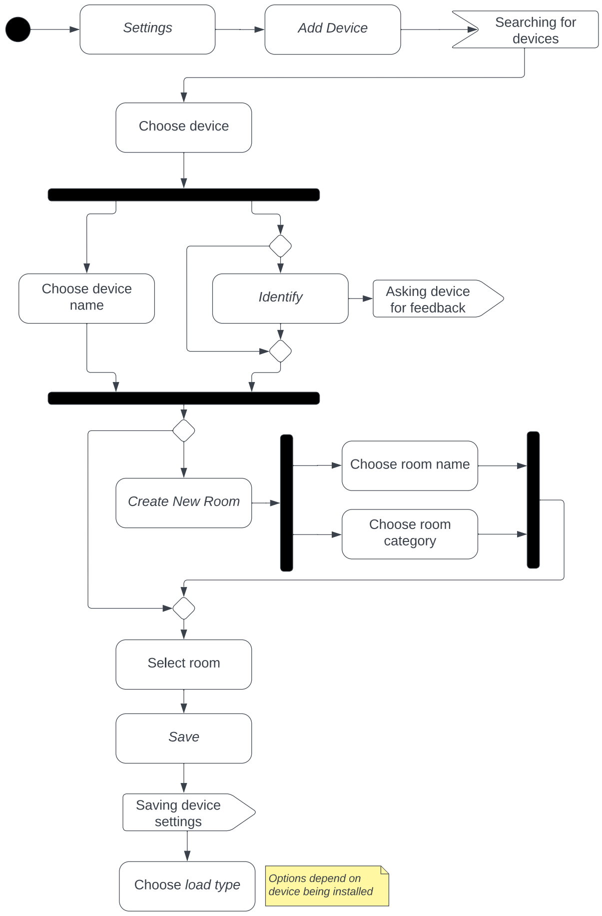


Figure 5.23: Activity diagram describing the process to add a new device to the system.

- a user needs to organize Rooms in higher-level groups, because Rooms alone can't conceptually suit with scaled-up environments;
- a user needs to feel in control in scaled-up environments, because they will avoid using other features otherwise (e.g. *Scenes*);
- a user needs to access device settings directly from the Home view, because it might be a struggle and take longer time to find them otherwise;
- a user needs to be able to turn their devices `ON` or `OFF` altogether in their system, because a lack of such feature may result in frustration and poor perceived control; scenes are currently created for this purpose but every time a new device is being added to a system, it has to be manually added to the scene;
- a user may need to control both devices individually or grouped together, because scaled-up environments may have big amounts of devices;
- a user needs to remember few, intuitive ways to interact with different categories of devices through physical buttons, to avoid any kind of extra cognitive effort;
- a user needs some kind of visualization when setting up schedules, because the

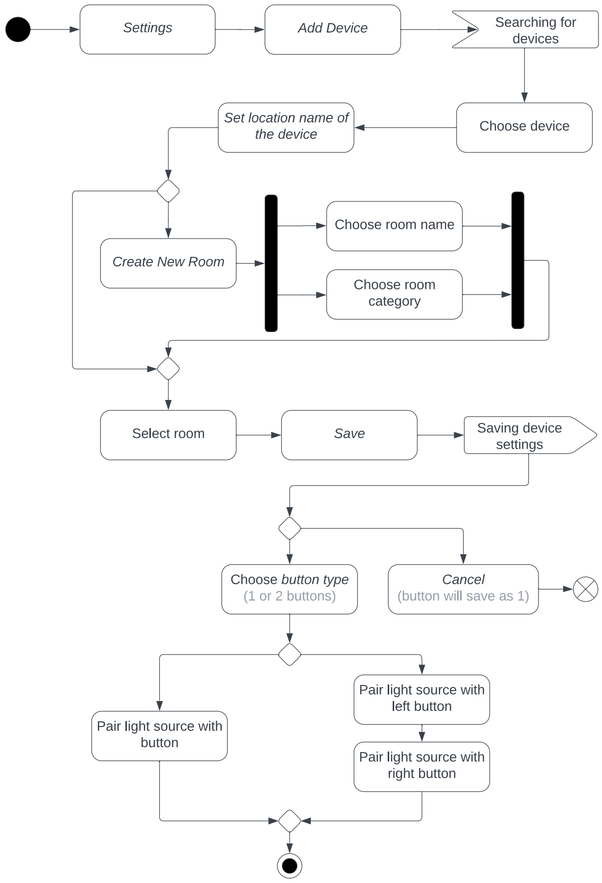


Figure 5.24: Activity diagram illustrating the installation flow to add a new button to the system.

process is currently difficult to understand;
- an electrician needs installation flows to be quick, because their work of installing and setting up devices in customer's homes is quite repetitive in their daily routine;
- an electrician needs to be able to remotely access their client's environments, when in need of supporting them.

5.2.3 Ideate

Just like it happened on Iteration I, once further knowledge, needs and insights about users were gathered, the *Ideate* stage followed: on Iteration II, this stage mainly consisted in turning PoV bullet points into How Might We questions, to then be applied on a Brainstorming session, and finally exploring and elaborating on a variant of the Extreme Characters method.

How Might We

As anticipated in the Methodology chapter (see Section 4.2.4), the Point of View method would logically extend into the How Might We method: therefore, the

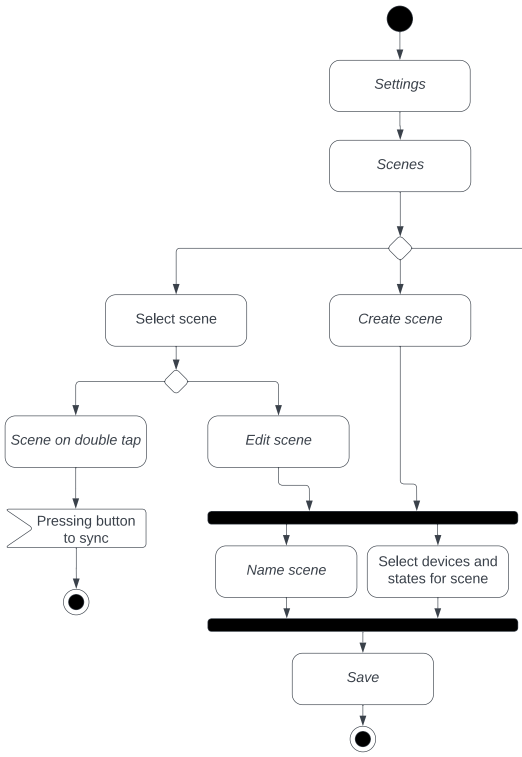


Figure 5.25: Activity diagram covering the overall management of scenes: rearranging the order scenes, creating or editing a scene.

ideation stage kicked-off by applying such method, mainly based on the PoV bullet points presented above. A selection of HMW questions that were developed is included here:

- *How might we* design the structure of the main home view considering groupings of rooms?
- *How might we* design for encouraging users with big environments use scenes?
- *How might we* let the user access settings of devices directly from the Home view?
- *How might we* limit the number of steps to reach specific views (e.g. *Settings*)?
- *How might we* let the users find devices more easily?
- *How might we* design the structure of room views to make different product categories coexist in the app?
- *How might we* let turn quickly everything `ON` or `OFF` in their system?
- *How might we* let the user control groups of devices as well as individual ones? (Especially for Category X's products)
- *How might we* make interactions with physical buttons consistent across different products?
- *How might we* bind scenes to rooms and schedule them?
- *How might we* better visualize the flow of setting up schedules?
- *How might we* make the installation flow for devices as quick as possible?

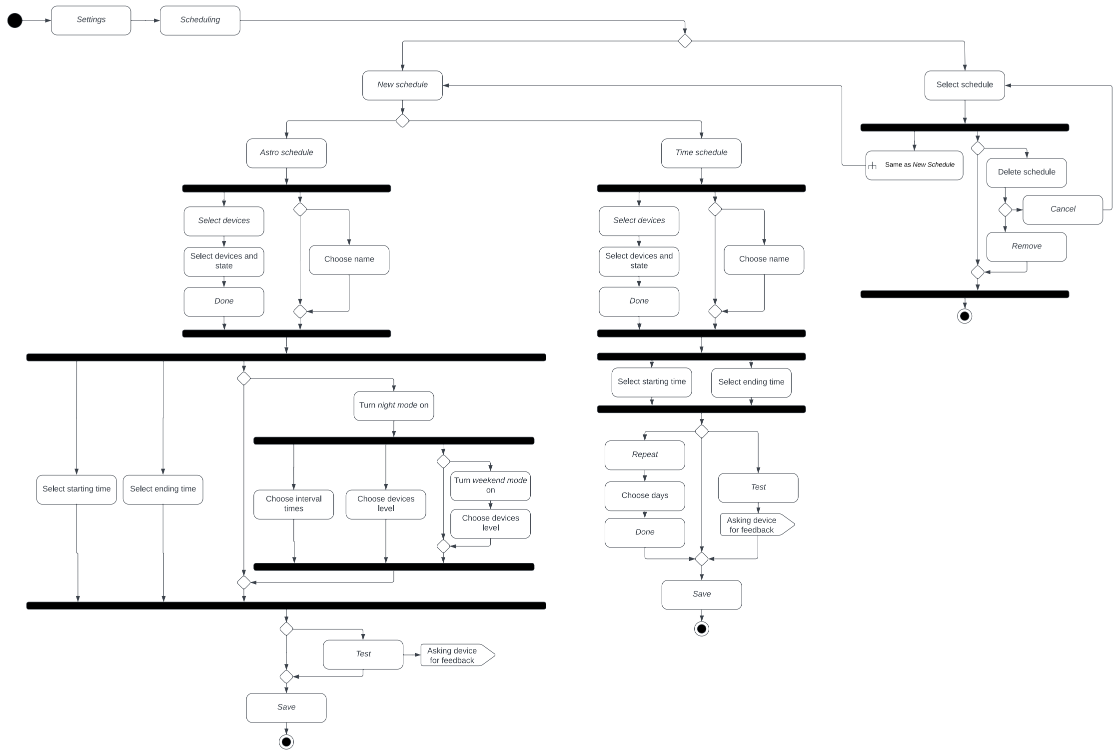


Figure 5.26: Activity diagram illustrating the overall process to manage scheduled events, such as creating or editing them, either based on time or on the astronomical clock.

Brainstorming

With the goal of generating new ideas for possible UI solutions that would address the problem of adding new product categories to The Company's app, a group of engineers (i.e. three) from The Company - all working on such new devices - and one member from the App Team, were invited to join a brainstorming session, planned to be sixty minutes long, as Kelley argues to be the optimum length [65]; moreover, two other students working on one specific new product category as their thesis project, were invited as well. In total, seven people joined this brainstorming session. Despite the session taking place in The Company's headquarters, the session was set in a hybrid mode: a virtual board on *Miro* - to exploit the power of spatial memory - and a call on *Google Meet* were set up for the brainstorming activity, as some of the participants were working remotely, while the rest of the people gathered in a conference room, each one with their laptop. In order to sharpen the focus, participants were asked to generate ideas around six main questions, which some of them were taken from the set of How Might We questions produced above:

- *How might we* design the structure of the *home view* considering groupings of rooms?
- *How might we* design the structure of *room views* to make different product categories coexist in the app?
- *How might we* let the user control groups of devices as well as individual ones in room views?

- *How might we* link and control linked devices (e.g. thermostats) together?
- *How might we* visualize *time predictions* in the app for devices with *higher latency* in reaching a target state set by the user?
- *How might we* design a controller that is suitable for both Category X's products and third-party devices?

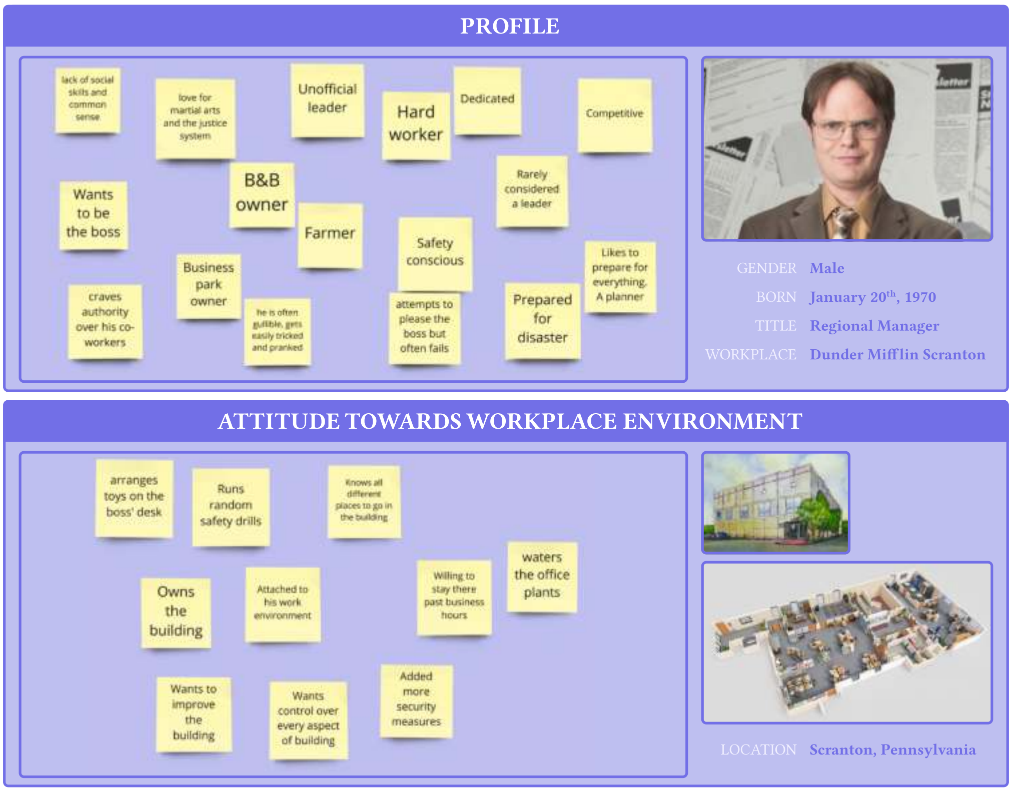
Figure 5.27: Ideas gathered during the brainstorming session. NB: some of the notes explicitly relate to new product categories; while notes referring to disclosable new product categories (e.g. thermostats) are shown as authentic, others - for instance, referring to Category X - have been partially manipulated (i.e. blurred) for non-disclosure purposes.

As we know, brainstorming sessions are an intensely group-oriented process, so brainstormers should not only generate ideas individually, but try building on each other's ideas and discuss them together in the group, as well. In this occasion, the session brought to a number of profitable learnings, as visible in the resulting board in Figure 5.27.
First of all, the need of a feature recalling what can be considered as a *Favourites section* emerged, possibly containing *widgets* for each product category; moreover, possibilities for room groupings (e.g. floors) or room filtering were discussed. The *home view* would need to be different from *room views* in The Company's app, in a sense that home views would just display general information about rooms through a list of room *cards*, while more detailed controllers for smart devices would be found

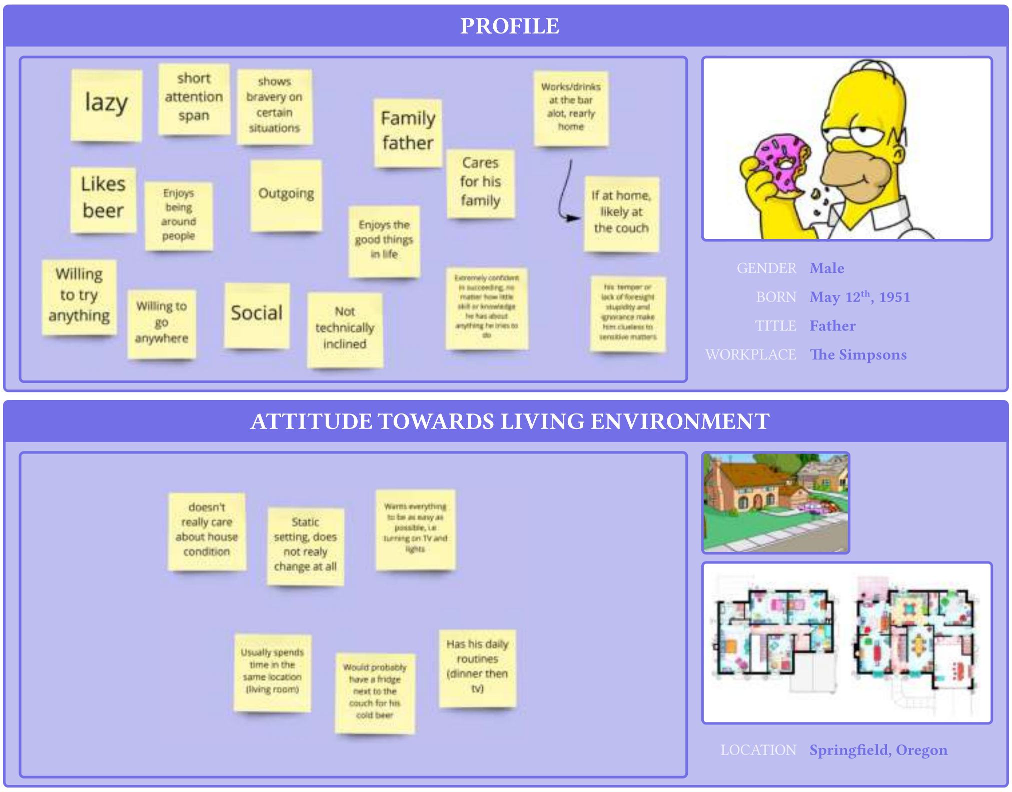
only inside the room views; room views were also suggested to display a *tab bar* - letting the user choose what product category they would like to manipulate - and *global toggles*, to turn `ON` or `OFF` all devices in a room. Participants also pointed out the need of changing the toggle switches, to better indicate what products would be controlled. To better represent products with high latency, transitioning to a target state, *loading bars* combined with a *timeline*, *animations*, or a *simple text* stating the estimated time needed to reach the target state were proposed. As for controlling specific products, participants hinted to alternative slider solutions, such as circular sliders or vertical slider overlays, with the suggestion to first evaluate the classic horizontal sliders.

Extreme Environments

With the desire of not only using well-established methods during the project, but also experimenting with more innovative and eccentric ones, it was decided to think about trying out the Extreme Characters method. As anticipated in the previous Chapter (see Section 4.3.5), this method aims to design for characters having exaggerated emotional attitudes: in this respect, however, the idea here is to apply a variant of such method, that we may call *Extreme Environments*, in order to gain more relevance for the domain we're working in. The pivotal point of this variant, in fact, would replace the attitudes a certain character would embody, with the traits that an environment - i.e. the house or the office a character would spend most of their time in - would embed; in other words, this variant aims at observing an environment and its relation with the character who's living or working there, with the hope of obtaining original solutions, just as it happens when using the extreme characters method. Another interesting perspective worth considering would consist in the relation between the physical environment, and the view a hypothetical app would replicate at a UI level: for instance, if the environment we're considering would contain a bunker, a possible idea that may arise would consist in implementing a secret view in the app.
To ideate on new design solutions through this Extreme Environments method, it was deemed appropriate to conduct it in a co-design fashion. Therefore, a questionnaire was sent out to the original set of eight participants who manifested their availability to help throughout the project (see Table 5.4), to invite them joining a co-design session, focused on the ideation through Extreme Characters. The questionnaire first enclosed what the session would be about, hence presenting Djajadiningrat et al.'s definition and application of the method - including the *drugsdealer* example in their paper, outlining both *profile* and *attitudes towards a specific topic*, and describing the design they came up with. With the attempt of convincing any possible skeptical prospect participant, given the peculiarity of this method, a motivation explaining the reasons why and how that method would be helpful in the design process was included. One constraint that emerged once considering this variation of Extreme Characters, however, is that people ideating around it will be required to own some extent of familiarity towards the environment of the character that is going to be picked. In this case, a number of characters coming from different TV series was proposed in the questionnaire, with the goal of letting participants choose who they're most familiar with, if any, in order to come at the ideation ses-



(a) Dwight Schrute (from *The Office*)



(b) Homer Simpson (from *The Simpsons*)

Figure 5.28: Resulting virtual boards on *Miro* after letting participants brainstorm upon Dwight Schrute's (5.28a) and Homer Simpson's (5.28b) profiles and attitude towards workplace or living environments.

sion with a prearranged couple of characters to ideate upon. A copy of the content within this questionnaire is reported in Appendix G. As a result, six out of the eight participants responded giving their availability, while two different sessions needed to be set up, due to participants' time constraints. On the other hand, Dwight Schrute (from *The Office*) and Homer Simpson (from *The Simpsons*) were chosen as characters to ideate upon, as they got voted the most in the questionnaire. Before the session, a virtual board on *Miro* was prepared, in order to let participants brainstorm around the two characters, with a focus on both their profile and their attitude towards their workplace or living environments. The resulting boards are shown in Figures 5.28a and 5.28b, respectively for Dwight Schrute and Homer Simpson.
As second step during the sessions, results from such boards were then summarized for each of the characters:

Dwight Schrute's profile

"Dwight Schrute is hard worker, putting dedication and competitiveness to the business of any nature he's into, to the point he wants to be the boss, craving authority over his co-workers, and attempts to please the real boss (but often fails), so he'd like to think he's the unofficial leader (or Assistant Regional Manager), even though he's rarely considered as such. Dwight lacks of social skills and common sense, to some extent. He's often guillible, as he gets easily tricked and pranked, and - due to his being extremely conscious about safety - he likes to plan for everything, even for disasters or worst-case scenario events. If you need to get advice on self-defence techniques, Dwight is arguably the right person to ask, as he loves martial arts and the justice system. In his spare time, he's a farmer and runs a B&B business; also, he's actually the owner of his office building, Business Park"

Dwight Schrute's attitude towards workplace environment

"Dwight gets to attached to his work environment that, at a certain point, actually becomes the owner of Business Park, the office building. Therefore, he knows every single inch of it and knows all the different places to go; also, he wants to improve the building and wants control over every aspect of it. Obviously, he added more safety measures, such as often running random safety drills. Other than that, he cares a lot about the office: sometimes, he waters the plants or he even arranges the boss' toys on the desk. Regardless of him being the owner of the building, he's willing to stay there past business hours"

Homer Simpson's profile

"Homer Simpson is a mid age man, he's a family father and he cares for his family, albeit his laziness, spending his time either at the couch, watching the TV, or drinking at the bar. In fact, he's very outgoing, social, enjoying the good things in life, such as being around people, or being willing to try anything or going anywhere. On the other hand, though, he's not technically inclined and shows having a quite short attention span: despite that, he's extremely confident in succeeding, no matter how little skill or knowledge he has about anything he tries to do, even showing bravery on certain situations. However, his temper or lack of foresight stupidity and ignorance make him clueless to sensitive matters"

Homer Simpson's attitude towards workplace environment

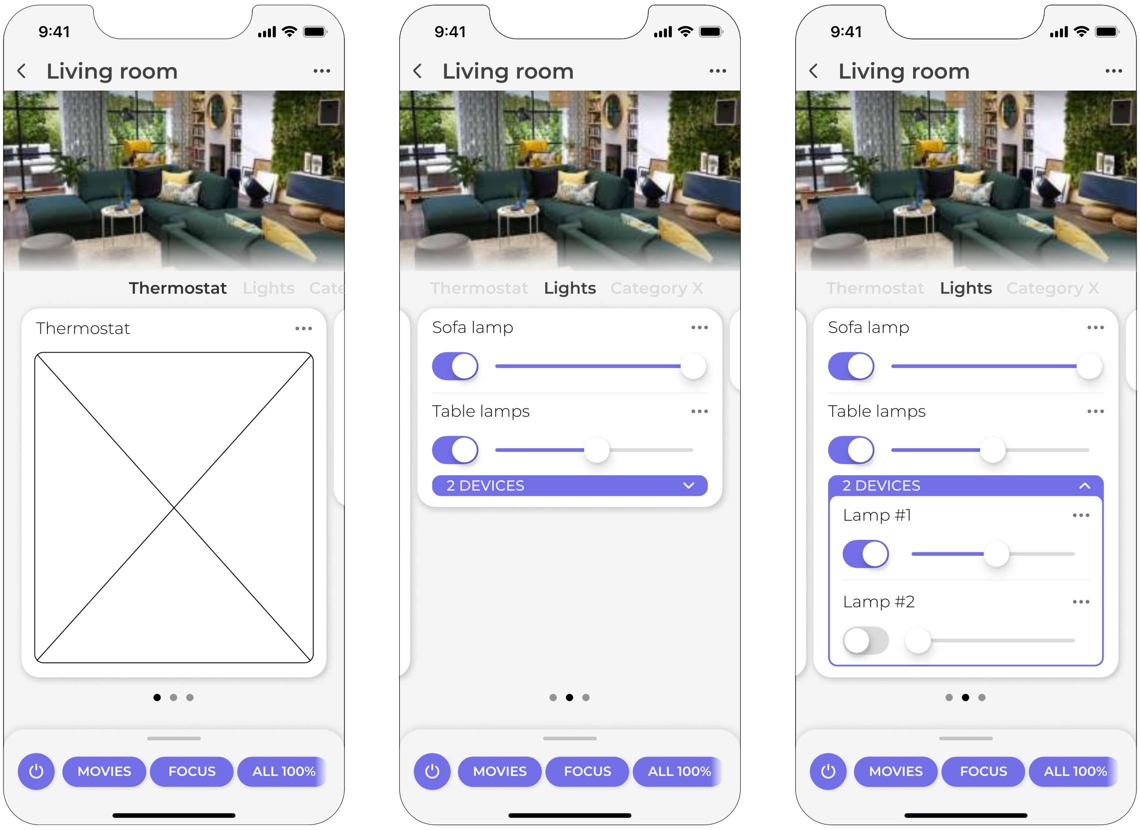
"Homer doesn't really care about the house condition, to the point its setting is usually 'static', without the willing to change it at all. When he's home, he has his daily routines, spending most of his time in the same locations, such as having dinner in the kitchen or watching the TV in the living room. Due to his laziness, he'd want everything to be as easy and at reach as possible, like turning on TV and lights from the couch, or even having a fridge next to the couch for his cold beer."

As final task for the sessions, participants were asked to imagine what Dwight Schrute's and Homer Simpson's ideal office or home automation mobile app would

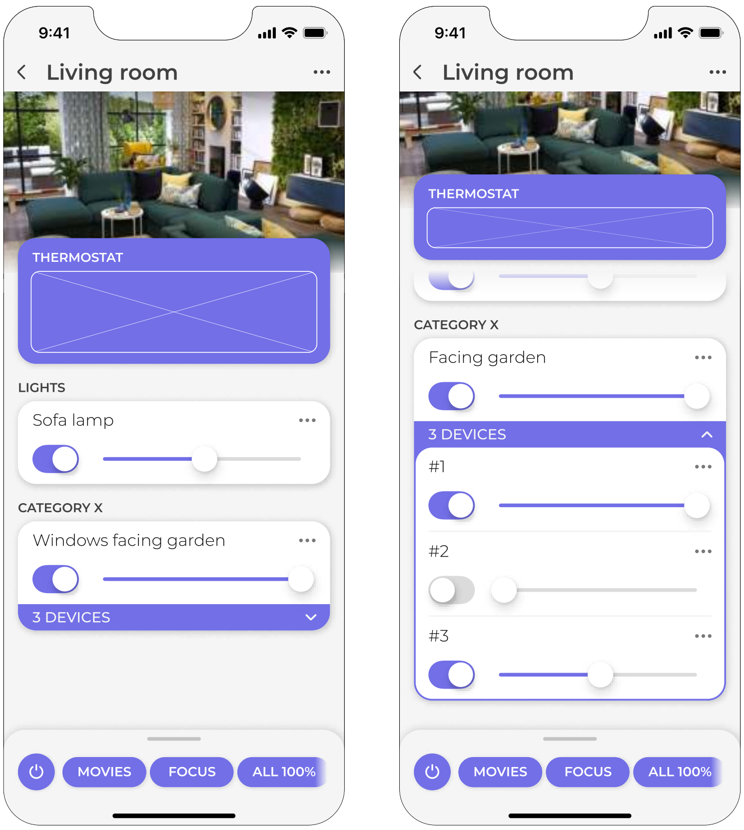
be like, with the goal of sparking ideas that would inspire innovative features for the app being designed in the project.
When it came to consider Dwight Schrute, in a security perspective, the app was imagined to be giving him more power in controlling devices than other employees would have, in a sort of parental control fashion: as *P03* suggested, *"[Dwight] controls everything, while employees can only control the light above their board. He should see some security options, for example whether doors are locked; he should also be able to track `ON` and `OFF` times of the other employees' lights, and limit their devices and schedules according to lunch break times"*. Likewise, Dwight should be able to manage efficiency of devices: *"He would control devices such as the coffee machine power and add a safety timer to it, so the coffee won't burn" (P01)*. Additionally, Dwight would need a big screen to keep track of every detail: *"Since he needs to control a big system, he may want to have an iPad or a computer; that might also be good because he always wants to bother his colleagues by showing them how the environment is supposed to work" (P04)*. Finally, his behaviour towards the smart environment would be very thrifty: *"Dwight is aware of the costs, so lights or other devices would be always `OFF` when not needed; thermostats, for instance, would always be set to the lowest" (P07)*.
Aspects emerging when taking Homer Simpson into consideration, instead, mostly concerned simplicity and ease of use: *"The interface needs to be really simple; everything should be in one spot, just grouped by room" (P03)*, *"lights shouldn't even be dimmable, Homer would barely turn them `ON` and `OFF`, so he would need just big toggle buttons" (P07)*, and *"setting up scenarios should be extremely easy, even if he's lazy he should be able to do it super fast; having a default All `ON` or `OFF` scenario would be great for him" (P04)*. Some participants imagined that Homer wouldn't even use the app in certain use cases: *"He might not use the app but rather have a remote for his lights to control from his sofa. Also, it would be good to have motion detectors installed in his house, so anytime he gets home from the bar, lights would automatically turn on" (P01)*. It is also worth considering one angle brought up by a participant, arguing that it would have helped more considering Marge over Homer, as she's the one caring more for their house affairs: *"Marge is the one that organizes a bit more, so I believe she would be the one using more the app to set up and schedule times for smart devices" (P06)*.
Despite this method unfolding, during the sessions, in a way that I didn't expect when preparing them, it provided useful guidance as it highlighted helpful ideas and relevant factors to consider later in the design process. Originally, in fact, this method was imagined to be sticking to the character's environment with a more profound spatial implication, being it a metaphor for the actual user interface. However, fairly valid results to be used further in the process were successfully collected.

5.2.4 Prototype

Within Iteration II, the activity of prototyping started to require more effort and attention to details, following insights, needs and suggestions that research participants - in the guise of users - pointed out until that stage in the project.



(a) Room view's version A.



(b) Room view's version B.

Figure 5.29: Two different design solutions for *room views*.

Wireframing and Prototyping

With the chance of group sessions being set up - in a co-design fashion, as mentioned above, mainly for ideation purposes - with some research participants, both existing and new mock-ups were revised, created and finally turned into partially interactive prototypes, so to be showcased in that event, and to grasp some new feedback and comments. Whereas Iteration I's Prototype stage (see Section 5.1.4) focused on the *home view*, this iteration would rather elaborate on the other, surrounding screens, such as the *room* and *favourites views*, but also on some specific features, such as *scenes* and *connection states*. Below is presented a selection of the mock-ups that were produced within this stage.

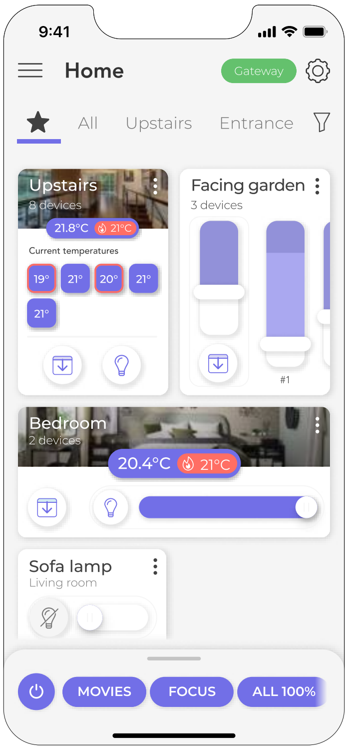
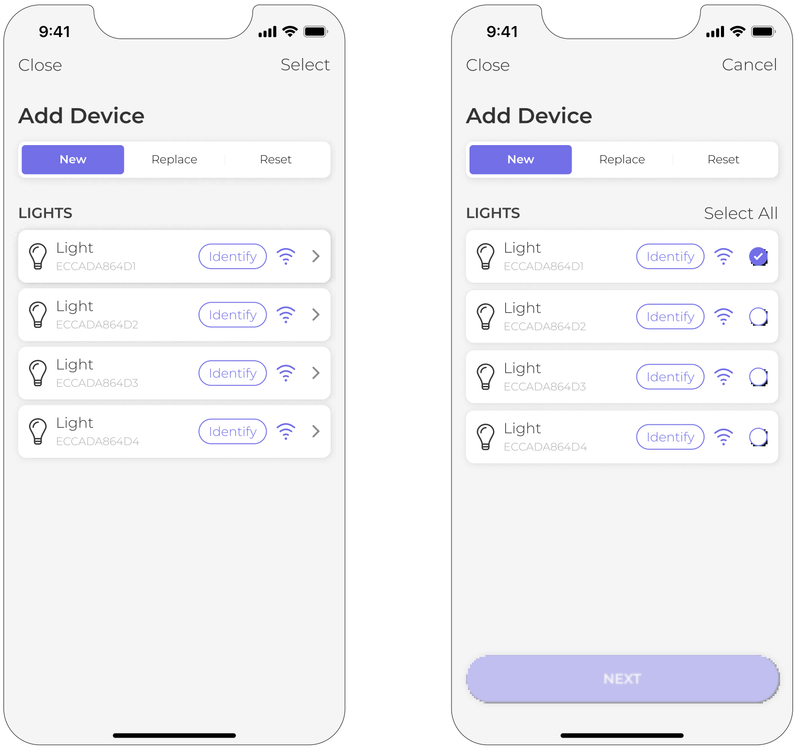


Figure 5.30: First draft for the *Favourites* view.

For the room view, two different versions were produced (as in Figure 5.29), both aiming to address the very central aspect of making multiple product categories fit together: version A - shown in Figure 5.29a - would do it by providing such product categories through a combination of a tab bar and a carousel of cards, each one presenting the list of devices belonging to one product category; on the other hand, version B - in Figure 5.29b - presents devices grouped by their categories in mere lists, with a section dedicated to thermostat devices, if any, between the room image and the list. Again, thanks to Figure 5.29, it is possible to observe a feature that would allow users to group devices - belonging to the same product category - together. It may be noticed that each device, listed in the room views, comes with a *'more'* button, indicated as a *three-dot* icon, with the goal of helping the user reach a device's setting menu more quickly, acting as a shortcut. Part of the time invested was aimed towards exploring and experimenting on a possible *Favourite*

section, allowing users to gather all their favourite devices, but also zones or rooms into one place; a first attempt of such space is envisioned in Figure 5.30.
Given the feedback provided at the end of Iteration I (see Section 5.1.5), the installation flow was improved, making it work just like The Company's real app would do. More specifically, a feature enabling users to install devices together, as a group, would be drafted: Figure 5.31, for instance, shows how the app would look while selecting multiple devices within the installation process.

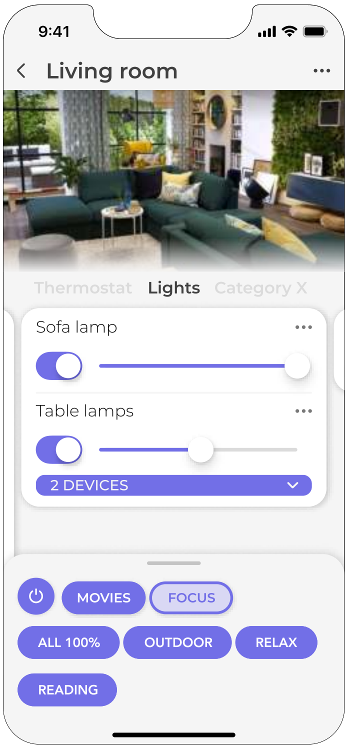


(a) List of devices available for installation.

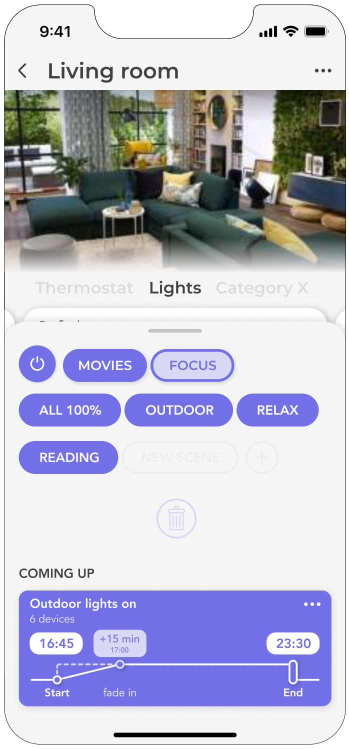
(b) The *Select* button will allow to install multiple devices at once.

Figure 5.31: Selection process of devices ready to be installed: by long-pressing on one of the devices available or tapping on *Select*, multiple devices - belonging to the same product category - can be installed together.

Effort was put on the scenes and scheduling features, as well. Originally, previously set up scenes would be listed horizontally in the lower part of the screen real estate; the more scenes a user sets up, the more likely the list will overflow, so it would be necessary to swipe sideways in order to find and activate the desired scene. Now, such list would be imagined to be lying within a card that could be vertically expanded (or collapsed) through swipe-up (or swipe-down) gestures (as in Figure 5.32a). In the same Figure it may be observed how the first scene in the list differs from all the others: it is in fact a preset default scene, enabling users to turn all devices in the environment `OFF`; however, it may also be observed how the *'Focus'* scene looks different from the others: in fact, it was considered beneficial to convert the scene's buttons into togglable objects, allowing the user to better understand which are `ON` and which not, hence enhancing their feeling of control over the system. Following the same principle, it was imagined that this card could be further swiped-up, so to visualize the first coming-up scheduled event programmed for the day, as presented in Figure 5.32b.



(a) Semi-expanded card for scenes.



(b) Fully expanded card for scenes including *coming up* scheduled events.

Figure 5.32: A vertically expandable card in the lower screen real estate displays the list of scenes and the first upcoming scheduled event for the day.

Finally, connection state labels were realized (see Figure 5.33), again with the aim of letting the user feel more in control over the system. When some problem occurs while the app tries to connect to the smart environment, such label would help understanding what is the origin of that problem. If, for instance, the phone is set on *Airplane mode*, or the smart environment is affected by a power outage, the label will turn red and will read *'Offline'*.
Within Iteration II, one final, brief activity - finding place within the Prototype stage - was conducted in the wake of some feedback provided in Iteration II's Test stage. As will further explained in Section 5.2.5, in fact, the reason for returning back to the Prototype stage was to examine the use of colour in some specific UI elements - i.e. the connection state labels (as in Figure 5.33) presented just above - possibly affecting what we may call the UI's *colour vibrancy*. Therefore, such UI elements would be transposed to gray-scale (see Figure 5.34), to assess whether any of the colours being used would be finely balanced with each other. Indeed, the

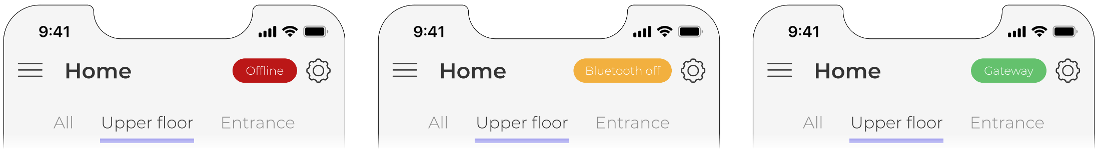
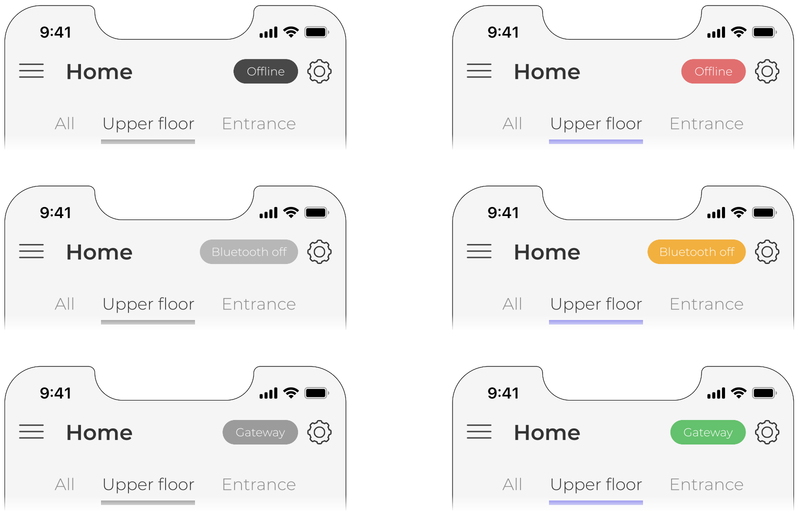


Figure 5.33: Connection state labels were created to constantly indicate in the app which technology would be used to keep the connection with the user's environment.

gray-scale version of such UI elements helped determine that the red label, used up until that point was too saturated and heavy if compared with the yellow and green labels; it was decided, then, to replace that tone of red (specifically represented by the *hex code* `#BB1717`) with a softer one (`#E26F6F`).



(a) UI elements being converted to gray-scale (with red as `#BB1717`).

(b) A softer tone of red was chosen (`#E26F6F`).

Figure 5.34: UI elements transposed to gray-scale to assess UI's colour vibrancy.

5.2.5 Test

Interviews

A round of group interviews - in the form of a focus group - was organized concurrently with the co-design ideation session, hence together with the same participants who joined the session to conduct the Extreme Environments method; the aim of this group interview was to present mock-ups and prototypes produced until that point, mainly during Iteration II, and get feedback on them. As prototypes were not implemented to be fully working interactively, participants couldn't really get the real feel of those, and were merely presented on the meeting room's TV screen. The first batch of mock-ups and prototypes mainly included various alternatives for home views. Participants unanimously preferred one specific type of room card over other alternatives, yet giving some comments on the sizing and positioning of buttons: *"Room cards with a white picture on top and a white portion on the bottom look cleaner, buttons may risk to be positioned differently depending on whether the slider controlling lights is shown" (P06)*, *"Buttons to control Category X products might be better positioned on the right, so their appearing slider won't cover the room name" (P04)*, and *"All the buttons in general feel a bit to small, but I should try them on a real phone... Also, the layout of the buttons may be left to the user's choice, providing a sort of left- or right-handed mode" (P07)*; participants also identified a critical point, i.e. some gestures might be difficult to be discovered during interaction with some UI elements: *"long press gestures can't be found so intuitively, so it's not clear what users can and cannot long press" (P01)*, implying that some sort of onboarding should be provided.

Shifting the focus to the room view, participants generally liked version A's UI solution (see Figure 5.29a) of a tab bar to separate between different product categories. Reasonably, *P04* and *P07* pointed out the need of replacing toggle switches with buttons, as they're used in room cards within the home view, arguing that a lack of consistency could be found otherwise: *"If you're using buttons with icons representing devices, do use them all over to have the whole app consistent"*; also, some participants appreciated the cards grouping multiple devices together: *"If we happen to need the grouping feature to group devices, dropdown is a nice way to expand or collapse the card" (P04).* An interesting observation, pointing out the actual role of the room view, came from *P01*: *"If I go to the room view, that's because I want to adjust something in particular, maybe just one light in that specific room, otherwise I control all lights of that room directly from home view".*

Some contrasting opinions were collected when it came to discuss the Favourites feature: despite the idea of such feature was appreciated, in principle, many of the observations were referring to the visual outlook of the prototypes presented. Some lamented the positioning and the meaning of some UI components: *"The vertical sliders are too close to each other, it feels a bit claustrophobic" (P06)*, *"The temperature is taking too much space" (P04)*, *"In that Zone card, you don't know which temperature belongs to which room" (P01)*, and *"Cards for widgets representing zones, rooms and devices look too different, it's a bit overwhelming. It's difficult to understand what's going on" (P03).* On the other hand, some appreciated the level of customization the UIs presented would imply - *"It's cluttered, but in a good way! I like the aspect of customization. Might be cluttered for anyone else, but for me it's not a problem" (P01)* -, and suggested actually having some sort of favourites for each room: *"This favourites idea is great, but I would want to have some sort of shortcut for favourites for each room, actually" (P01).*

Regarding the header portion of the UI, participants focused on the animated label showing the connection state to the environment. They suggested, for example, that it would be important for the app to tell the user if there's a connection problem rather than when there isn't any: *"If the app is connected over Bluetooth, show the label only when you have a problem. Otherwise if it's connected through gateway, just show the label in green" (P01)*; other participants pointed out the potential problem of users setting long names for their environment, hence affecting the position of the connection state label: *"The label might just be on the right all the time, on the same*

position; there might be a problem with long site names..." (P06). Accessibility-wise, a brief ad-hoc interview was called with a close friend of mine - affected by colour blindness - to evaluate, at least to a minor extent, the effectiveness of the colours being used on the connection state labels to communicate whether the app would be connected or not to the smart environment: *"I can't really notice the difference between the two 'Bluetooth off' and 'Gateway' in terms of colour, they both kind of look yellow-orange to me, I guess they're the same colour. Rather, I feel the red label being a bit too vivid and saturated, actually..."*. This brought to check on the different connection state labels' saturation, with the aim of warding off potential issues affecting vibrancy, and caused by overwhelmingly saturated colours. As Figure 5.34 shows (see Section 5.2.4), this was assessed by converting UI elements to gray-scale, and it was determined that the red label - indeed being more saturated than it should - should be replaced with a softer tone of red.
Participants liked some solutions for the Scenes feature, and especially liked the swipe-up gesture to get to see more: *"I like the idea of swiping up to get to more scenarios, I like the vertical movement... Feels like more up-to-date apps" (P04).* However, some technical constraints arise if togglable scenes are to actually be implemented: *"How should the system go back? What if a light in a scene was dimmed to 0% and another one in the same scene was dimmed to 100%?" (P04).* A number of suggestions emerged: as different UI variants were shown, participants preferred having a simple '+' button to let them add a new scene; participants would also like to have feedback on whether a scene is `ON` or not: *"It would be nice to always show an overview of the scenes that are active" (P04)*, and *"Buttons of scenes that are activated become white, and if you press them to turn them back `OFF`, they will turn back to blue" (P03)*; one participant also hinted at the idea of letting scenes be somehow scheduled: *"When adding or editing a scene, I would like to have the option 'Add auto `OFF` scene' " (P01).*
This final suggestion makes a perfect segway to talk more about Scheduling. Participants saw some real and valid purpose for the Upcoming scheduled events feature, yet providing with some suggestions: *"Once you have the list of upcoming events for a day, it would be nice to ignore such events not only for that day but rather until a day" (P06)*, and *"I would like to select an upcoming event so I can edit it quickly; it's nice to have options through the swipe gesture..." (P03).* Participants also mentioned the possibility of an interactive timeline to show events: *"The timeline is felt like something I can interact with, like drag the end time to postpone the end a bit later" (P07).*
All this feedback, provided by participants in the form of suggestions and comments, would then be used during the third and final iteration, aimed at converging into one prototype, providing UI solutions for The Company's future version of their mobile app.

5.3 Iteration III

In this Section, the third and final iteration in the project - heavily focused on finalizing the ultimate prototype and evaluating it, as shown in Figure 5.35 - is analyzed. As this iteration marks the fact that we got quite ahead in the project, it might be worth anticipating that - considering the five-stage design process model being adopted - early stages such as *empathize*, *define* and *ideate* will turn out to be fairly thinner in comparison to the previous iterations. As it will be further discussed in Chapter 7, however, such design process model shouldn't be seen as an inflexible approach to design, so stages are not always supposed to be approached sequentially, and some times - depending on the amount of progress being made in the project - some stages may be prioritized over others.

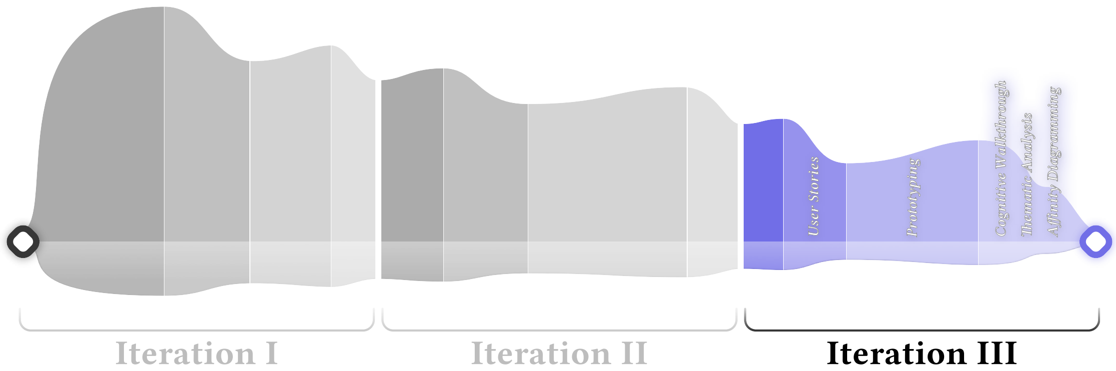


Figure 5.35: Visualization of the third iteration within the entire project's design process.

5.3.1 Empathize

Within the third and final iteration of the project, no methods were explicitly used in support of the empathize stage; however, it may be argued that time during this stage was mainly spent to process and assimilate all the information and feedback gathered during the interviews conducted on Iteration II's Test stage (see Section 5.2.5), aimed at further understanding participant's thoughts on the mock-ups and prototypes build until then.

5.3.2 Define

Despite being quite ahead in the project, it is always good to keep the designer's mind refreshed on what are user needs and requirements, which may eventually evolve or expand throughout the project. As presented in Section 4.2.3, user stories are an ideal method to capture what a design is intended to do, presenting brief scenarios to also capture usability and user experience goals.

User Stories

A brief selection of user stories that were created at this stage - aimed at laying down some user's evolving needs and requirements - will now follow:

- *As a user, I want to find devices quickly, so that I can control them in a matter of seconds;*
- *As a user, I want to find devices quickly, so that I can access their settings more easily;*

- *As a user, I want to group devices, so that I can better organize my environment;*
- *As a user, I want to easily set up and use scenes, so that I don't need to worry when I have large amounts of devices in my environment;*
- *As a user, I want to have feedback on what scenes are active, so that I know why certain devices automatically turned* `ON`*;*
- *As a user, I want to easily understand what is going on with the system and what is about to happen, so that I get higher awareness and feel more in control in terms of environment's behaviour;*
- *As a user, I want to schedule scenes, so that I don't have to recreate the same groups of devices twice;*
- *As a user, I want to turn everything* `OFF` *in the environment, so that I'm sure that everything is really off when I leave;*
- *As a user, I want to visualize the process of setting up a schedule, so that I can gain a better understanding on how it would work;*
- *As an installer, I want to the installation flow for devices to be quick, so that I can save time and can support more clients;*
- *As an installer, I want to jump between my clients' environments in a quick way, so that I can promptly assist clients, on the fly.*

5.3.3 Ideate

Within this third and final iteration in the project, the ideation stage didn't really come with well-established methods for that purpose, but it was rather subtly merged with the prototype stage (see Section 5.3.4), where it was definitely needed some ideation to work around a number of what may be called UI 'headaches' - i.e. UI problems that needed a solution - and get some solutions out of the hat. Ideas, then, mainly consisted in finding the right UI elements and components to fit in The Company's app layout.

5.3.4 Prototype

As anticipated in Section 5.2.5, research participants providing feedback on the mock-ups and prototypes lamented the fact that they couldn't really get a real feel on how the prototypes produced until that stage would actually work hands-on, through an actually working prototype in their hands. It was time, then - within the third and last iteration -, to finally deliver a working interactive prototype, available to be tried and tested on a real smartphone; therefore, focus was mainly aimed towards this direction.

Prototyping

With the goal in mind of creating a working, interactive prototype, mock-ups and prototypes realized in previous iterations up until this stage, should be reworked, as they didn't really follow some essential guidelines and rules of thumb used to design MUIs.

A considerable amount of time in this stage, then, was committed in the activity of constantly switching between *Figma* on my laptop, reworking and adjusting the mock-ups, and its mirror app on my personal mobile medium (i.e. an iPhone 13 Mini), ensuring that the guidelines being applied on such mock-ups would actually look and feel sensible to the eye, as well. To name a few aspects that needed some fixes, the text size generally needed to be increased, following Apple's Human Interface Guidelines (see Section 2.3.1.1) typography specifications; most buttons didn't comply with Apple's recommendation of providing a hit target of at least 44x44 points to accommodate a fingertip, so they should be dilated to different extents; still, some UI elements just could not provide - at least directly - with that recommended hit target size, and yet do act as manual affordances: it is the case of what Cooper et al. call *drag handles* [24], for instance, the *'more'* buttons on device cards, available in the Room view. Therefore, Saffer suggests using the so-called *iceberg tips*: like icebergs that are mostly underwater, iceberg tips are controls that have a larger target than what is visible, so the hit target is larger than the visible UI object representing it [115]. Therefore, as it is shown in Figure 5.36, this technique would be applied to some UI elements of the prototypes, such as to the scenes card's drag handle or on the *'more'* button in device cards, i.e. by using auxiliary and invisible shapes on Figma. As a consequence, with text and UI elements (e.g. buttons) growing in size, spacing also became an important factor to consider, with the aim for the whole interface have enough room to breathe.

Figure 5.36: The *iceberg tip* technique applied to the scenes card's drag handle and to the *'more'* button in device cards: the dotted lines represent the invisible edge of the hit target.

Once all these adjustments were applied to the old mock-ups and prototypes, it was time to iterate on some of the concepts offered by the user interface, following the feedback provided on Iteration II (see Section 5.2.5). Among all changes implemented within this iteration, just the major advancements carried out will now be presented.

In regard of the *Home* view, a set of new UI elements - which may be called *shortcut buttons* - was added for every zone in the environment: here, each button would act as a toggle button, allowing to quickly change state (e.g. turning `ON` or `OFF`) for all devices located in that zone, and belonging to the same product category. For example, as may be observed in Figure 5.37, we have three shortcut buttons in the *'Ground floor'* zone, one for lights, one for Category X and one for thermostats. These newly added UI elements may be considered as a reinterpretation of the suggestion proposing favourites in each zone: that is of course quite not the very same idea, yet such buttons would allow users to quickly find and manipulate devices, not only based on their location property, but on their category, as well. Moreover, as the user navigates through different zones in the app, some of these shortcut buttons may disappear, in a sort of filtering manner. It can be noticed, for instance, that the screen on the right - in Figure 5.37 - only presents the lights shortcut button, in the *'Entrance'* zone: that means that lights are the only device category available in that zone. The same principle applies to the scene list, in its respective card: in fact, depending on which zone a user is in, the scene list will update accordingly, only including scenes that are directly affected by devices located in that zone. For example, the only scene that is affected by devices located in Entrance is *'All 100%'*.

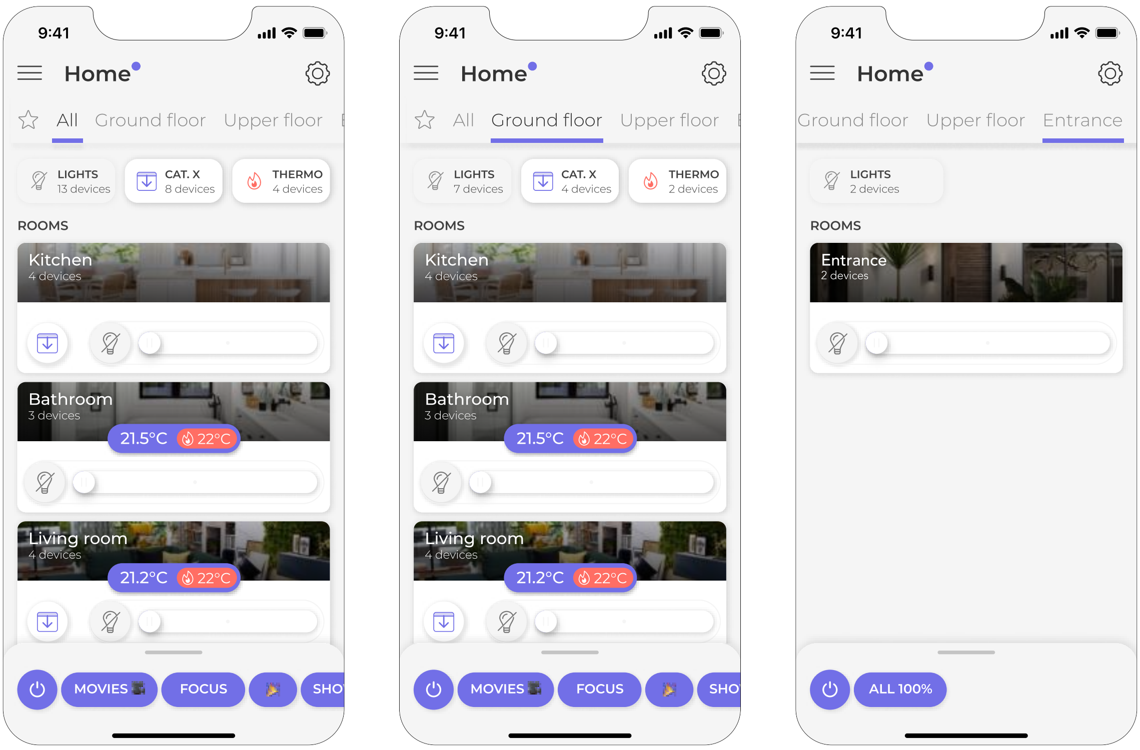


Figure 5.37: The *Home view*: depending on which zone the user is navigating, both rooms and scenes will get filtered.

Moving forward, the *Favourites* view - available in Figure 5.38 - was reworked, with the attempt of making it less visually cluttered, and the cards for widgets representing zones, rooms and devices look a bit more consistent with each other, so looking less overwhelming as they were said to be on Iteration II's prototype.
The *Room* view was subject to a few improvements: the tab bar listing the various product categories present in a room was enriched with a representative icon for each category, with the aim of making options at disposal look more intuitive; devices that would be set as favourite, in fact, would then exhibit a star imprinted on a bookmark icon on the device card, right besides the device name; finally, the *'more'* button on each device card was given an actual purpose, i.e. providing the device setting options. As a result, for instance - as it is shown on the screen on the right, in Figure 5.39 -, users may rename their devices directly from the Room view.
Another portion of the prototype that received some improvements is the scenes card, that would now provide with a list of the first three upcoming scheduled events, if any. Additionally, the UI elements representing such events would be

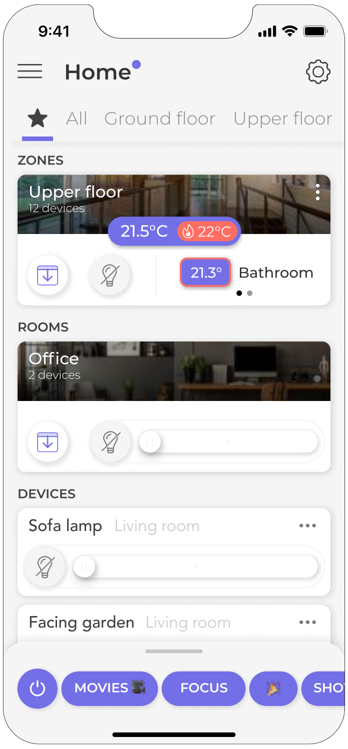


Figure 5.38: The *Favourites view.*

made interactive: in fact, a swipe-left gesture would reveal contextual actions, e.g. to reschedule or even skip that instance of scheduled event, for that day. This interaction gesture - following a pattern that was initially introduced by Apple in the iOS Mail app, and got more and more popular in many apps over the years - is meant to provide the user with what Li calls *contextual swipe* [77].
Some supplementary resources in terms of time and effort were actually employed after having conducted the cognitive walkthrough study as final evaluation session as well, described in Section 5.3.5. In fact, feedback and insights collected in that occasion were used to benefit the very final refinements on various aspects of the app's UI; therefore, for one last time, mock-ups and prototypes were revised.
For example, it can be observed how shortcut buttons in the Home view were looking like, in Figure 5.37, and how they were finally revised, but how they would even react to different interaction gestures - as visible in Figure 6.5 - within Results (see Section 6.1).
With the idea of conducting a Cognitive Walkthrough as for testing the final design solutions, the prototype was developed specifically and more in detail just around what were deemed the most relevant areas in this app for the project: as it will be further explained in Discussion (see Chapter 7), it would have not been neither feasible nor worthy to prototype every single 'corner' of the app, given the scope of this project. Therefore, the final prototype was built following a goal-directed design approach, hence giving priority on the most common tasks users perform while interacting with the app. In truth, the set of tasks that would be asked participants to perform, actually took shape already by this Prototype stage, working on the final prototype with those tasks in mind. In a way, then, it was given the priority

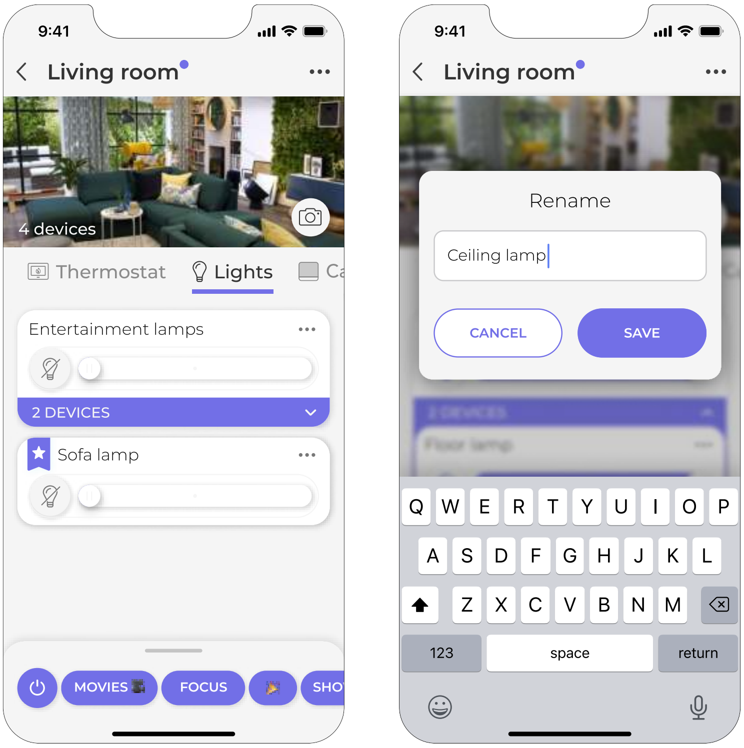


Figure 5.39: The *Room view*, including a peripheral screen showing the possibility to rename a certain device directly for that view, through a dialog box.

to first prototype the essential interfaces that a user would go through, to achieve a common task: that is the so-called *Golden Path*, known as the key set of steps that user is supposed to take as the ideal, default way of interaction with a product, without focusing on exceptions or errors [45].

5.3.5 Test

Being it the last iteration in the project, this Test stage acquired quite significant value for the sake of the final results for the project, emerging as design guidelines. With the goal of collecting richer amounts of data, seven additional participants were recruited - specifically for these final evaluation studies - joining the other eight participants, who offered their help during the whole project (see Table 5.4). Therefore, a total of fifteen people were available to participate to the final evaluation study: the set of seven, newly recruited participants, was composed of both The Company's employees (three) and students at Chalmers University of Technology (four), whom were not disclosed what company this project would be conducted in collaboration with; before the actual evaluation study would begin, these seven participants were also asked to provide some general information, as reported in Table 5.6. For this evaluation study, the Cognitive Walkthrough method was chosen to inspect the usability of the system - the prototype, in our case - and assess how it would respond to drilled down, specific tasks.

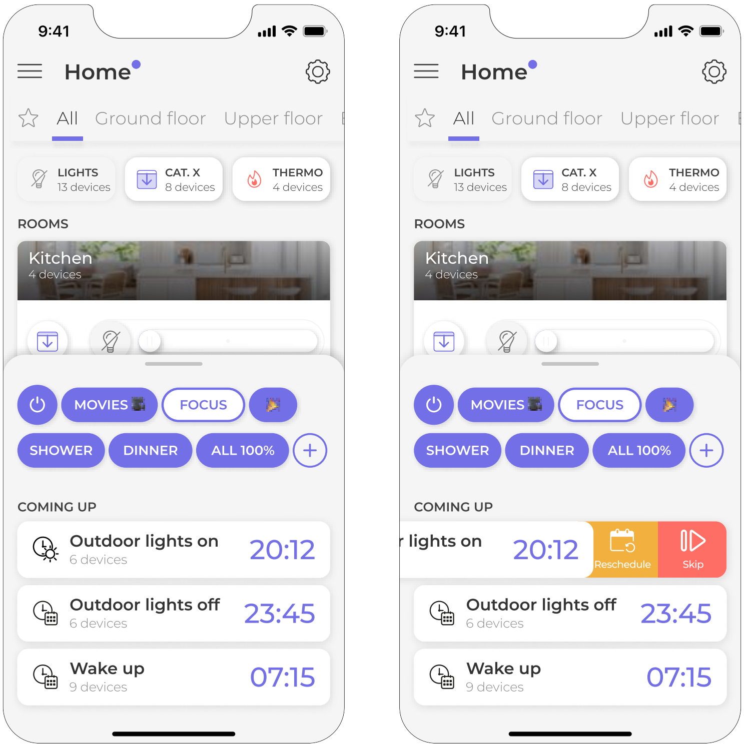


Figure 5.40: The Scenes card, including a list of the first three upcoming scheduled events, if any.

Cognitive Walkthrough

After a time and place were agreed with each of the participants, an informed consent - prepared on *Google Forms*, and available in Appendix I - was sent out to participants, expecting to be returned with the consent being accepted with their signature. This informed consent would be briefing participants on the object of the study, on the sessions being recorded (audio only) for automatic transcription, and on the data being collected as for research purposes only, without disclosing their identity and having the data stored for a definite amount of time, before it would be permanently deleted.

In parallel, a dedicated meeting room at The Company's premises was booked (whereas a group room at university was booked for the sessions with students) to have individual sessions, acting as a usability laboratory, as shown in Figure 5.41. In preparation of the sessions, many of the tips provided by NNG's UX Specialist Flaherty to plan the usability test for a mobile experience [36] were followed: the set of tasks being prepared was printed out for participants to refer during the study, in case they would be unsure how to proceed; before starting each task, also, participants would be asked to read these out loud, so to make sure that they would understand the activity to perform; moreover, participants would be instructed to think aloud during the session - i.e. verbalizing their thoughts as they move through the prototype's user interface (see Section 4.5.4); the laptop's microphone combined with services offered by *Otter.ai* would be used to automatically record, store and transcribe the sessions, as they were planned to be audio-recorded; furthermore,

Participant	Platform	**Expertise** *(1 to 5)* *Smartphones*	**Expertise** *(1 to 5)* *Smart Home apps*
Participant #9 ***(P09)*** *Employee at The Company*	iOS	Expert *(5/5)*	Proficient *(4/5)*
Participant #10 ***(P10)*** *Employee at The Company*	iOS	Expert *(5/5)*	Expert *(5/5)*
Participant #11 ***(P11)*** *Employee at The Company*	Android	Proficient *(4/5)*	Proficient *(4/5)*
Participant #12 ***(P12)*** *student*	iOS	Expert *(5/5)*	Basic *(1/5)*
Participant #13 ***(P13)*** *student*	Android	Proficient *(4/5)*	Proficient *(4/5)*
Participant #14 ***(P14)*** *student*	Android	Proficient *(4/5)*	Basic *(1/5)*
Participant #15 ***(P15)*** *student*	iOS	Intermediate *(3/5)*	Intermediate *(3/5)*

Table 5.6: Newly recruited (seven) participants' general information. The *Platform* column indicates what operating system they're most familiar with; the *Expertise - Smartphones* column illustrates what they deem is their expertise level working with smartphones, while the *Expertise - Smart Home apps* portrays their self perceived level of expertise specifically in using smart home apps.

a comfortable chair would be provided for participants; finally, before participants would arrive to the session, all software - such as *Figma* on mobile used to mirror the prototype, or *Otter.ai* to transcribe the recording - was up and running, and tested ahead of time to make sure it would be functioning properly.

Figure 5.41: The setting being prepared in The Company's meeting room for Cognitive Walkthrough sessions, acting as a usability laboratory.

As a brief, ice-breaker assignment at the beginning of each session - to better explain what the study would be about -, participants were verbally asked to perform a couple of quick tasks on The Company's real and current app, installed in the smartphone at disposal: these would examine, for instance, how participants would adjust the controller for a specific device, or reach the settings menu to edit a scene. Immediately after, participants needed to deal with a set of ten tasks, available in Appendix H. To provide with a couple of examples, Task #3 and and Task #5 are reported below:

3. Now turn `ON` the light called *Floor lamp*, that belongs to a light group in the living room. Once the *Floor lamp* is `ON`, access the settings of the *Ceiling lamp* light to rename it into just *Ceiling*.
5. Now that you've installed them, add this group of Category X's products as favourite. Then, go to the *Favourites* view and move *#1* to 100%.

As one could observe in Appendix H, the set of tasks was structured into three main parts (*Part A*, *Part B* and *Part C*). In fact, each participant was asked to perform them in different orders: for example, while *P03* faced the tasks following the order *Part B*, *Part A* and *Part C*, *P08* did that following the order *Part C*, *Part B* and *Part A*. The reason behind this decision lies within the *learnability* aspect of the user interface: the cognitive walkthrough methodology was chosen, of course, to gain insights about the user's perspective, with myself acting as an observer, rather than helping the participant; however, such method is in fact best used to uncover design problems that could hinder a system's learnability for new users [117]. Therefore, tasks were decided to be proposed to each participant in different orders, so that they would explore the prototype following different paths, based on their prior experience - i.e. the previous tasks they've been performing -, with the ambition of guaranteeing and achieving more various, more diverse results in terms of learnability.

The setting of the tests, as previously shown in Figure 5.41, also needed to be considered. Since such study was planned to take place in what we may define as a lab, it could definitely not be considered as a context-based test, so all factors related to the context of use would be given up. For this reason, participants were asked - once having completed the cognitive walkthrough activity, as a complement - to come up with their own tasks, based on their homes and their routines, with the purpose of finding any that would possibly *break* the prototype; this was thought as making it a good starting point to come up with possibly useful and specific guidelines.

In retrospective, if the goal of these cognitive walkthrough sessions were to only estabilish whether the user would be likely to succeed in completing a task at any step of the flow, Salazar's proposal of process could be followed - *step-by-step* - by asking four key questions, acting as analysis criteria to uncover potential causes for failure [117]. These four questions would be:

- *will users try to achieve the right result?*
- *will users notice that the correct action is available?*
- *will users associate the correct action with the result they're trying to achieve?*
- *after the action is performed, will users see that progress is made toward the*

goal?

If I were to answer these four questions, in general, participants did understand what the actions at the ready would be needed to reach their larger goal most of the times, as well as easily noticing what interactive elements would afford them to achieve the various steps, obviously with some being noticed more easily than others; on average, for instance, participants with previous knowledge of The Company's app, would tend to try accomplish some tasks following well-established steps, available in the app. Anyway, when interactive elements would be found, participants would generally understand their meaning and would know to engage with them; finally, nearly all times participants understood whether their actions were correct and helped them make progress or not, getting closer to the goal, based on what would occur after they would interact with the prototype.

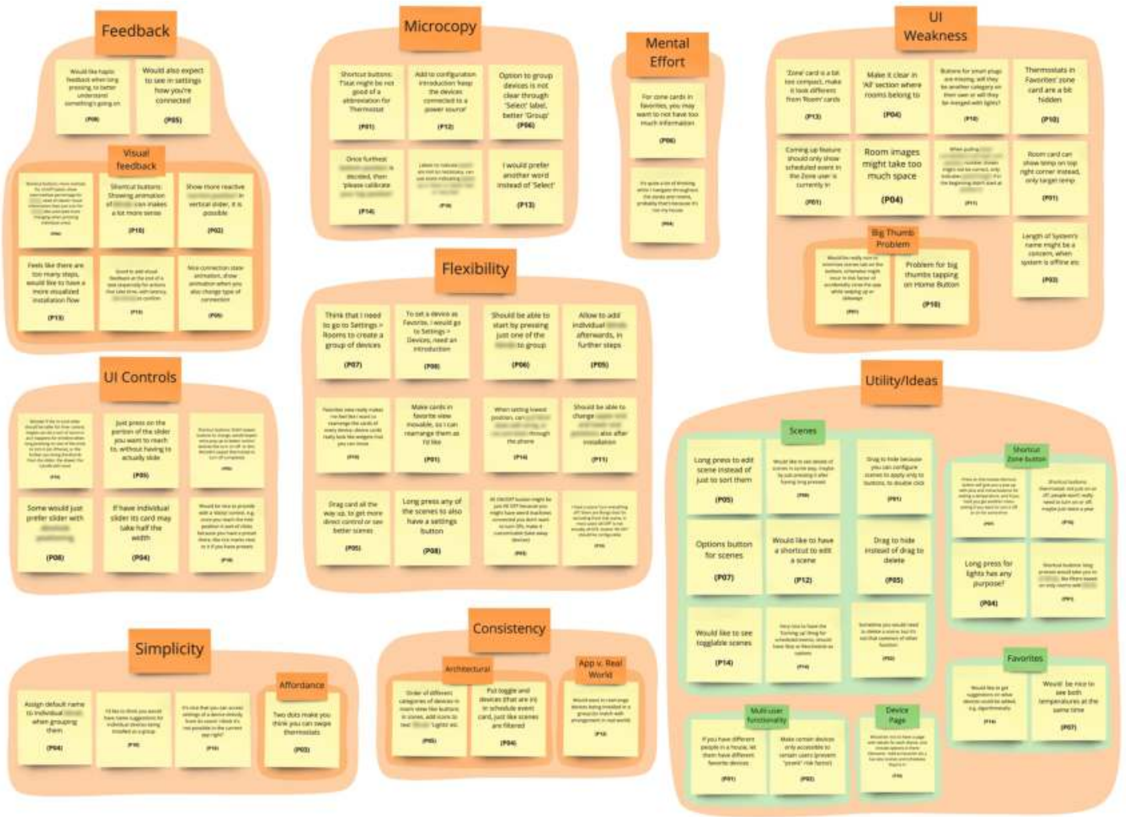
Instead, unlike the quite usual approach of collecting quantitative metrics during usability test methods like cognitive walkthroughs - such as the time spent to achieve a task or the amount of microinteractions (e.g. taps) applied to achieve such task -, qualitative data was prioritized within this evaluation study. Therefore, data collected were analyzed through a thematic analysis and resulted in two affinity diagrams, one gathering the results from the cognitive walkthrough sessions (in Figure 5.42a), and one presenting answers related to participants' own though complementary tasks (in Figure 5.42b).

Results coming from these affinity diagrams - contributing to the process of informing a set of design guidelines as very final result (which will be presented in Chapter 6) - will now be presented.

First comes the affinity diagram gathering the results collected while conducting the cognitive walkthroughs (as in Figure 5.42a). A considerable amount of observations concerned the *feedback* prototypes would provide, and the visual feedback in particular: participants really appreciated animations within the UI, which mostly relate to the representing of latency, smart devices being successfully manipulated or the connection state being changed. Some participants, however, would prefer some more visual interfaces, such as the ones of the installation flow for Category X. Talking about feedback more in general, participants would expect to be provided with some information (e.g. connection state) in other sections of the app, such as within Settings; also, they would expect some form of haptic feedback happening when long pressing.

One aspect that may affect the one of feedback, is *microcopy*: here participants complained about some abbreviations used, which wouldn't be fitting so well in the app (e.g. *T'stat* standing for Thermostat); some participants from The Company, thanks to their expertise and insights on projects such as Category X's, also suggested t*he integration of some more clear instructions within installation flows, such as "keep the devices connected to a power source"*; many participants also pointed out the need of providing with a more effective microcopy in the *Select* button - allowing to select multiple devices and group them -, suggesting to use *Group* instead.

One quite delicate factor that emerged, threatening the app's intuitiveness, is *mental effort*: in one occasion, participants complained about the exaggerated amount of information provided within the *Zone* cards, in the *Favourites* view; under other circumstances, another participant lamented the amount of thinking he had to put



(a) Affinity diagram gathering results collected through the cognitive walkthrough sessions

(b) Affinity diagram gathering answers related to participants' own thought complementary tasks

Figure 5.42: Resulting affinity diagrams from the final evaluation studies

while navigating throughout zones and rooms, blaming - nonetheless - the environment in the prototype, as being not their home nor the one they're used to interact with.

Three major themes emerging from the evaluation study relate to three qualities the app would need to embed: *flexibility*, *simplicity* and *consistency*. Participants, in general, appreciated some features of the prototype making the app more flexible, such as accessing a device's settings directly from its card in the Room view; however, participants called for even more flexibility: that is the case for some steps in the installation flows, having different ways provided to create groups of devices, or having default scenes - i.e. *All* `OFF` - customizable, being able to eventually exclude from devices from them. Simplicity-wise, participants brought some points to make the app even simpler, given the solutions presented in the prototype: for instance, when installing new devices as a group, individual devices may be automatically assigned with a default or a suggested name. Participants also correctly understood some UI elements as affordances, such as the dots representing elements in a carousel. When it comes to consider consistency, relevant comments from participants related to what we may call architectural consistency, and consistency between the app and the real world: for example, participants suggested to rearrange the order of product categories within the tab bars in Room views according to the order of the shortcut buttons offered in the Home view; some participants also pointed out the importance of enabling users rearrange devices in the app in a way that would match the way the are positioned in the real world.

A good part of comments from participant relates especially to UI elements, such as the various controls available, and the potential weaknesses associated to such UIs. Many comments were specifically aimed towards slider controllers: participants highlighted the need of various alternative interactions with sliders, so they would be enabled to not only slide such controller, but also to tap on the level they desire to reach; another proposal was to add tick marks as a reference when adjusting a slider; some participants also manifested their concern on the small size vertical sliders for Room cards would be characterized by, implicitly suggesting various scrubbing speeds to better affording fine tuning while adjusting such sliders. Other valuable observations concerned the shortcut buttons in the Home view, where participants would expect it as a way to quickly access a pop-up list of devices belonging to one category, rather than a mere toggle button to turn `ON` or `OFF` all those devices in a Zone. Moving towards what may be seen as UI weaknesses, participants often pointed out problems about sizing, such as the room images taking too much space, or the Zone cards for Favourites being too compact; some focused on what is called the *big thumb* problem, especially in the lower side, where scenes may be mis-tapped with the Home Button; another problem would concern the environment's name on the header: what happens when users would enter a long name? Would it fit in the header? Finally, one participant noticed - as product categories (such as Lights, Thermostats, Category X, etc.) would be explicitly shown as tab bar elements, inside the Room views - the Smart Plug category missing.

Finally, participants indicated a number of ideas that would eventually take form as features or would affect existing UI elements or even sections of the app. Participants suggested, for instance, different ways of interaction to interact with scenes: making scenes buttons togglable, to better know when one is active, or long-pressing them to quickly access their settings and edit them; for the Favourites view, instead, they would propose device suggestions to add, based on the user previous activities; participants also suggested providing a device page, in which users could access device details, setting options, but also read what scenes and schedules they're in. Finally, participants recommended the implementation of multi-user features: it would be ideal, for example, to let different users in an environment have their own devices set as favourite; moreover, in a security perspective, devices could be made available and accessible to certain users only - so that, based on the user role, they

may become beyond reach for some users - in order to prevent issues, such as users playing mischievous acts - i.e. pranking - with each other.
Focusing, instead, on the second and final affinity diagram (see Figure 5.42b), the tasks that participants would think of when interacting with The Company's app would most often relate to the topics of *scenes*, *alerts*, and *room orientation* in the app. Regarding the topic of scenes, users would mostly associate them with a handful of activities, such as *going to sleep*, *waking up*, *leaving home*, *coming home*, or would relate to *home routines* and *hobbies*. This provides one further evidence in suggesting preset scenes to users, like other apps offer (e.g. Philips Hue and IKEA Home Smart, as in Section 5.1.2). One participant focused on the notification role the app may inherit: for instance, if they happened to set a temperature for the thermostat to reach, the app may notify them as soon as that temperature has been reached, and eventually let the user take further actions. Finally, another participant brought the attention towards the specific activity of arranging rooms in the app, while setting it up. In fact, they explained how such arrangement would strictly tie to the spatial distributions of the rooms within the environment: as they would enter the house from the entrance, the entrance room in the app would be first in the list, whereas the cellar would be last. This would definitely bring a certain level of correspondence between the real world and the app, hence possibly reducing the user's mental effort while navigating in the app.
Feedback and insights collected during this evaluation study not only helped inform a set of design guidelines, meant as the main and very final result for this project, but helped me revise and apply some ultimate refinements to the prototype, as mentioned above; in fact, it can be noticed how some interfaces finally evolved, if you get to compare the mock-ups presented in Section 5.3.4, with the ones in Section 6.1, within Results (see Chapter 6).
As a side note, these evaluation sessions marked the very final occasion to meet and thank the eight participants who helped out throughout the whole thesis project. Therefore, as promised in the preliminary recruiting questionnaire (see Appendix B), a compensation to each participant was offered, as a token of appreciation for their contribution: such compensation materialized in the form of movie tickets, one per participant (more information is provided in Appendix J).

6
Results

This Chapter presents the main results achieved out of this thesis project: the *high-fidelity prototype*, and the set of *design guidelines and patterns*. As it will be further discussed, the former may be viewed as an auxiliary result in support of the latter, which may be considered as the very main and final result for the project.

6.1 High-Fidelity Prototype

The final high-fidelity prototype consists of a Figma prototype, which was developed throughout three main design iterations, beginning with a set of sketches and wire-

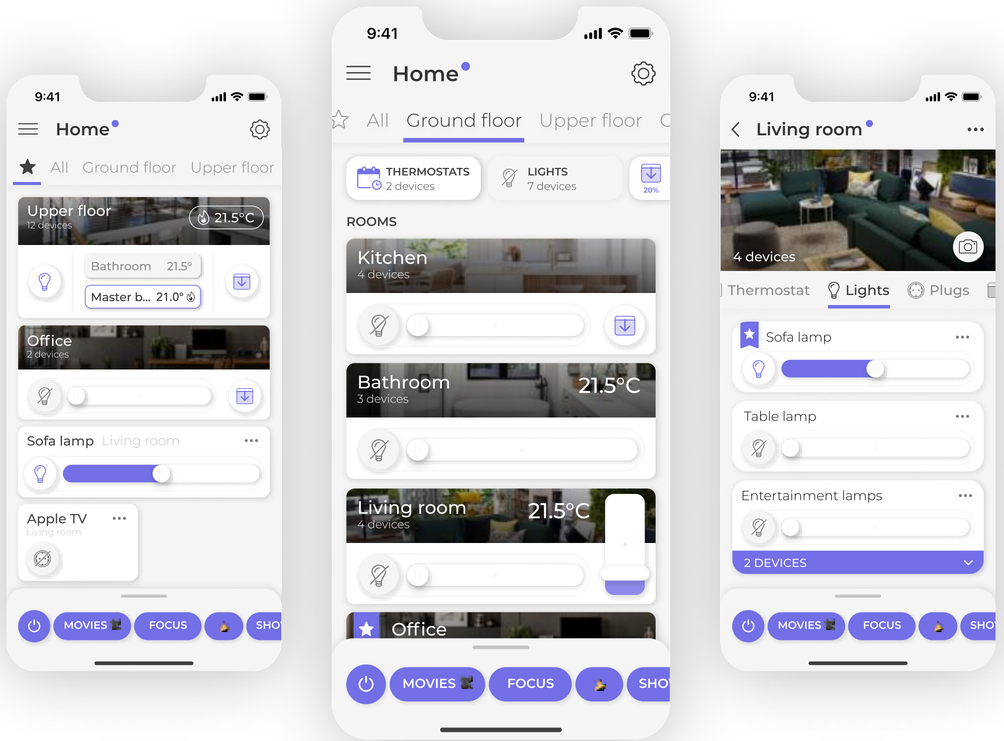


Figure 6.1: The main sections of the prototype, respectively the *favourites*, the *home*, and the *room* views (from left to right).

frames, which were then converted into mock-ups, and finally turned into interactive interfaces, precisely in the form of prototypes. Based on the feedback catered by research participants in the last iteration's cognitive walkthrough activity, some specific parts of the MUI underwent further refinements and adjustments. Accordingly, as briefly anticipated in Section 5.3.4, the MUI presented in this report will slightly differ between the last design iteration - in Section 5.3 - and here, in Results.
The main sections of the prototype - the *home*, the *room*, and the *favourites* views - are displayed right below, in Figure 6.1, with details being further elaborated, in a walk-through fashion, in the following sections; however, being them of support for describing design guidelines and patterns, additional details about other prototype's peripheral screens will be revealed throughout Section 6.2.

6.1.1 Home View

In Home View, you as a user will get to find all spatial elements that add up to your smart environment: zones and rooms. The tab bar on top - right below the header, representing the name of environment you are controlling, and the connection state label, indicating whether or how the app is connected to the environment - will easily allow to switch between zones available: for each zone the user is going to navigate to, a list of rooms will be offered, presenting rooms disposed accordingly and providing with controllers to adjust smart devices as a group; controllers for specific device categories will allow a long press gesture, to afford more advanced interactions. Right between the tab bar and the list of rooms, a set of shortcut toggle buttons is offered, one per each device category that will be present in a zone: the user, then, will be enabled to apply changes to their devices not only by browsing through the rooms they are in, but also according to the device category they belong to. In fact, these shortcut toggle buttons - on a long press gesture - will display a list of all the devices belonging to the category represented by the button. On the bottom, a rather ubiquitous UI component may be observed, also available in other views: a vertically sliding card presents the list of scenes available within the zone the user is currently in: thanks to their toggle property, it may be easily determined whether a scene is active or not. Finally, if you slide this card further up, coming up scheduled events will appear, listing the first three events that are soon coming up: here, the user is free to reschedule or even skip the events for that day.

6.1.2 Room View

Room View will enable you managing and controlling devices individually: a tab bar has been introduced, to better organize the various device lists at disposal, using device categories as criteria to organize the lists. For each element in the tab bar, a representative icon of the category is included, to help the user select the desired category more quickly and intuitively. Just below the tab bar, according to the selected device category, you will find the devices available in the room: each card will represent either a single device, or grouped devices, which can be expanded through the dropdown option to find what single devices they're composed of. Both cases, different kinds of controller - such as sliders or toggle buttons, depending on the device the card is representing - will be available to perform adjustments. Each card will also display a *more* button on the top right corner, acting as a shortcut to allow the user to perform a number of actions, such as renaming the device or adding it as a favourite; moreover, through a long press gesture, cards can be rearranged to the user's liking. Last but not least, Room View may be customized to a certain extent: right between the header on top - indicating the room name - and the list of devices, a representative default image is offered, which may be easily changed by tapping on the camera icon.

6.1.3 Favourites View

Favourites View will collect all smart devices installed in your smart environment that you, rather trivially, set as favourite: this view - available as the first element in the Home View's tab bar, listing Zones, and represented by a star icon - may, in fact, be seen as a shortcut to find all your favourite or most used devices in one single place. Not only devices, but rooms and zones may be set as favourite as well, with cards specifically designed according to the environment's object (device, room, or zone). Moreover, a particularly useful feature, called *Favourite suggestion*, is provided within this view: right below the list of objects being set as favourite, a banner recommending the user to set some device, room, or zone will appear, based on past user behaviour; through a swipe-left gesture, the banner will reveal a contextual action of confirming, and hence adding the suggested object as favourite. Otherwise, further down, the *Add to Favourites* call to action will be at the ready, providing a complete list of objects that may be added.
All in all, however, the prototype may be considered just as a supporting output for the main and most important result: the set of 21 design guidelines, complemented with proposed design patterns, will now follow.

6.2 Design Guidelines and Patterns

Below is the main result of the project: the formalization of a set of design guidelines within the context of home automation mobile apps, enumerated under a number of key areas - i.e. *user control*, *user feedback and situational awareness*, *spatial awareness*, *security and privacy in multi-user environments*, and *customization and flexibility* - and informed through the various design stages and iterations conducted within this project. For each one of the 21 design guidelines, a proposed design pattern is suggested as a complement, in support for a better understanding of the corresponding guideline and giving an actionable direction towards design. Moreover, many of such guidelines or pattern proposal will be integrated with elucidative figures, providing one further explanation of a notion or of a concept through visual means. Literature such as Tidwell et al.'s *Designing interfaces: Patterns for Effective Interaction Design* [124], or Saffer's *Designing Gestural Interfaces: Touchscreens and Interactive Devices* [115] and *Microinteractions: Designing with Details* [116] was taken as a reference to pick up some inspiration on the style their design guidelines and patterns were laid down.

User Control

GL_1 **Provide advanced user gestures to perform advanced tasks**. The most straightforward and simplest interaction that components in a MUI may suggest is *tapping*, usually performed to trigger basic and most essential actions in an app. On the other hand, the very same components should sometimes afford for more advanced tasks, as well.

> *"I wonder if the slider should be longer for finer control... maybe you can do a sort of zoom-in like it happens when trimming a video on iPhone, or the further you bring your thumb from the slider, the slower it will move? I saw it working like that somewhere..."* (P10)

(a) Category X's control buttons afford long-pressing to access their slider

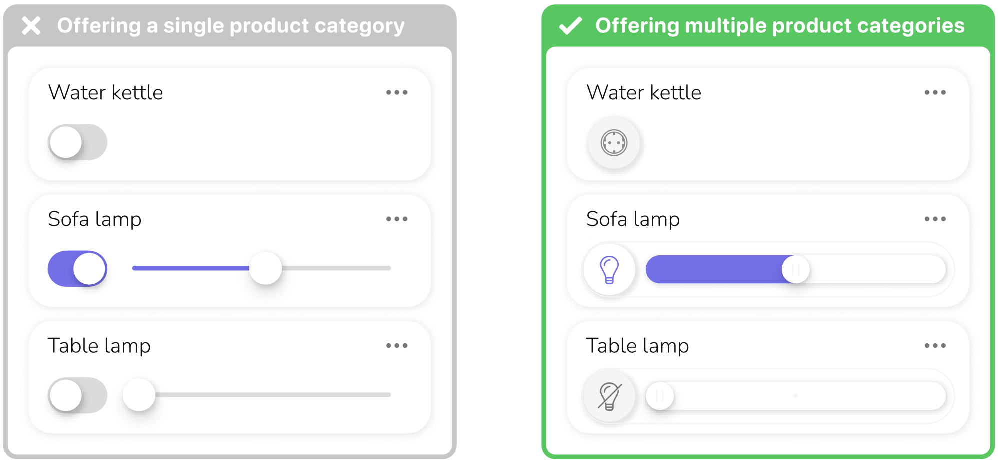
(b) Pulling to the left while sliding will result in finer scrubbing speed levels

Figure 6.2: Some UI components will afford to perform more advanced tasks through more advanced user gestures.

Proposed design pattern: *provide the long-press gesture to access advanced options of a UI component, if available (see Figure 6.2a). Taking inspiration from a pattern identified by Baig and LeVitus, specifically for fine-tuning slider* *objects, provide different 'scrubbing speeds' [10]: as you slide perpendicularly to the main direction the slider object is deployed (horizontal v. vertical), the scrubbing speed will change. Taking Figure 6.2b as example, the more to the left the user slides, the slower and the finer the slider's thumb will move.*

GL_2 **Allow the user to quickly recognize and determine what smart device category a UI controller affects**. As long as all smart appliances in a smart environment fall into the same category (e.g. lights), it is alright to use standard toggle switches (see Figure 6.3a). However, with the advent of a number of product categories, standard toggle switches become too generic and result in a higher cognitive load when it comes to identifying both the category a device would belong to and the meaning such control would have in regard to that product category.

"I'm afraid the UI will be harder to learn once we will add the new products..." (P04)



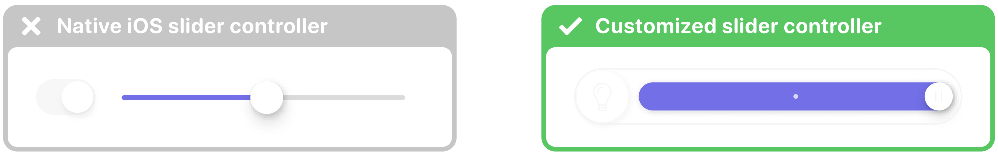
(a) Standard toggle switch **(b)** Toggle button

Figure 6.3: The proposed pattern would replace standard toggle switches (a) with buttons embedding a representative icon (b) of the smart device being controlled.

Proposed design pattern: *replace standard toggle switches with simple toggle buttons, representing the smart device they are controlling through an icon (see Figure 6.3b). By means of animations, the icon may also reflect the state its respective device is currently in.*

GL_3 **Support different user's interpretations of manipulation fitting into the same UI controller**. Sometimes, mobile operating system only afford specific interactions with native user interface controllers (see Figure 6.4a). Findings from this project suggest the need to support alternative interactions on the same controller, with the user's goal of achieving a task in a quicker way.

"[...] it's very hard to tap on the edges [of the slider] to jump back and forth, can only slide" (P05)

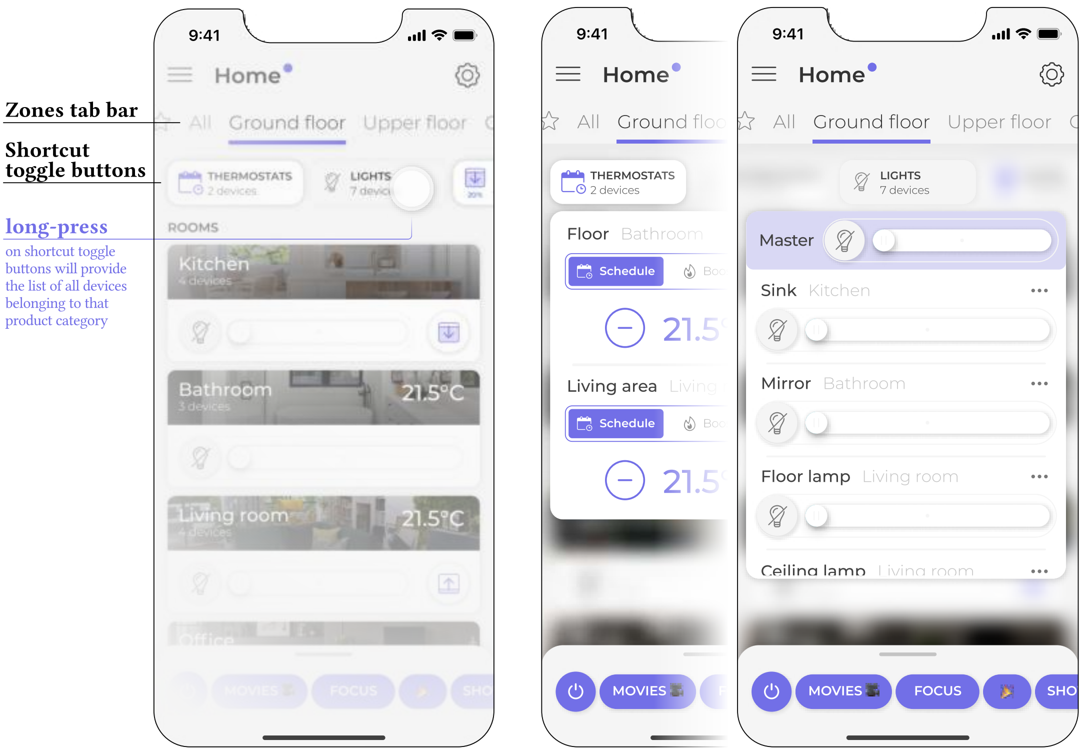


(a) Affordance for slides only

(b) Affordance for both taps and slides

Figure 6.4: The proposed pattern suggests reshaping UI controllers to better hint at alternative user interactions.

Proposed design pattern*: offer customized UI controller components better hinting affordances for alternative interactions; taking slider controllers as example, make their track thicker, better suggesting its support not only to slides but to taps as well (see Figure 6.4b).*



(a) Shortcut toggle buttons are displayed right below the Zone's tab bar

(b) On long-press, the corresponding smart devices are shown

Figure 6.5: Shortcut toggle buttons are automatically displayed on each smart environment's Zone view.

GL_4 **Allow the user to quickly find, access and control the whole set of smart devices, belonging to the same product category and being installed within the same spatial portion of the smart environment (i.e. Zone or Room)**. When smart environments become increasingly crowded with smart devices, it becomes essential to offer access and control for devices not only according to their spatial dependency but also depending on the product category to which they belong.

"[...] I would want to have some sort of shortcut for favourites for each room, actually" (P01)

***Proposed design pattern**: once providing the user with a spatial hierarchy of their smart environment through Zones, include shortcut toggle buttons - one per each product category present in a Zone - automatically grouping all devices that belong to the same category (see Figure 6.5a). These shortcut buttons will allow users to quickly find, access and control all devices of the same category being installed in the same Zone through the long-press gesture (as Apple's Interface Design Guidelines (see Subsection 2.3.1) suggests, long-presses are usually applied to reveal additional controls or functionality); the effect of the long-press gesture is shown in Figure 6.5b. In the Zone view, Room cards allow one to quickly access and control devices of the same product category being installed in the same room.*

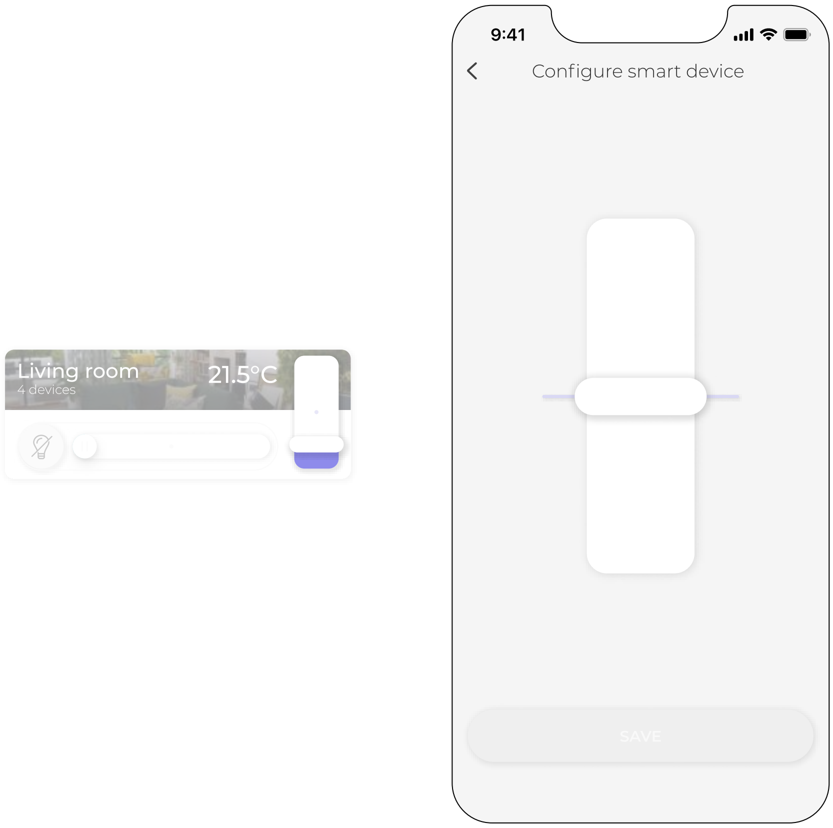
GL_5 **Design UI controllers according to the smart device's property that needs to be manipulated**. Depending on the context of use, a user may want to adjust a value of a smart device in absolute terms (e.g. adjusting the intensity of a dim light from 50% to 85%), whereas other times they would prefer to adjust it relative to time, for instance, so that the adjustment can be performed with different velocities.

"I usually don't look at my phone while I'm dimming [through the slider], I look at the lights" (P01)

***Proposed design pattern**: offer standard slider controllers when the smart device's property to be controlled relates to a fundamental physical magnitude (e.g. length, temperature, or luminous intensity) (as in Figure 6.6a); offer a 'joystick' controller when the smart device's property to be controlled relates to a derived physical magnitude (e.g. velocity), as shown in Figure 6.6b.* Behaviour of the 'joystick' controller solution is further elaborated in Section 5.1.3.

GL_6 **Provide the user with suggestions about pre-set state levels**. Users may want to quickly adjust smart devices to specific levels; possibly, such levels have been set on the same device, already, for scenes or scheduled events.

"I do use scenes... I mean, it's usually for the night that I want to turn on lights and have them be dimmed at a specific level..." (P03)



(a) Standard slider controller (highlighted)

(b) Joystick controller

Figure 6.6: Despite the two example sliders controlling the same product category, different properties of that product are actually being controlled.

Proposed design pattern*: within the tracker portion on the sliders, include key points, each one representing either reference or pre-set levels, following the rich visual modeless feedback (or RVMF) principle. For example, a key*

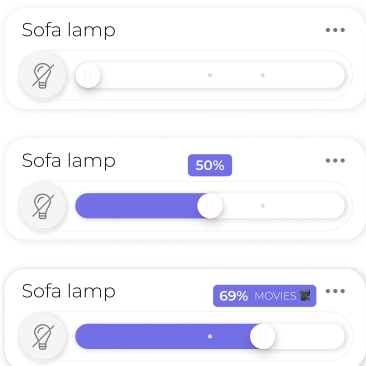


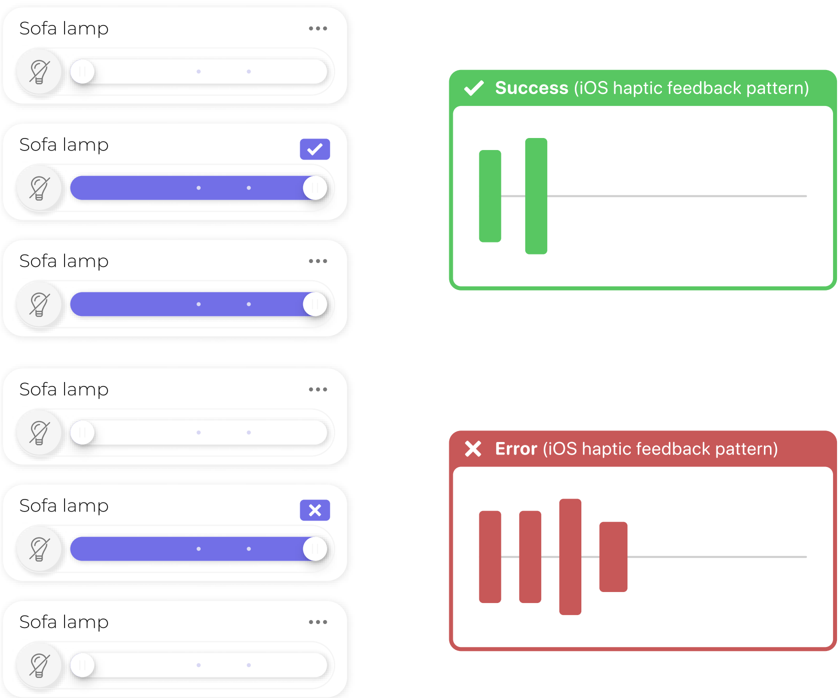
Figure 6.7: Dots along the slider's track are shown to suggest reference or pre-set key points. Labels are temporarily shown as the user slides over the corresponding key points.

point indicating 50% may be included, whereas other key points may indicate levels that the device being controlled is set to in scenes or scheduled events. Once the user slides over any of such key points, a label indicating its meaning will temporarily appear, as portrayed in Figure 6.7.

User Feedback and Situational Awareness

GL_7 **Provide the user with a confirmation of a task being performed**. A clear indication of a task being successfully performed and accomplished is needed. This becomes extremely beneficial for the specific use case of adjusting some smart device's settings remotely, away from the user's own smart environment, hence not being able to see directly the actual change happening through their eyes.

> *"It's a bit confusing if I enter the room view, change some values to a device and go back. It would be good to have a clearer idea if these changes have been actually applied, maybe through some confirmation or some green icon..."* (P04)



(a) Standard feedback icons to communicate success and error

(b) Visualization of Apple's standard haptic feedback patterns for success and error

Figure 6.8: Visual and tactile means of feedback to communicate the outcome of a task.

***Proposed design pattern**: show a feedback icon (e.g. a check mark for success or a cross mark for error, as in Figure 6.8a), close to the controller being used, to communicate the outcome of a task being performed; if possible, complement such visual feedback with haptics, using standard haptic patterns (e.g. communicating success or error, as in Figure 6.8b).*

GL_8 **If any, make smart devices' temporal latency visible to any environment's change of state applied by the user**. With the advent of new product categories, it becomes important to consider the aspect of latency. As anticipated in Chapter 5, while it is negligible to consider latency when adjusting one light's dim level to another, it becomes worthwhile to consider for other product categories - such as Category X - as the time taking between the event of a change being triggered and the event of that same change reaching the target state may result in the order of magnitude of seconds.

(a) Before the user sets the slider to a new level, current and target states are at the same level

(b) The user has just set the slider to a new level: a difference between current and target states is visible

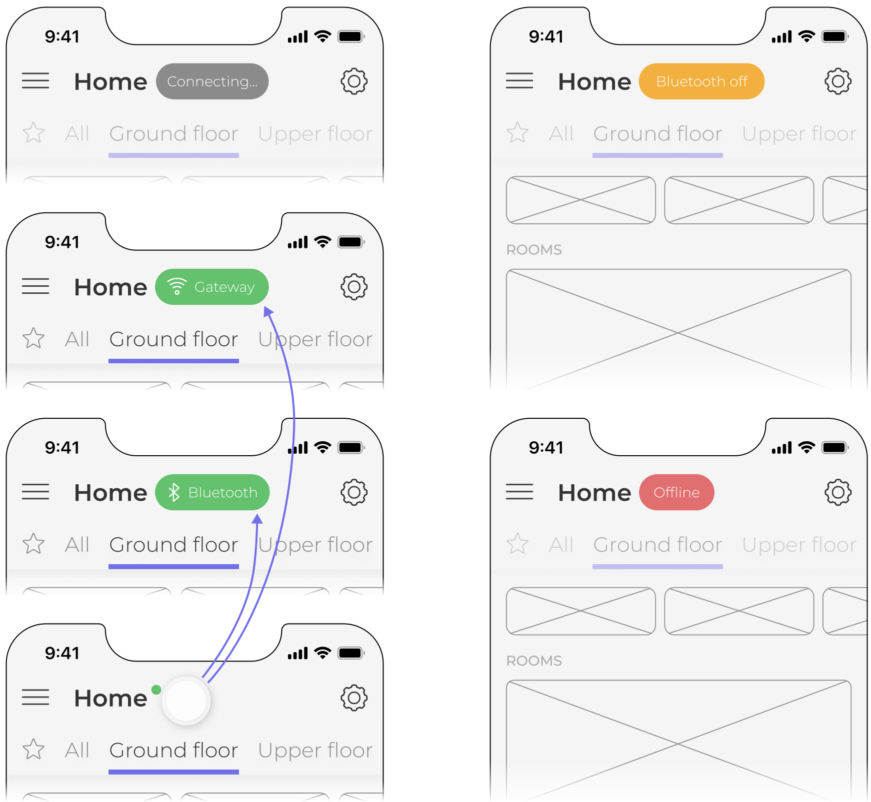
(c) After a few seconds, the track representing the current state reaches the target state

Figure 6.9: Representing latency in the app.

***Proposed design pattern**: on slider controllers, show the difference between the current state and the target state of the property being changed, by adding a second, semi-transparent track to the controller. Ideally, use the semi-transparent track to represent the target state, whereas use the solid-coloured track to represent the current state (see Figure 6.9). When it comes to consider toggle buttons, animate the icon representing the smart device as long as the target state is reached.*

GL_9 **Communicate whether the user's smart environment is connected to the app; if so, communicate what wireless technology is being used**. The Company's app offers the flexibility to connecting to the system either over Bluetooth or over the Internet. To readily let the user know about the state of their smart environment and whether any changes are possible, this information needs to be communicated.

> *"Every time I enter it [the app] shows in green if that's connected over Bluetooth or Internet, the banner covers the first room and it's quite annoying to me. I don't think this is needed to be shown every time, especially in such an obstructive way..."* (P04)



(a) Connection state collapsed into a dot and expanded into a label

(b) Possible connection failure messages

Figure 6.10: Various states the connection UI element, communicating the connection state, may change to.

Proposed design pattern: *include a connection dot in the header, close to the smart environment's name, indicating the current connection state; whenever a connection update occurs, or the user taps on the header, the dot expands into a label for a very short time (e.g. three seconds), indicating either wireless technology being used for the connection (see Figure 6.10a). In case of any problem occurring while establishing a connection, the label will be persistently shown, communicating a connection failure message (see Figure 6.10b); to complement with that, everything but the header is greyed out, meaning that no controlling action is possible, other than fixing the connection.*

GL_{10} **Provide the user with clear overall understanding of the environment's current state**. The user should be able to get an overview of the current smart environment's status at a glance: whether a device, a group of devices or a scene is `ON` or `OFF`, or what scheduled event is coming soon.

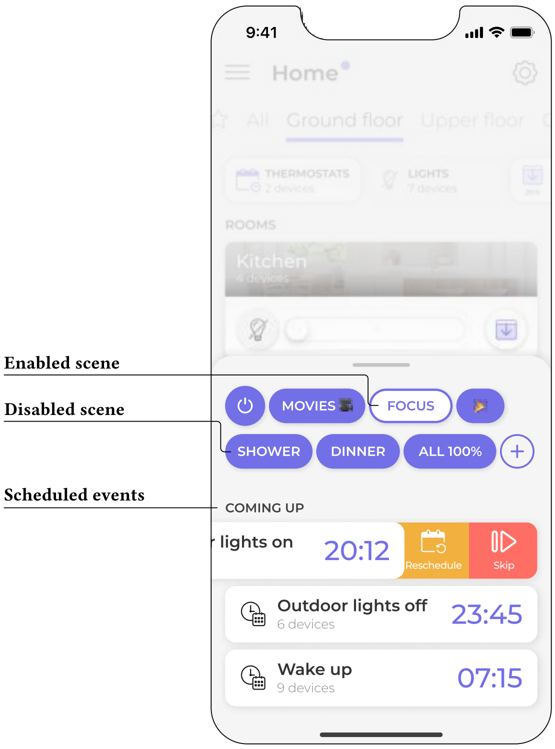


Figure 6.11: Enabled (`ON`) and disabled (`OFF`) scenes, and coming up scheduled events for the day.

Proposed design pattern*: buttons controlling smart devices would illustrate a representative icon; ideally, the icon would act as a means of communication for the state of the smart device; moreover, if a device is* `OFF`*, its controllers are greyed out, just as portrayed in Figure 6.3b). Toggle buttons representing scenes have a clear contrast between the* `ON` *and* `OFF` *states. Finally, a list of 'coming up scheduled events' should be provided (see Figure 6.11).*

Spatial Awareness

GL_{11} **Allow the user to group smart devices according to a hierarchy of spatial portions of a smart environment (i.e. Rooms and Zones).** Allowing the user to group devices by Room only - especially in big, scaled-up smart environments - may result in frustration for the user, as they may end up having a hard time orientating and finding where a specific smart device is located, so they may want to group smart devices differently, in order to browse through, and switch between spatial portions of the smart environment in a more agile manner.

> *"If you have a lot of scenes to take care of, you might just rather control a room or one floor instead"* (P05)

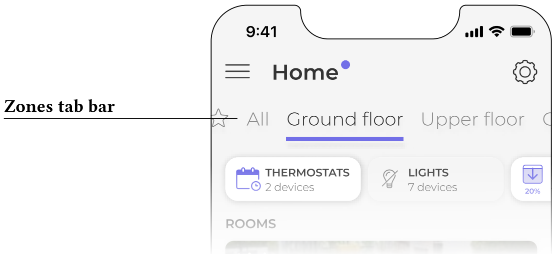


Figure 6.12: The tab bar on top, listing zones, will expedite the user's need of quickly locating a room or smart device in a smart environment.

***Proposed design pattern**: on top of a view listing all rooms in a smart environment - as The Company's app currently offers, already - add a tab bar to let the user navigate through different zones, i.e. groups of rooms. This tab bar, acting as a sort of filter option, will make it easier finding rooms and smart devices located in specific areas of a smart environment (e.g. Upstairs or Outdoors). An example application of this pattern is provided in Figure 6.12).*

GL_{12} **Allow the user to rearrange the disposition of spatial portions of the smart environment**. To better map with their mental model and spatial a-

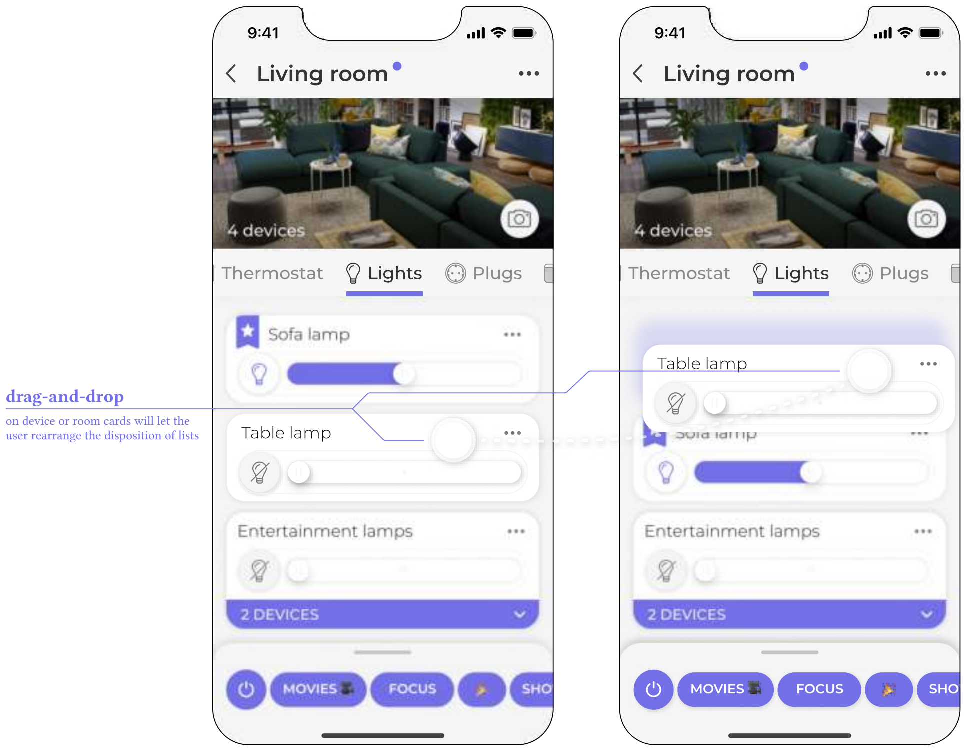


Figure 6.13: Supporting the drag-and-drop gesture to rearrange UI objects, referring to device or room cards.

wareness towards a specific smart environment, users should be provided with the ability to rearrange Rooms and/or Zones. For instance, while a user may want to dispose Rooms sticking to some personal priorities, another one may want to do so mimicking their habits when working themself through the house.

> *"I have a specific way to order [Rooms]. I go from the bottom... or I actually go from the entrance, and then I work myself through the house, down to the cellar..."* (P07)

This aspect, of course, deals with other key areas related to *Multi-User Environments* and *Customization*, as well.

Proposed design pattern: *to complement with the alternative of ordering spatial portions of a smart environments through traditional Settings options, make their respective UI objects provide built-in support for the quite well-established and familiar drag-and-drop gesture (as exemplified in Figure 6.13), as suggested by Apple's Interface Design Guidelines (see Subsection 2.3.1).*

GL_{13} **Coherently present content and properties in relation to the smart environment's spatial portion they belong to.** The more content and

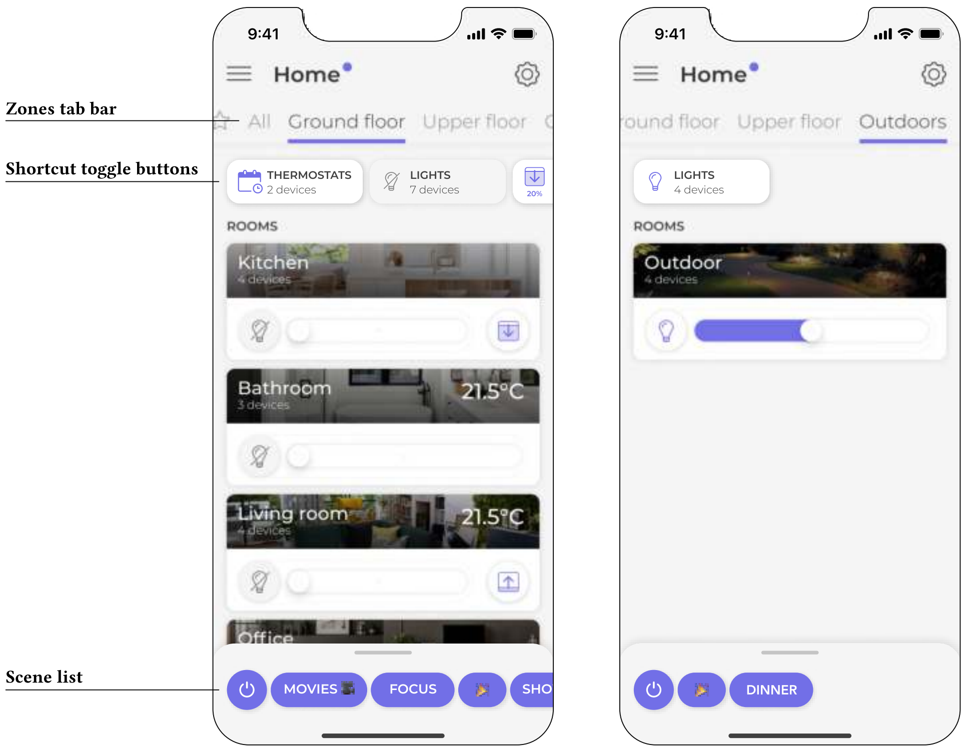


Figure 6.14: Scenes in the Scene list and shortcut toggle buttons are filtered, depending on the Zone the user is currently consulting.

properties in a smart environment, the harder it gets to find them. It is fundamental, then, to present such content and properties only when in close relation with the spatial portion of a smart environment that is being consulted in the app.

Proposed design pattern: *the introduction of the Zone spatial idiom comes* *with the opportunity to filter in content and properties that are related with that Zone. This means, for instance, that content and properties - such as scenes in the Scene list or shortcut toggle buttons - can be filtered and presented accordingly to the Zone the user is currently consulting in the app (see Figure 6.14).*

GL_{14} **Allow the user to quickly access instances they interact the most with (e.g. smart devices, Rooms or Zones) in their smart environment**. With the introduction of new product categories, the amount of smart devices is likely to scale-up quickly in a smart environment. Yet, users may happen to spend most of their time only in specific spatial portions of their environment; therefore, they may want to get extra-quick access to only few of their Rooms or Zones. Accordingly, it is unlikely that they would control any device in their smart environment with the exact same frequency; rather, they may happen to control just some of them more frequently, as others may be controlled automatically through scheduled events.

> *"Should we maybe provide with possibility to prioritize the top devices that are used more commonly?"* (P04)

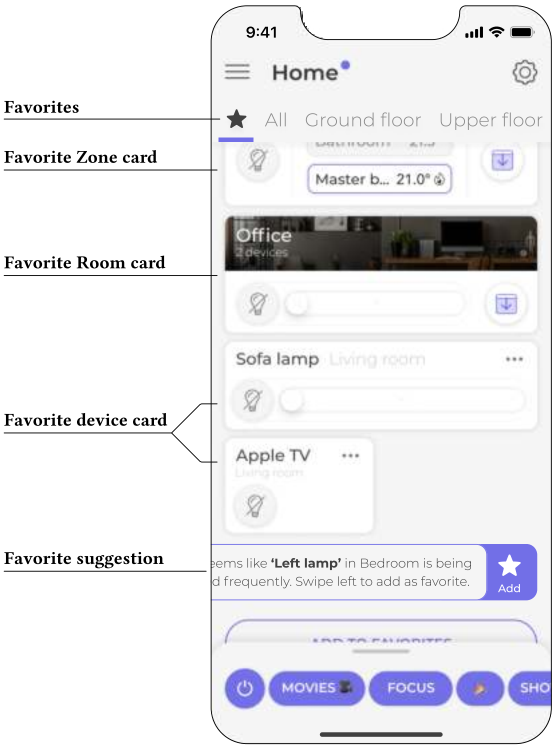


Figure 6.15: Example view of the Favourite section, including suggestions below the list of devices set as favourite (here being slid to the left).

***Proposed design pattern**: specifically for this purpose, provide the user with a specific view in the app, gathering smart devices, Rooms and Zones being used the most. This can be getting shape in the form of a Favourites view, presented* *as first element in the Zones tab bar. As a consequence, in order to add smart devices, Rooms or Zones to such view, each instance should provide with the setting option 'Add as Favourite'; taking one step further, this Favourites view may not only present instances set as favourite, but also suggest instances that are used most frequently (see Figure 6.15). This feature gets inspiration from Apple's iOS Widget Suggestions - where apps being most used automatically appear in the rather new iOS UI component called Smart Stack, at the right time, based on the user's past activity.*

GL_{15} **Let smart devices being grouped together and make them findable according their product category**. Another problem related to the introduction of new product categories can manifest itself within Room views. Here, smart devices may end up risking being shown within a single, eventually long list. It is important then to provide a way to browse through them according to the product category they belong to.

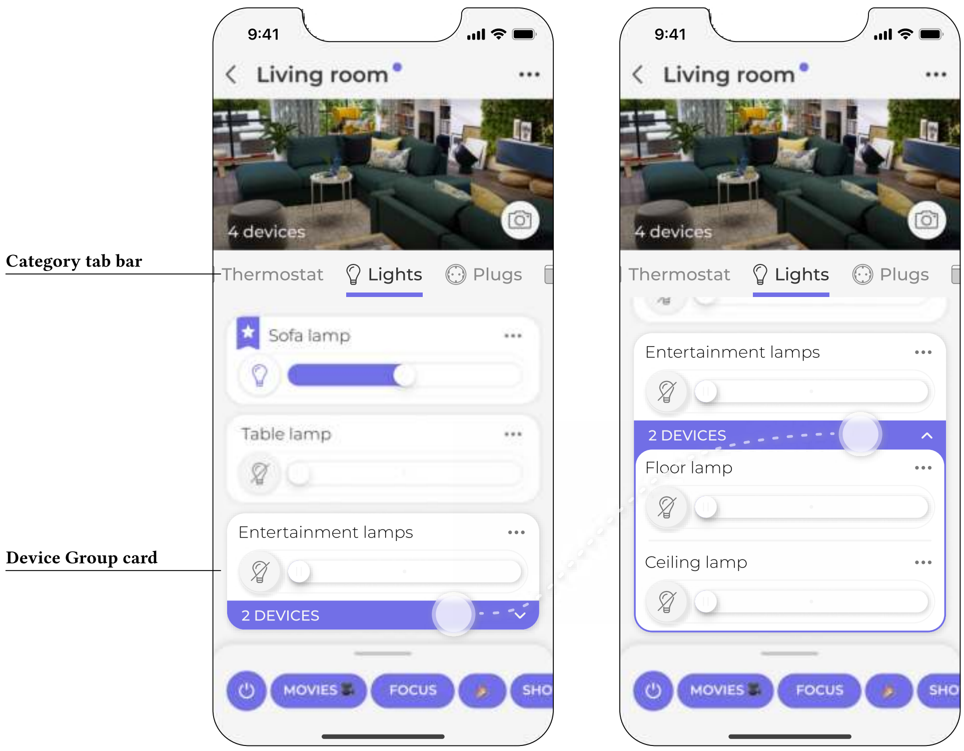


Figure 6.16: Inside the Room view, a tab bar indicating the different product categories is offered; moreover, cards could represent either single or grouped devices. An instance of Device Group card is shown here, collapsed on the left and expanded on the right.

> *"Some kind of functional groups might be good. Maybe it's like... if you have different things tagged in different ways that's basically the same thing as having groups, but you can tag 'window lamp' as 'ambient' "* (P07)

Proposed design pattern*: tab bars indicating the different product cate-*

gories may be included in Room views, slimming down a possible long list of devices into multiple, shorter ones; moreover, allow devices of the same product category and located within the same Room to be grouped together, as suggested in Figure 6.16 (this would especially help with particular product categories, such as Category X, as multiple devices may be installed and yet being considered as just one).

Security and Privacy in Multi-User Environments

GL_{16} **Enable different user roles in a smart environment**. Reflecting the stakeholders found for The Company's app, we may identify different needs and requirements for both of them. Therefore, it is important to assign a user role to any user who accesses a smart environment for the first time.

***Proposed design pattern**: default user roles may be provided. The Company's app currently provides the owner role, granting full access to a smart environment; user, which can control a smart environment; and installer, who is enabled to edit the smart environment's settings. However, other user roles may be thought of: a visitor role, for instance, may guarantee access and control to only a selection of smart devices, such as those located in common living areas or even Rooms and/or Zones.*

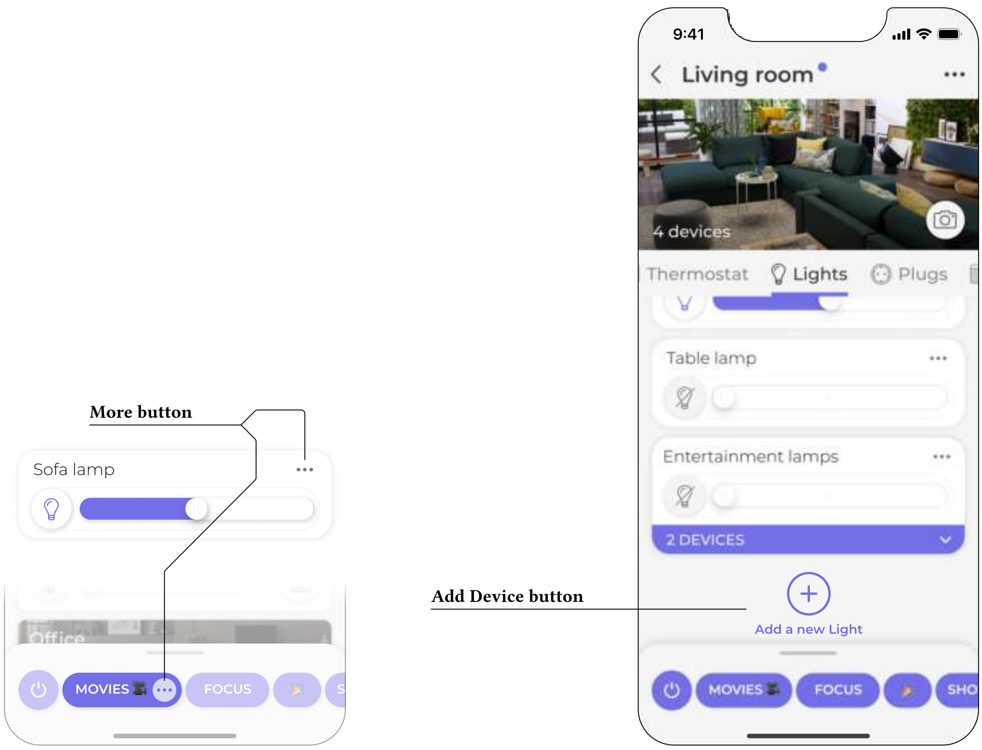
GL_{17} **Depending on their role, allow the user to apply access limitations to specific smart devices**. If you will, this guideline acts as corollary to the previous one. As briefly anticipated in Section 2.2.1, research suggests that security and privacy are two major concerns when it comes to considering smart environments and their challenges from a social perspective. When someone is having guests over just for a dinner or even for leisure, for a few days, they may not want to give access to some smart appliances, installed in specific spatial portions of their smart environment; the same might happen within the dynamics of a family, in which a user may not want smart devices installed in their own bedroom to be accessed or controlled by other family members.

> *"One thing that strikes me is how should devices be available in the app: right now I live alone, but I see the problem of having devices being controlled by other people, for the privacy sake... if I had roommates or siblings, we would prank each other and that would be kind of annoying, that's definitely a privacy issue!"* (P02)

***Proposed design pattern**: allow the owner of a smart environment to manage other users' access to all smart devices, Rooms and/or Zones, sticking to the philosophy of features like parental control; if needed, owners may change roles of other users in the environment, in order to restrict or, on the contrary, delegate their power. As a result in the UI, users affected by limitations may* *find greyed out instances like smart devices, Rooms, or Zones, meaning that they can see but are not allowed to control them; alternatively, such instances may be even completely hidden to certain users.*

Customization and Flexibility

GL_{18} **Provide the user with multiple entry points to access specific sections of the app.** Research conducted in this project suggests the need of adding auxiliary entry points to reach specific sections of the app, that are otherwise reachable only by following a single 'default' path. That is the case, for instance, for accessing a smart device's settings: as of now, The Company's app allows one to access a device's settings only by tapping on *Settings* (i.e., the *cog wheel* icon), *Devices*, and finally tapping on the desired device; however, usability tests showed the tendency of first looking for the room such device would be located in, and then try accessing its settings from that screen. The same issue, however, can be observed in other use cases, such as adding a new device in a room, or even adding or editing a scene.



(a) 'More' button applied to a smart device card and to a scene (after long pressing it)

(b) 'Plus' button applied to a room

Figure 6.17: Provide visual affordances to enable access to an instance's details, options or settings.

"If I want to rename a device, I'd need to go to settings, devices, look for the device and then rename it; and I'd follow that path only because I know how the app works... But it would make sense for me to go into a room and select the device from there, in order to rename it. Now it feels like there are quite a few steps to do." (P06)

Proposed design pattern*: whenever any instance in a smart environment is displayed in the app, think about what visual affordances may enable access to its details, options or settings, in a sort of 'shortcut' manner. One way to address this need would consist in embedding 'more' button - usually manifested as a three-dot icon - within the representation of such instance (see Figure 6.17a). Instances that are represented by smaller UI components, such as scenes, may be long-pressed in order to make the additional 'more' button fit and be revealed (this approach, once again, follows Apple's Interface Design Guidelines (see Subsection 2.3.1) suggestion for long-press gestures). Moreover, 'plus' buttons may also be used to ease the process of adding a new instance in the smart environment (e.g. adding a new device in a Room or a new scene in the scenes list, as exemplified in Figure 6.17b.*

GL_{19} **Allow the user to set up scenes - i.e. grouping smart devices set in specific states - that could be automatized through scheduled events**. The *Scenes* feature affords to group smart devices together into a scene and set them to specific states, enabling users to activate such scene whenever they would need. However, another feature that The Company's app is lacking is the ability to bind such scenes to scheduled events, so that they could be activated automatically, at a specific time of the day. Research suggests that such feature would definitely be appreciated by users; also, according to one of the interviewed participants, it should be relatively easy to integrate this feature implementation wise, as scenes were reportedly said to be implemented just like scheduled events, with the only difference of the activation time being the timestamp corresponding to the user's tap on the scene button.

"Schedules are not too hard to program in my opinion, but it would be nice if you can reuse a scene and schedule it for specific times" (P05)

Proposed design pattern*: in the process of creating a new scene, provide with the option of scheduling it; alternatively, in the process of creating a new scheduled event, let users select not only among smart devices, but the scenes in the smart environment, as well.*

GL_{20} **Suggest pre-set and pre-labelled scenes and/or scheduled events, yet allowing users to customize them**. One aspect that needs to be taken under scrutiny - emerged quite recurrently during research - concerns the Scenes feature, focusing on how users manage them and what activities they're most employed for. The competitor benchmarking activity conducted during Iteration I's Empathize stage (see Section 5.1.1) led us to observe how other home automation mobile applications do offer pre-labelled scenes and scheduled events: for example, a pre-set scene offered by *IKEA Home Smart* is *All* `OFF`, which automatically includes all devices belonging to the user's smart environment and turns them off; likewise, *Philips Hue* offers pre-labelled scheduled events, such as *Wake Up*, *Go To Sleep*, *Coming Home* and *Leaving Home*. In support of these findings, participants in research highlighted the fact that most of their scenes and scheduled events are tied to activities such as waking up, going to sleep, coming home or leaving home. Other activities users thought of, after their *cognitive walkthrough* session, that would inform scenes in their smart environment also included home routines - such as preparing or eating *dinner* - or hobbies - such as *drawing* or watching *movies*.

> *"I have a 'night' scene that turns off all lights but the table lamp in my bedroom"* (P11)

> *"Many times, I turn on the kitchen lights for cooking dinner, modifying the 'cozy' scene. I forget to turn them on when I go have dinner in the living room area. In this case, I enter the app and toggle the kitchen only"* (P09)

> *"I do have a scene in my app to turn everything off - that I use when I leave - but there are things that I'm excluding from that scene, so in most cases 'All* `OFF`*' is not actually all off and it should be configurable"* (P10)

Proposed design pattern*: to cover the most frequent user activities, then, pre-set and pre-labelled scenes and scheduled events may be proposed while in the process of creating new ones. However, one specific factor about pre-set scenes and/or scheduled events shall be discussed: even though it is important to cater pre-set instances for the user, it is likewise critical to let them customize such instances. If we are to consider IKEA Home Smart's All OFF scene, for example, it would be ideal to let the user opt out some devices from it, if they wish.*

GL_{21} **Provide different options to set up both start- and end-points of a scheduled event**. Research suggest that users highly rely on the customization and flexibility aspects offered when setting up a scheduled event. For instance, they may want lights in their bedroom to start dimming at 7:30 in the morning, or they would like their outdoor lights to turn on between 10 minutes before sunset and midnight. As observed in the competitor benchmarking activity (see Section 5.1.1), this functionality is also provided by other apps, such as *IKEA Home Smart* and *Philips Hue*.

> *"I do use the astronomical times feature to automatically turn on lights when it's dark outside, and then I turn them off at a specific time, with a scheduled event"* (P07)

Proposed design pattern*: provide schedule events to be set according to* *absolute times or relatively to astronomical events. In the process of setting up a schedule event, the use of a tab bar may address the need of selecting the type of event a user may want to schedule, either based on absolute times or on astronomical events (i.e. sunrise and sunset). An auxiliary scroll wheel may be offered to let the user choose either a specific time of the day, or the amount of minutes before or after the astronomical event happening, to trigger the start- or end-point of the event. To enable selection of times based on astronomical events, make sure to geolocalize the user's smart environment.*

7
Discussion

In the following Chapter, I will hold a discussion around the thesis, starting with aspects regarding the research question, the execution and the process of this project. I will further discuss the results that were produced and how they were presented in compliance with the NDA agreement. After complementing with some general ethical considerations around the project, this Chapter will finally conclude by touching upon and suggesting possible directions towards improvements, but also opportunities for future iterations.

7.1 Research Question

The aim of this thesis project was to understand the variety of product categories that may fit within a smart environment - with a focus on a few specific categories, being the project conducted in collaboration with The Company -, and to design for a suitable user experience accordingly, in the form of mobile user interface (or MUI), so to control and interact with such products; the ultimate purpose, finally, was to formalize a design framework around the MUI being prototyped, in the form of design guidelines, to be considered as relevant recommendations for HCI researchers in need to inform MUI designs within the home automation context.
Keeping such premise into account, the purpose of this thesis was to investigate the following research question:

What design techniques should be considered - in a home automation context - when informing a mobile user interface for multiple product categories in a smart environment?

Along with the supporting sub-questions:

What factors of user experience are affected by the introduction of new interface components in a smart environment application?

What solutions should be produced to address a framework of design recommendations, in order to make it actionable?

Considering the results achieved out of this project, the research questions were answered by providing research with a set of guidelines to inform MUIs for smart environment applications. As answer to the first sub-question, this set of 21 guidelines was categorized into five different key areas, identified as factors of user experience affecting use of a MUI applied to the home automation domain: these key areas are described as *user control*, *user feedback and situational awareness*, *spatial awareness*, *security and privacy in multi-user environments*, and *customization and flexibility.* Answering the second sub-question, each one of the guidelines produced was complemented with a proposed design pattern, suggesting actionable design solutions to address the corresponding guideline.

7.2 Execution and Process

Potential factors in relation to the execution and the process that could have affected the outcome of the work for this project will be discussed in this section.

As thoroughly presented in Methodology (see Chapter 4) and in Design Process (see Chapter 5), it was decided to follow *Hasso-Plattner Institute of Design at Stanford*'s five-stage design process model, that contemplates the stages of *Empathize*, *Define*, *Ideate*, *Prototype* and *Test* [51]. It was also decided to try to fit such model in three design iterations - of about three to four weeks each -, in order to better understanding and empathizing with users, but also to guarantee the natural flow of ideas and interface solutions being regularly tested, evaluated, and ultimately improved.

As opposed to how it was initially imagined, pretty naively, I realized quite early how it would have just not be materially feasible - given the resources at my disposal - to iterate *horizontally*, i.e. to focus on the bigger picture and cover the whole app as a product at once, and to move forward altogether, iteration by iteration. This becomes quite valid of an argument especially when considering the amount of effort The Company is putting on the app under scrutiny, with a whole team working and keeping it under development for years. In fact, the approach that ended up doing its course throughout the project was about working over *vertical iterations*, hence working from a key screen - by going deep on that one and trying to get all the details right - and start adding neighboring screens as working out the details: eventually, it was possible to go back to the original key screen and apply some changes, based on what has been developed elsewhere [47]. This approach became especially helpful in my case, as completely new screens - accommodating different home automation product categories - needed to be designed from scratch.

Another aspect related to the process - that I believe is worth mentioning - is the management of balance and time distribution among the five stages throughout each iteration, depending on the phase of the project: by experiencing this process in a real work environment, I realized how crucial it is to weigh them differently while working further in the project, albeit one may assume having them all evenly distributed, as all are equally important: as the first iteration focused mainly on user research, the second one heavily focused on sketching and prototyping, whereas the third and last iteration was primarily aimed to converge into a final design and evaluate it. For instance, it is of course optimal to have design ideas projected into paper early on in the process, and even evaluate them since the very first iteration, during the *Ideate* and *Test* stages; however, it felt more important - at least within the scope of this project - to first dedicate most of the resources, i.e. time and effort

- into the *Empathize* and the *Define* stages, in order to grasp as much information as possible by engaging with users, so to better understand them, know what their needs and thoughts are, but also by understanding and interacting with the different products offered by The Company. On the contrary, although it is still important to empathize with users, much more priority was given to the stages *Prototype* and *Test* in the final iteration, as evidence to converge into a final design began to emerge and as some conclusions were drawn through testing towards the end of the project.

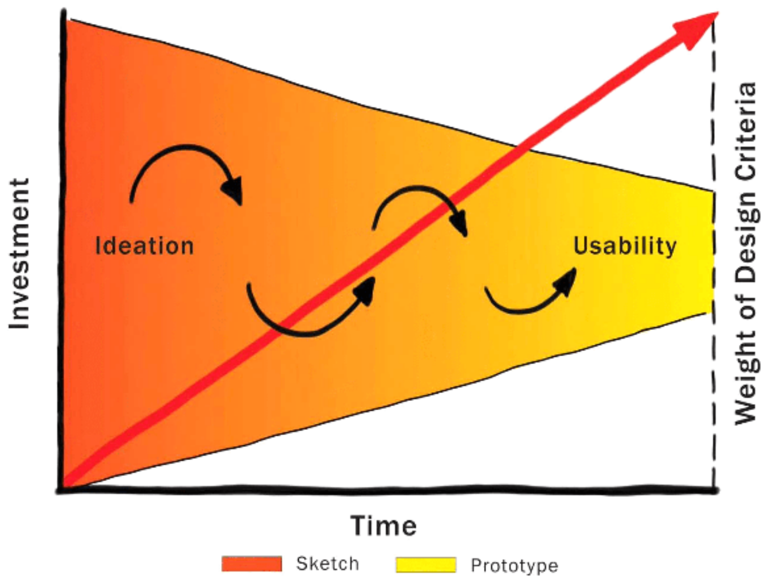


Figure 7.1: Buxton's *Dynamics of the Design Funnel* [19].

If you wish, this consideration may be contextualized as an extension of what Buxton calls the *Dynamics of the Design Funnel*, in which he only considers - if transposing his argument into the five stage process used in this project - the *Ideate*, *Prototype* and *Test* stages: indeed, Buxton describes it as beginning with ideation, largely dominated by sketching, and ends with usability testing, where more refined prototypes provide the basis for it. Consequently, as we can see in Figure 7.1, the overall investment in the process grows, and so should the weight of the criteria used to evaluate design decisions [19]. In other words, the management of the different stages depends on which phase of the process we are currently in.

In general, the Hasso-Plattner Institute of Design at Stanford's five-stage design process model proved to be a pretty effective way of working; also, thanks to its iterative nature, it allows for some more freedom when it comes to choose which stage to start working from. In the big picture - as anticipated in Design Process (see Chapter 5) -, this project traditionally kicked off with the *Empathize* stage: more specifically, however, you may observe how that stage actually encroached upon a scaled-down chunk of its adjacent *Test* stage, which was hence conducted in the first place, as well. This was deemed to be a necessary path to follow, with the argument that understanding the user should go in hand with understanding and evaluating the current state of the art of the product they're using, i.e. The Company's app. However, given the scope of this project, it may be questioned whether such a model - just like other process models - might arguably be better suited for projects with longer time spans.

7.3 Results

This section discusses the two main deliverables produced within this thesis project: the prototype, and the design guidelines. Together with that, topics of ethics, accessibility, security, privacy, and other matters exclusively dealing with this projects, such as the non-disclosure agreement and informed consents, are tackled as well.

The Prototype

The final high-fidelity prototype, built on Figma, got positive feedback, and yet received a number of suggestions and points for improvement. However, it is important to mention that the usability tests - conducted in the form of cognitive walkthroughs - were made in a lab, whereas the natural setting for using this kind of mobile application would be out in the wild, in the context of smart environments. Another factor to consider, that partially influenced the feedback given by research participants, is the fact that the prototype was built around a fictional smart environment: this affected, to some extent, their level of awareness towards such environment, as they were not provided with any reference of it in the real world. An example solution to this may have been a map of such an environment, possibly printed on paper and provided during the tests.

However, regardless of the quality achieved on the high-fidelity prototype, some interactions would have required an actual implementation of the interface by code, in order to actually feel how they would realistically be: in other words, the Figma prototype couldn't let the user turn on or off an actual light in a real environment by pressing a button nor feel haptic feedback while interacting with some UI components (e.g. sliders). That could only be mediated, relatively, by applying the Wizard of Oz method or by verbally telling about those supporting interactions during evaluation. As Hix and Hartson argue, nonetheless, "the degree of fidelity needs to match its purpose" [52], so too much fidelity might result in a counterproductive waste of resources. Therefore, the degree of fidelity of the final prototype - that tools such as Figma are capable of - may be deemed adequate, keeping the scope of this project into account. However, one key factor that would have benefited from a real working prototype is the research participants' actual feeling, immersed in a real context: a lot of manipulations, in fact, would trigger changes in a physical manifestation, in the real world.

Also, another aspect that deserves some attention goes hand in hand with the one presented above, in Section 7.2, i.e. the one dealing with *vertical* v. *horizontal* iterations. As a consequence of working through vertical iterations, rather than through horizontal ones, the resulting high-fidelity prototype is limited to the most relevant screens, or the ones that users are more likely to interact with; other, more peripheral screens were considered to not be worth including in the prototype, both for time constraints and for not being worth exploring further. In other words, resources employed towards designing a high-fidelity prototype were mostly funneled into the interfaces that would be tested during the final, comparative study.

The Guidelines

Guidelines - each accompanied by a suggestion of design pattern - were produced by letting them emerge from the high-fidelity prototype that was produced throughout the project, hence following a bottom-up and research-through-design approach. The guidelines have been categorized into five main key areas, that are *user control*, *user feedback and situational awareness*, *spatial awareness*, *security and privacy in multi-user environments*, and *customization and flexibility.* As will be discussed in more detail in Section 7.5, the set of 21 guidelines being produced would definitely deserve to be evaluated.

NDA Agreeement Limitations

As the project for this thesis was carried out in collaboration with a company, and as such a company provided me with some sensible information - of different nature - to deal with during the project, a *Non-Disclosure Agreement* needed to be signed. This entailed that any of the information relevant to NDA matters should be protected; also, any of the text or visual contents produced during the project could be included within the hereby report document, without disclosing the company's identity by any means; accordingly, examples of interfaces produced and included within this document - originally designed following the company's brand style guide - have been purposely edited to offer different typography and colour scheme. Moreover, any of the people who got involved in this project - by participating to this project's user research studies (see 7.4 - Informed Consent), by offering inputs and feedback, or by simply advising and mentoring me through the process - is anonymized and only referred to by alluding to either their role in the company or their randomly assigned code for the above mentioned user research studies.

Future of Smart Environment Mobile Applications

The rise of smart environment mobile applications goes hand in hand with the wave of transformation of products and services into smart ones - thanks to latest and novel technologies within what we may identify the *Internet of Things* field -, hence enhancing device interoperability [83]. If I have to think about what future reserves for smart environment mobile applications, different aspects emerge.

Referring back to Aldrich's hierarchy of smart homes - as presented in Section 2.2 - it can be reasonably imagined that, whilst most common smart homes in the real world may be currently classified simply as *homes containing intelligent, communicating objects* or *connected homes* [3], smart homes of the future will assumably approach to Aldrich's definitions of *learning homes* - where users' needs are anticipated by their patterns of activity being recorded, so to exploit the accumulated data to control the technology accordingly through machine learning algorithms - and *attentive homes* -

in which both activity and location of people and objects are constantly registered, so that the information can be used to control technology in anticipation of the occupants' needs [3] -. In other words, it can be imagined that future smart homes will be equipped with advanced machine learning algorithms, capable of learning and mimicking human behavior in the interaction between a user and their own smart environment.

On a bigger picture, some elaboration on an energy-related topic may be discussed, as well: with the ever increasing device count and the introduction of pervasive computing in residential homes, naturally also the energy demand constantly rises [67]. In parallel, as Kofler et al. argues, a widely neglected potential for energy savings resides in the use, control and interaction of such appliances, so a comprehensive software system able to orchestrate all energy facilities in an environment is needed. Energy consumption and energy efficiency, then, play an important role, but become even more relevant in specific historical situations - as it is happening in the current days -, potentially affected by geopolitics or economics factors.

If we get to speculate on the future, the aspects considered above will inevitably have an impact on specific user experience factors - such as the ones identified in this project, of *user control*, *user feedback and situational awareness*, *spatial awareness*, *security and privacy in multi-user environments*, and *customization and flexibility.* In turn, the app will need to evolve accordingly, possibly offering features with a greater focus on energy consumption and learning and attentive technologies.

7.4 Ethical Considerations

During the design practice - not only through research, but also in relation to the social and cultural values within the context we're designing for - it is common that ethical challenges emerge and therefore need to be considered. In this Section, the most urgent ethical aspects for this thesis project, such as privacy, accessibility and security, are taken under scrutiny.

Informed Consent

Both for user research and for the evaluation of prototypes, participants recruited to help out along this project were asked for their consent on few specific aspects. Just as imagined when planning the work, such request for their consent has been instantiated as *informed consent form*, which protects the interests of both the data gatherer and participants. The gatherer wants to know that the data they collect can be used in their research, whereas participants want reassurance that the information they give will not be used for other purposes or in any context that would be detrimental to them [108].

Considering the specific case of this project, such informed consent forms were to be sent out digitally to participants, prior to any planned sessions (e.g. interviews or usability tests) and be returned with a confirmation when a participant decides to give their consent. Within this form, the full set of relevant information about the session was shared, making sure participants had a clear idea of what the session was about and what way I made use of the results. Also, it was specified that participants could deliberately withdraw their consent - and, accordingly, their data - at any moment before or during the sessions, for any reason, if they wished. To guarantee the maximum transparency, such information was also verbally briefed before the sessions started. One - arguably the only - risk worth considering to prevent harm involves how I, the researcher, interacted with my participants, and how I handled their data: obviously, it was essential to never pressure participants nor making them feel uncomfortable by saying or revealing anything inappropriate. Whatever form of data that has been stored, it was ensured that participants' personal data, including recordings, was safe and stored on password-protected services, such as *Google Sheets* or *Otter.ai*; in addition to that, it was ensured that whatever data was stored, it would have an "expiry date", meaning that it would be permanently erased as soon as judged not relevant for the project anymore (e.g. one month after the end of the project).

Accessibility

Some aspects of inclusion and accessibility are to be considered, as well. The international Standard ISO 9241-171:2008 on Ergonomics on Human-System Interaction, issued by the *International Organization for Standardization* (or ISO), defines the term *Accessibility* as "the usability of a product, service, environment, or facility by people with the widest range of capabilities" [56]. Petrie and Bevan think of this definition as conceptualizing accessibility as simply usability for the maximum possible set of specified users accommodated [107]. Microsoft Design defines accessibility as "the qualities that make an experience open to all" [84]. The United States government - within their guide for embedding inclusive design practices into a workflow - also provide their definition of accessibility as the "usability for people who interact with products differently". Despite a quite generic definition, they do highlight the designer's role to help approach accessibility as a facet of user experience rather than checklist of requirements [29]. Aizpurua et al. suggest how important it is to consider how accessibility plays a critical role within user experience: to gain a better understanding of the interplay between these two, they found that most UX attributes are significantly correlated with perceived accessibility [2]. In other words, accessibility focuses on whether all users are able to access an equivalent user experience, however they encounter a product. Accessibility might sometimes be confused with usability: theoretically, we may say that usability includes accessibility - since an inaccessible product to some users becomes unusable -, but it practically tends not to specifically focus on the user experience of people with disabilities. Nevertheless, it is worth mentioning that accessibility often also brings benefits to all users, as accessibility features that help people with disabilities often help other people, too. Part of this project mostly resulted in a MUI in the form of high-fidelity prototype, and its evaluation was conducted by involving the use of a smartphone; it was possible, then, to interact with the resulting MUI, but assistive technologies - natively offered on mobile devices - were not available, as not capable of being integrated with the prototype. Some people with disabilities heavily relying on such technologies, such as visually-impaired people, were hence excluded and unable to test the prototype. An applicable solution to that, if deemed necessary for the project, would be an evaluation performed by means of expert review of accessibility guidelines using smartphones, as de Oliveira et al. did to evaluate a range of home automation-related mobile applications and assess how accessible are to people with visual disabilities [27]. Additionally, whereas the current mobile application takes care of smart lighting only, the introduction of new smart home product categories will expand the service offering, tackling new kinds of use cases. Such event would trigger interest among new potential categories of customers: this might reasonably involve physically impaired people as well.

Security and Privacy

One further aspect to consider relates to issues that will need to be addressed in the future with respect to surveillance and data leaks, as are generally seen within the *IoT* domain, in a home automation context. The ability of smart homes to collect and store a vast amount of private data raises ethical concerns, such as privacy, whose potential intrusion may act as a major inhibitor to smart home acceptance and adoption [83]. Already in early literature, before smart homes actually became popular, privacy was highlighted as one of the social implications of what were once called *Aware Home Technologies* [33]. In support of this ethical concern, Zhao et al. argue that - in their smart home research - many security issues still need to be solved and the quality of user experience can be negatively affected by inadvertent information leaks [135]; other research studies focused on exploring the relationship between UX design, security and privacy in smart homes to develop a conceptual framework around it [20], later proposed as user-centered design guidelines and recommendations to improve data protection in smart homes [21]. Some literature also investigates such privacy concerns in conjunction with user *trust*: Schomakers et al. highlight an automation dilemma - i.e. *how automated do users want their systems to be* - since a strong entanglement of privacy and trust was found, as key drivers for (not) using a system, in the context of smart systems integrated into living space [120]; Zheng et al., instead, investigate user perceptions of smart home IoT privacy, and note several recurring themes, such as users trust in IoT device manufacturers to protect their privacy but do not verify that these protections are in place [136].

7.5 Future Work

This section will investigate which aspects would need to be expanded, if this project were to be continued: as major key points to consider, the project should naturally follow by evaluating the guidelines that were produced as main deliverable for this thesis; the high-fidelity prototype would need further iterations to concretize a number of ideas that were only conceptualized in this project; further comparative studies may be needed to understand whether certain interface solutions are effective; finally, on a more academic matter, to spur on the idea of a new ideation method, based on the Extreme Characters method, and specifically suitable for the ideation stage for design projects within the home automation context.

Evaluating the Guidelines

The set of guidelines produced and presented in Chapter 6 resulted as one of the major outputs of this thesis project. However, it would be ideal - just like it happens with other deliverables, such as interactive prototypes - to actually evaluate and assess whether potential future iterations may improve their effectiveness in guiding other designers and practitioners in the HCI community that will need to inform MUI designs within the home automation context.

Iterating on the High-Fidelity Prototype

First of all, as mentioned above in Results (see Section 7.3), peripheral screens and interfaces that were not considered relevant for the evaluation stage were not implemented into the high-fidelity prototype. Trivially, it goes without saying - then - that a natural prosecution of this project would consist of covering all of the screens that were not included in the prototype, and iterate on the remainder: for example, it was mentioned how helpful would be to provide with an enhanced device page, gathering all information about a device (e.g. what state it is currently in, what scenes or scheduled events it belongs to, etc.), or even provide with onboardings, introducing users to new features and how they may interact with them, in order to mitigate the discoverability problem. Accordingly, the guidelines previously formalized would need to be reviewed and reworked, eventually. Another point that was discussed above in Results questions the need of actually implementing the high-fidelity prototype by code, *de facto* realizing a working mobile application, once it is decided - hypothetically - to finally opt for a design solution.

Such implementation would definitely help with the evaluation of the app itself, so to experience how specific interactions would actually feel to the user: that is the case, for instance, of haptic feedback, or even merely - by the adoption of a more ecological approach - for controlling actual smart home appliances, enabling a real connection between the user and the surrounding environment they need to control, that could have been evaluated through longitudinal and diary studies, providing the working app to a group of participants for an extended period of time. Both cases, however, would just not be available to replicate on a Figma prototype. Certainly, such aspect may be classified as future work - as it would definitely be a good way to examine the user's real behaviour - even though it was never considered to be in the scope of this thesis project: The Company's app team I've been collaborating with could not really provide any resource towards this direction, as they're obviously putting all their effort on the current version of the app.

Further Comparative Studies

The main planned activity for the third and last iteration was a comparative study between the official, current version of The Company's app, and the high-fidelity prototype that was produced along this project. As mentioned in Theory (see Chapter 3), methods such as *A/B testing* would afford a quite accurate comparison between alternative design options for specific interface layouts, by putting in production (i.e. releasing) two different versions of the same app: through this approach, a considerable amount of end-users would become the actual testers of the two interfaces, providing considerable amounts of relevant, quantitative data, to help informing design decisions. Therefore, if the prototyped interfaces were to be actually implemented by code, and if resources would be made at disposal for that, A/B testing would definitely be a method I would suggest The Company to pursue.

Extreme Characters and Extreme Environments

One of the takeaways from this project that can definitely be counted as possible future work would be motivated by an academic research purpose. As originally thought and tried to apply within the project, the *Extreme Characters* method seemed to be suitable for an interesting twist towards the home automation domain. Such method, as described in Methodology (see Subsection 4.3.5), allows to consider - as opposed to more shallow, flat personas - characters with exaggerated emotional attitudes, so to see them as a springboard to help designers give birth to new, interesting ideas. Just like for the Extreme Characters method, this possible extension of it - which we may call Extreme Environments - would require to know, to some extent, the character that's going to be picked; in addition to that, though, the environments such character lives or spends most of their time in should be known, as well, so that the design that gets ideated through this method would be possible to relate to that environment. To provide you with a very brief example, let us take Joseph Robinette Biden Jr. [1]: just like we can think and imagine on him as extreme character, we might do the same for the environment he spends most of his time in, i.e. the White House. Nothing prevents us from imagining that such a building hides some secret bunker floors. Accordingly, if we are to design a mobile application, we might reflect such an aspect of the environment into the app interface, e.g. providing some secret, difficult-to-reach screens in the app. Therefore, despite the results it produced for this work, there would definitely be room to further explore, adapt and develop the Extreme Characters original method towards this direction, possibly within a standalone academic project.

[1] 46th and current president of the United States of America

8
Conclusion

The purpose of this Master's thesis project was to investigate the following research question:

What design techniques should be considered - in a home automation context - when informing a mobile user interface for multiple product categories in a smart environment?

The project was carried out in collaboration with *The Company*, specialized in the home automation industry, and indeed interested in exploring this research question, as it would be widening their product portfolio, hence in need of applying major changes to their app's *mobile user interface*, to accommodate new product categories. Therefore, the project - following *Hasso-Plattner Institute of Design at Stanford*'s five-stage design process model - adopted a research-through-design approach, aiming for a design framework - in the form of a set of design guidelines - based on a high-fidelity prototype, to guide designers and practitioners in the HCI field informing MUI for smart environment applications. Thereafter, since a prototype was expected as first output, the process did undergo three main design iterations - heavily relying on interaction design methodology hence understanding, empathizing and defining by conducting user research, ideating, prototyping and testing - with the aim of constantly improving the artifact being prototyped. In the end, the findings based on the evaluation of high-fidelity prototype - but also on the whole knowledge acquired throughout the process - culminated in a set of 21 design guidelines, covering five key areas of user experience of *user control*, *user feedback and situational awareness*, *spatial awareness*, *security and privacy in multi-user environments*, and *customization and flexibility*.

As discussed in Section 7.5, improvements and further research can be conducted to refine and validate the final outcomes being produced in this thesis work, i.e. both the prototype and the design guidelines. However, given the tools and resources provided for this project, I believe that the research question may be answered through the set of design guidelines that have been formalized in this document (in Chapter 6), presented as the main deliverable of the study. All of the 21 guidelines, together with their related proposed design patterns, should provide enough knowledge and insights to help HCI researchers in need to inform MUI designs within the scope of home automation.

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A

Project Planning

The following time plan and Gantt chart describe the different phases I encountered along the thesis work. The weeks are indicated as calendar weeks of year 2022.

Planning and Understanding (week 3 through 7)

1. Finalize thesis proposal;
2. Literature review: study relevant literature and work about home automation within the HCI domain, smart home mobile applications, theory about designing mobile user interfaces (MUIs) in form of frameworks and guidelines, with focus on ease-of-use and complexity;
3. Familiarize with The Company's (both current and future) product offering and vision about home automation;
4. Understand and evaluate current version of The Company's mobile application, by analyzing - through the use of evaluation methods - the current MUI design.
5. Write planning report;

Design Iterations (week 8 through 16)

6. *Diverge* and *Transform* by iteratively empathizing with users, ideating, building and evaluating prototypes of new, possible MUI design solutions for The Company's mobile application, accommodating controls for new product categories;
7. *Converge* into one final high-fidelity design prototype from the alternative MUI design solutions emerged during the iterations;
8. Evaluate the final high-fidelity design prototype with target users either in lab or in a naturalistic setting;

Develop a Design Framework (week 17 through 20)

9. Formalize findings and outcomes achieved during the process into a Design Framework for adding features to a MUI within the context of home automation applications;
10. Investigate methods for a comparative study between the current version of The Company's mobile application and the high-fidelity design prototype produced;
11. Conduct a summative and comparative study;

Dissemination (week 21 through 23)

12. Presentation prep;
13. Thesis defence and thesis opposition;
14. Write report: the report was continuously written throughout the project's time span - i.e. *week 8 through 23* - but finalised in the last weeks.

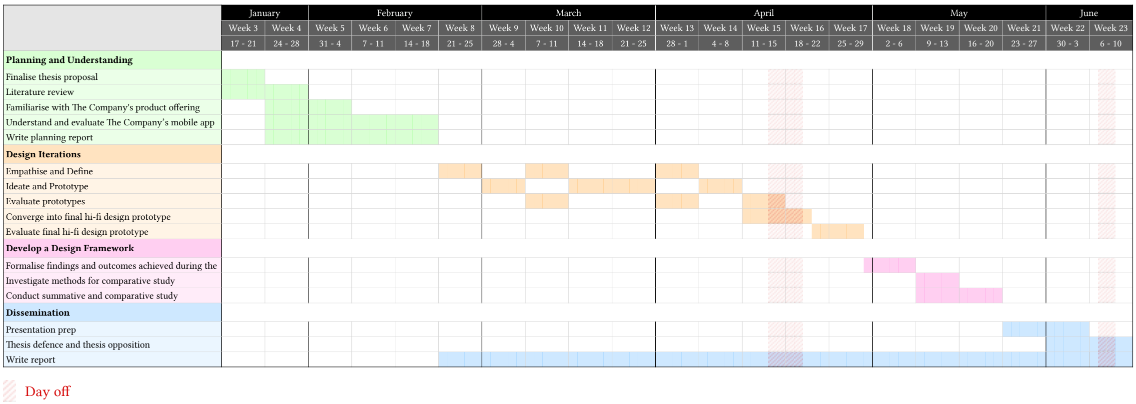

Figure A.1: The initial time plan, represented on a Gantt chart, prepared at the beginning of the project.

B
Recruiting Questionnaire

Willing to help out with the new app's UI/UX?

Dear respondent,

my name is Amos, a final year graduate student from Master's Program in Interaction Design and Technology, at Chalmers University of Technology. This semester, I will be working closely with the app team at *The Company* on my Master's Thesis project, addressing the need of a new user interface for *The Company*'s app, to be designed according to new product categories that *The Company* is willing to release in the future.

Insights from participants in user research and evaluation studies are crucial to achieve seamless user experience solutions, and that is why I would appreciate you to participate in my future research and evaluation sessions! Such participatory design approach will empower you by contributing with valuable feedback about both current *The Company*'s app and potential interface design solutions, through questionnaires, brainstormings, interviews or usability tests. As I will iterate throughout my design process, multiple research and evaluation sessions will occur: most likely, they are expected to take place during Week 10 (March 7th through March 11th), Week 13 (March 28th through April 1st), and Weeks 16-17 (April 21st through April 29th), but you may likely not be required to participate in all of them. If selected, you will be contacted on *Slack* about each session's details and informed consent beforehand. In exchange, as a token of gratitude, you will get a chance of winning a movie ticket!

N.B.: this is an internal questionnaire, and will approximately take 2 minutes to fill. If you're not interested in filling the questionnaire nor participate in future research and evaluation studies, feel free to close this tab.

Thank you for your time!

Amos Cappellaro
Master's Thesis in Interaction Design and Technologies
Chalmers University of Technology

For any inquiries, please drop me a line on *Slack* or at `amosc@student.chalmers.se`.

- In general, how would you rate your level of expertise on using smartphones, on a scale of 1 to 5? `[5-point Likert scale]`

Home Automation apps

- *Have you ever used home automation (or smart home) apps?* `[Yes or No]`
- *Do you consider yourself a Company's user (i.e. you regularly use The Company's app and you have any Company's products installed at home)?* `[Yes or No]`
- *Do you consider yourself a Company's installer (i.e. you install The Company's products in our clients' homes on a regular basis)?* `[Yes or No]`

So, are you willing to help us out?

How can we reach out to you on *Slack*? Your name will be collected exclusively as contact information for further communications about our research and evaluation sessions. You may withdraw - as soon as you've offered your availability to participate through this questionnaire - at any time, just reach out to Amos on *Slack* or via email (`amosc@student.chalmers.se`).

- *Your full name* `[Text field]`
- *I'm available to participate in research and evaluation sessions (e.g. questionnaires, interviews, usability tests etc.)* `[Checkbox]`
- *I'm comfortable with research and evaluation sessions being held in English* `[Checkbox]`

C

Research Questionnaire

Ever used Home Automation apps?

Dear respondent,

thank you for participating in our research and evaluation sessions! The aim of this questionnaire is to better understand whether you've experienced using home automation apps, which ones, and what are your thoughts, insights, or even ideas on them. The time to fill the questionnaire varies depending on how certain questions will be answered, but worst case it shouldn't exceed a 15 to 20 minutes time.

NB*: this internal questionnaire is fully anonymous (none of your contact details will be collected). This is to encourage you providing us with feedback and thoughts that are not biased nor influenced by the company you're working at.*

Thank you for your time!

Amos Cappellaro
Master's Thesis in Interaction Design and Technologies
Chalmers University of Technology

For any inquiries, please drop me a line on *Slack* or at `amosc@student.chalmers.se`.

General questions

- *Do you consider yourself a The Company's app user (i.e. you regularly use The Company's app and you have The Company's products installed in your environments)?* `[Yes or No]`
- *Have you ever been using Philips Hue and or IKEA Home Smart?* `[Yes or No]`
- *Do you use or have been using any home automation app, other than The Company's, Philips Hue and IKEA Home Smart?* `[Yes or No]`
- *What do you like most about the app?* `[Text field]`
- *What do you like the least about the app?* `[Text field]`

- *Which features do you use the most, apart from turning devices on or off (scenes, widgets, dimming, schedules, invite users, integrations, ...)?* `[Checklist]`
- *Are there any features that you think you need but are missing in the app?* `[Text field]`
- *What are your goals when you want to use the app?* `[Text field]`
- *With the existing features, does the app help you to achieve your goals? How?* `[Text field]`
- *In the last couple of weeks, did you experience any situation which the app has been most particularly useful to you?* `[Text field]`
- *On a scale of 1 to 5, rate the navigation of the app.* `[5-point Likert scale]`
- *On a scale of 1 to 5, rate your experience using the app.* `[5-point Likert scale]`
- *On a scale of 1 to 5, rate the interface of the app.* `[5-point Likert scale]`
- *On a scale of 1 to 5, rate the intuitiveness of the icons.* `[5-point Likert scale]`
- *Are there any strength or weakness points to improve you would like to highlight about this app? Or what are your overall thoughts about the app?* `[Text field]`

System Usability Scale (reformulated)

- *I like using the app frequently.* `[5-point Likert scale]`
- *I find the app unnecessarily complex.* `[5-point Likert scale]`
- *I think the app is easy to use.* `[5-point Likert scale]`
- *I think that I would need the support of a technical person to be able to use the app.* `[5-point Likert scale]`
- *I find the various functions in the app are well integrated.* `[5-point Likert scale]`
- *I think there is too much inconsistency in the app.* `[5-point Likert scale]`
- *I would imagine that most people would learn to use the app very quickly.* `[5-point Likert scale]`
- *I find the app very cumbersome to use.* `[5-point Likert scale]`
- *I feel very confident using the app.* `[5-point Likert scale]`
- *I needed to learn a lot of things before I could get going with the app.* `[5-point Likert scale]`

D

Informed Consent

UX Interview

What this study is about

The purpose of this study is to get further understanding of how users think of home automation apps, with a focus on *The Company*. Your participation in this study will help me evaluate the current version of *The Company*'s app, and will help me design a new version better accommodating user needs.

Your participation in this study is voluntary

You can take a break at any time. Just tell me if you need a break. You can leave at any time without giving a reason.

Information I will collect

I will ask you some questions about your thoughts and habits when interacting with home automation apps or living at home, and will ask you to perform few tasks for evaluation sake, both on the current version and on newly prototyped interfaces, focusing on the interaction with one of the product categories that will be marketed by *The Company*. I will observe how these tasks are conducted, and will take notes during the session. If consent is given, I will record the session (audio only) to automatically get it transcribed with *Otter.ai*.

How I ensure your privacy

I, the undersigned, will be the only one having access on possible recordings, which will be treated as confidential and will not be shared outside our company. I may publish research findings that include your comments and actions but your data will be fully anonymous. This means your name and identity will not be linked in my research report to anything you say or do.

Your consent

Please sign this form showing that you consent to me collecting these data. You give your consent:

- *for the researcher to observe me while conducting tasks during the session;* `[Checkbox]`
- *for the session to be recorded (audio only) for automatic transcription;* `[Checkbox]`
- *for the researcher to use comments and actions and report them anonymously.* `[Checkbox]`
- Your name `[Text field]`

If you want to withdraw your consent

If you want to withdraw your consent in the future, contact me on *Slack* or via email (`amosc@student.chalmers.se`), so any personal data I hold about you (such as audio recordings) will be destroyed. Otherwise, I will delete personal data after six months from now.

Thank you for your time!

Amos Cappellaro
Master's Thesis in Interaction Design and Technologies
Chalmers University of Technology

For any inquiries, please drop me a line on *Slack* or at `amosc@student.chalmers.se`.

E

UX Interview

Script

Home Automation Apps and *The Company*'s

- *(double-check with interviewee which automation apps uses or has used)*
- *When did you start using the app? How long did it take for you to learn how to work with the user interface?*
- *How frequently do you happen to use the app?*
- *Do you use widgets? When interacting with The Company's system through your smartphone, what you think is the balance of usage between the app itself and widgets?*
- *Do you use the scenes feature? Do you have particular activities for which you use them? Would you say it is important for you to know whether a scene is active?*
- *Do you use integrations such as Google Home or Apple HomeKit? Was it easy to set up your environment?*
- *Would you group lights differently than how they're currently grouped (i.e. in Rooms)?*
- *Have you ever happened to wish that you could just quickly turn on or off all your devices in your environment?*
- *Sliders play an important role in controlling lights. Are you happy with how they work right now? Any thought about the haptic feedback?*

The Company's App

- *Do you use the scheduling feature? If so, what activities do you use it the most for? Is it easy for you to set up schedules? Could there be supporting means (e.g. visualizations) while setting them up?*
- *What do you think about the hierarchy of features and functionalities, and how they are arranged throughout the app?*
- *Let's say you want to rename the light called 'Desk' inside the Office, how would you do that?*

- *Now, how would you adjust its dim start level setting to 5%? What are your thoughts on the interface offering '+' and '-' buttons for such setting, instead of other possible controls, such as a slider?*

Apps in General

- *When you need to navigate back in an app, do you press the 'Back' button, or do you rather perform any shortcut gesture, like swiping left, if the app affords it?*

Product Category X

- *Do you have [redacted] in your home? How do you usually [redacted] them [redacted]? Do you usually [redacted] them to certain intervals? How would you interpret them as in an `ON` and `OFF` state?*
- *[Show Category X's installation flow] What is this flow about? How do you imagine the controller would work?*
- *Try tapping that button within the Room card. What does it mean to you?*
- *Now try long press that button. What do you think the violet area represents? What do you think the grey area below represents? What do you think of this controller?*

***NB**: some of the text within this script needed to be censored for non-disclosure purposes.*

F

MAUX-C Evaluation Tool

Mobile Application User Experience Checklist (or *MAUX-C*) is a comprehensive and objective assessment of app quality based on key factors contributing to user experience [109]. Table F.1 summarises the 45 questions included within this evaluation tool.

Usable

1. Is at least one of the following true?
   a. The app offers a tour, tutorial, or provide support within the app
   b. It takes less than 5 minutes to learn how the app functions
   c. The app has a "frequently asked questions" section
2. Is the look and feel of the app consistent throughout?
3. Does the layout of the app appear organized?
4. Are the visual cues of functions clear? (e.g. it is obvious when a button should be tapped, visual cues are used consistently)
5. Is the content clear and concise?
6. Can the app be personalized?
7. Are the available features to share content easy to use and appropriate for the context?
8. Is one of the following is true?
   a. All pages loaded quickly with no delay
   b. There was a delay and an indication acknowledged the delay
9. Does the app accept user feedback?

Useful

10. Does the app or app store description identify its purpose?
11. Does the content in the app meet your expectations based on the identified purpose?
12. Does the apps brand appear to have key indicators of authenticity and suited for the targeted audience?
13. Is the content well written and relevant to the target audience's needs and interests?

Desirable

14. Is the design consistent with recently made apps and websites? (i.e. the app does not appear dated)
15. Does the app provide a description of the origin or creator? (i.e. a section similar to: about us, about our story, our mission, who we are, etc.)
16. Does the app create positive memories? (e.g. an engaging story)
17. Would you describe the app as fun, surprising, impressive, impactful, captivating, or clever?
18. Does the app use high quality photography, video, animations, and/or graphics?

Findable

19. Without reading everything, does the important content obviously stand out?
20. Are the apps navigation options simple and clear? (if uncommon navigation options, do they include a short teaser to describe what the option is?)
21. Does the app make use of current or emerging features on the platform?
22. Does the app have a search function and is relevant information retrieved when searching for a specific term or phrase?
23. Does the app retain a record of what you have done within the app? (e.g. recent search history, sections visited)
24. Does the app save content/place when you are interrupted from the session (e.g. if interrupted by a text or call the app will resume exactly where you were before)
25. Were you able to achieve your primary goal within the app without being redirected to a full website?
26. Is the contact information available and easy to find?
27. There were no errors found within the app (e.g. typos, broken links)

Accessible

28. Does the app use plain language?
29. Does the app use pictures or symbols for links to convey function?
30. Can text be resizable?
31. Can you zoom on the content within the app?
32. Does the text and content appear distinct from the background and easy to read?
33. Is there sufficient room around buttons and/or links to easily touch?
34. Can the layout adapt to screen orientation? (i.e. layout remains consistent in portrait or landscape orientation)
35. Is one of the following true?
    a. There is no flashing content within the app
    b. There is flashing content, but it occurs less than 3 times in a one second period
36. Is the app accessible to people who are hard of hearing?

Credible

37. Is at least one of the following true?
    a. The app is offered by a legitimate source (e.g. reputable institution, commercial business, government, university)
    b. The author or organization that takes responsibility for the app's content and distribution has credentials that are listed and verifiable
38. Does the source of the content (author, etc.) show experience and expertise on the app content?
39. Has the app been endorsed by a trusted third party?
40. Within the app, does the app generally provide content that appears unbiased?
41. Does the app include a privacy statement/policy?
42. Is it clear how the development and maintenance of this app is funded?
43. Is the content that requires reference to an external source linked to the appropriate source? (e.g. citations, embedded link to original website)
44. Does the app identify when the content was last updated?
45. Does the app link to external unbiased sources? (e.g. review sites, social media)

Table F.1: The *MAUX-C* checklist, containing 45 questions concerning topics of *usability*, *usefulness*, *desirability*, *findability*, *accessibility*, and *credibility*.

G

Extreme Characters Questionnaire

Dear respondent,

Between this and next week (Week 13 and 14, March 29th through April 4th) I'd like to conduct an ideation method called *Extreme Characters* (details about research paper here: `https://dl.acm.org/doi/10.1145/347642.347664`). First of all, I'd like to prime you with a brief definition provided by Djajadiningrat et al. (the researchers who propose this method):

> *"Designing for Extreme Characters is a method that tries to steer away from the usual designing for a prototypical persona from a target group. In fact, it takes the opposite approach. Instead of designing for characters that are emotionally shallow, we design for characters that have exaggerated emotional attitudes. By taking characters that are extremes, character traits can be exposed which, though common, remain hidden because they are antisocial or in conflict with a person's status."* [30]

Example of Extreme Character: the Drugsdealer

To better let you understand how this method works, I'll now provide you with an example: with the goal in mind of designing a *PDA* (or *Personal Digital Assistant*), researchers Djajadiningrat, Gaver and Frens decided to design it for *"the drugsdealer"*. As a result, here's the outcome they achieved by first trying elaborating on the profile and the attitude towards appointments - through their ideas and thoughts - a drugsdealer would have, and then by prototyping a possible design solution of a PDA for drugsdealers.

Drugsdealer's Profile

The drugsdealer is a powerful person who manages rather than commits crimes. To cover up his illegal dealings, he is also involved in legal activities. The drugsdealer is highly aware of his place in the drugs trade hierarchy. Above him in rank are the big players from whom he buys, below him are the drugs runners to whom he sells. It is a rough world, and in response the drugsdealer has adopted an opportunistic attitude in his pursuit of money and power.

Drugsdealer's Attitude towards Appointments

The drugsdealer has two agendas, one legal and one illegal. The information about his illegal activities is very sensitive. It should not fall into the wrong hands, be it 'colleagues' or the police. Clearly, he is very careful with whom he makes appointments and where. Meeting places are specified by their characteristics. Roads which will allow a quick get-away and buildings which will provide cover are important considerations. The drugsdealer does not plan very far ahead. Dealers come and go; the scene may look very different next week. The drugsdealer is ambivalent about exposing his appointments. On the one hand, they contain sensitive information. On the other, exposing them means enforcing his position in the hierarchy, a kind of powerplay which draws new trade. In his appointments he needs to express his respect for the big players and his superiority over the smaller dealers to whom he sells.

Based on this, researchers Djajadiningrat, Gaver and Frens came up with the following:

The appointment manager for the drugsdealer consists of a set of rings and a pouch in which the rings can be stored when not in use G.1. Each ring that the drugsdealer wears stands for an appointment G.2. Since the drugsdealer plans only one day ahead, the number of rings which fits on both hands is sufficient for one day. Which finger a ring is on determines the importance of the appointment: the more towards the little finger, the more trivial. The rings are available in different forms and materials so that when the drugsdealer makes an appointment with a person, he can choose a ring matching that person's place in the trade hierarchy. Rings can consist of two parts so that when a task is delegated, one part is given away, with completion being signalled by the parts being reunited. A sleeve-like ring which prevents a finger from bending can function as a physical reminder of an urgent appointment. Embedded electronics make each ring aware of its value and the appointment's time and place. Finally, abstract patterns of light emitted by a ring can signal conflicting appointments as the drugsdealer tries to fit an appointment into his schedule.

Figure G.1: Premodels for the rings for the drugsdealer. [30]

Figure G.2: The rings for the drugsdealer. [30]

The design of the drugsdealer's rings reflects his ambivalent attitude towards exposing his appointments. On the one hand, he shows of how busy he is, enforcing his position. On *the other, he does not want to disclose any details about his appointments. The rings form a kind of augmented 'knot-in-a-handkerchief' appointment manager.*

Nice, but what's the point of all this?

You may now be wondering why I'd like to try out this method... so this is the right time to underline how it can be useful even when designing home automation apps. Considering the example above, the rings prototyped for drugsdealers may be of inspiration to design innovative features for more 'actually marketable, feasible and actionable' design solutions for a PDA, as they may sparkle ideas that wouldn't be explored otherwise.

Extreme Characters for Designing Home Automation Apps

I would like to consider two extreme characters from TV shows where scenes are predominantly filmed in their main set or in their domestic set. In our case, as we're designing for a home automation app, I'd like to focus both on the profile of the extreme characters that we're gong to pick, but also on the environments where such characters spend big part of their time in.

Now, having an ideation session in mind later this week, it is important for me to know what TV series with the properties pointed out above that you've watched, and what characters you feel are suitable - or even fun - to be picked as extreme characters.

- *Which of the following TV shows have you watched? (If you watched other TV shows that you think are suitable for this method, please include below)* `[Checklist (open)]`

    a) *The Office* (American series) (Figure G.3)

    b) *The Big Bang Theory* (Figure G.4)

    c) *Friends* (Figure G.5)

    d) *The Simpsons* (Figure G.6)

Figure G.3: a) *The Office* (American series)

Figure G.4: b) *The Big Bang Theory*

Figure G.5: c) *Friends*

Figure G.6: d) *The Simpsons*

Figure G.7: a) Michael Scott (from *The Office*)

Figure G.8: b) Dwight Schrute (from *The Office*)

Figure G.9: c) Sheldon Cooper (from *The Big Bang Theory*)

Figure G.10: d) Penny Hofstadter (from *The Big Bang Theory*)

Figure G.11: e) Rachel Karen Green (from *Friends*)

Figure G.12: f) Homer Simpson (from *The Simpsons*)

- *According to your answer above, which characters do you think it would be most suitable picking as extreme character? (If you included other TV shows above, please indicate the characters that you believe are worth considering for this method)* `[Checklist (open)]`

    a) Michael Scott (from *The Office*) (Figure G.7)
    b) Dwight Schrute (from *The Office*) (Figure G.8)
    c) Sheldon Cooper (from *The Big Bang Theory*) (Figure G.9)
    d) Penny Hofstadter (from *The Big Bang Theory*) (Figure G.10)
    e) Rachel Karen Green (from *Friends*) (Figure G.11)
    f) Homer Simpson (from *The Simpsons*) (Figure G.12)

- *Your full name* `[Text field]`

Thank you for your answer and for your time! Once answers from all participants are collected, I'll get back to you with the instructions for the next steps.

Amos Cappellaro
Master's Thesis in Interaction Design and Technologies
Chalmers University of Technology

For any inquiries, please drop me a line on *Slack* or at `amosc@student.chalmers.se`.

H

Cognitive Walkthrough Tasks

PART A

1. Turn `ON` all lights in *Upper floor*, and turn down all Category X's products in *Ground floor*; after that, turn `OFF` all thermostats in the whole system and turn them back `ON`;
2. Now turn `ON` all lights in *Upper floor*'s bathroom;
3. Now turn `ON` the light called *Floor lamp*, that belongs to a light group in the living room. Once the *Floor lamp* is `ON`, access the settings of the *Ceiling lamp* light to rename it into just *Ceiling*.

PART B

4. You've just mounted four Category X's products in the living room of your home; now, you want to configure and install them as a group in the app. You want to call them *Facing garden* as a group, and *#1*, *#2*, *#3* and *#4* individually. In the process, set a customized top end level for the group at 30%.
5. Now that you've installed them, add this group of Category X's products as favorite. Then, go to the *Favorites* view and move *#1* to 100%.
6. Now, directly from this *Favorites* view, turn `OFF` the bedroom's thermostat, located in the upper floor.

PART C

7. Fine tune Category X's products in *Upper floor*'s guest bedroom room moving them almost to 100%, without entering the room view.
8. Determine if the system is currently connected over *Bluetooth* or *Internet*.
9. Set up a new scheduled event: activate the 'Party' scenario between sunset and midnight on Saturdays.
10. Go to *All* zone and turn `ON` the *Dinner* scenario. After that, get an overview of all scenarios available in the system.
    a. how would you sort scenario here, and how would you remove them?
    b. browse through the different zones: why do the scenarios change?

***NB**: some of the tasks, for non-disclosure purposes, needed to be edited in order to be reported within this Appendix.*

I

Informed Consent

Cognitive Walkthrough

What this study is about

Your participation in this study will help me evaluate the mobile app prototype that I've produced and iterated throughout my thesis project, based on future user needs and insights acquired while conducting research. The purpose of this study is to evaluate various aspects of the new user interface, like efficiency, ease of use, findability and learnability.

Your participation in this study is voluntary

During the session, you can take a break at any time. Just tell me if you need a break. You can leave at any time without giving a reason.

Information I will collect

I will provide you a set of ten tasks that I will ask you to achieve using the prototype at disposal on the mobile device. The tasks are grouped under three major parts - Part A, Part B, and Part C - which you can perform in whatever order you would prefer, at your own will. While you will perform the tasks, you will be asked to think aloud while performing them, and I will observe the actions that you will take. If consent is given, I will record the session (audio only) to automatically get it transcribed with *Otter.ai*.

How I ensure your privacy

I, the undersigned, will be the only one having access on possible recordings, which will be treated as confidential and will not be shared outside our company. I may publish research findings that include your comments and actions but your data will be fully anonymous. This means your name and identity will not be linked in my research report to anything you say or do.

Your consent

Please sign this form showing that you consent to me collecting these data. You give your consent:

- *for the researcher to observe me while performing tasks during the session;* [Checkbox]
- *for the session to be recorded (audio only) for automatic transcription;* [Checkbox]
- *for the researcher to use comments and actions and report them anonymously.* [Checkbox]
- Your name [Text field]

If you want to withdraw your consent

If you want to withdraw your consent in the future, contact me on *Slack* or via email (amosc@student.chalmers.se), so any personal data I hold about you (such as audio recordings) will be destroyed. Otherwise, I will delete personal data after six months from now.

Thank you for your time!

Amos Cappellaro
Master's Thesis in Interaction Design and Technologies
Chalmers University of Technology

For any inquiries, please drop me a line on *Slack* or at amosc@student.chalmers.se.

J
Compensations

As a token of appreciation for their contribution to research, ideation and evaluation sessions in my thesis project, the eight participants recruited early on in the project were compensated with a movie ticket eligible to be used at *Filmstaden* movie theaters. A customized ticket for each participant (as visible in Figure J.1) was created to send compensations digitally, at the end of the project, over *The Company*'s *Slack* workspace.

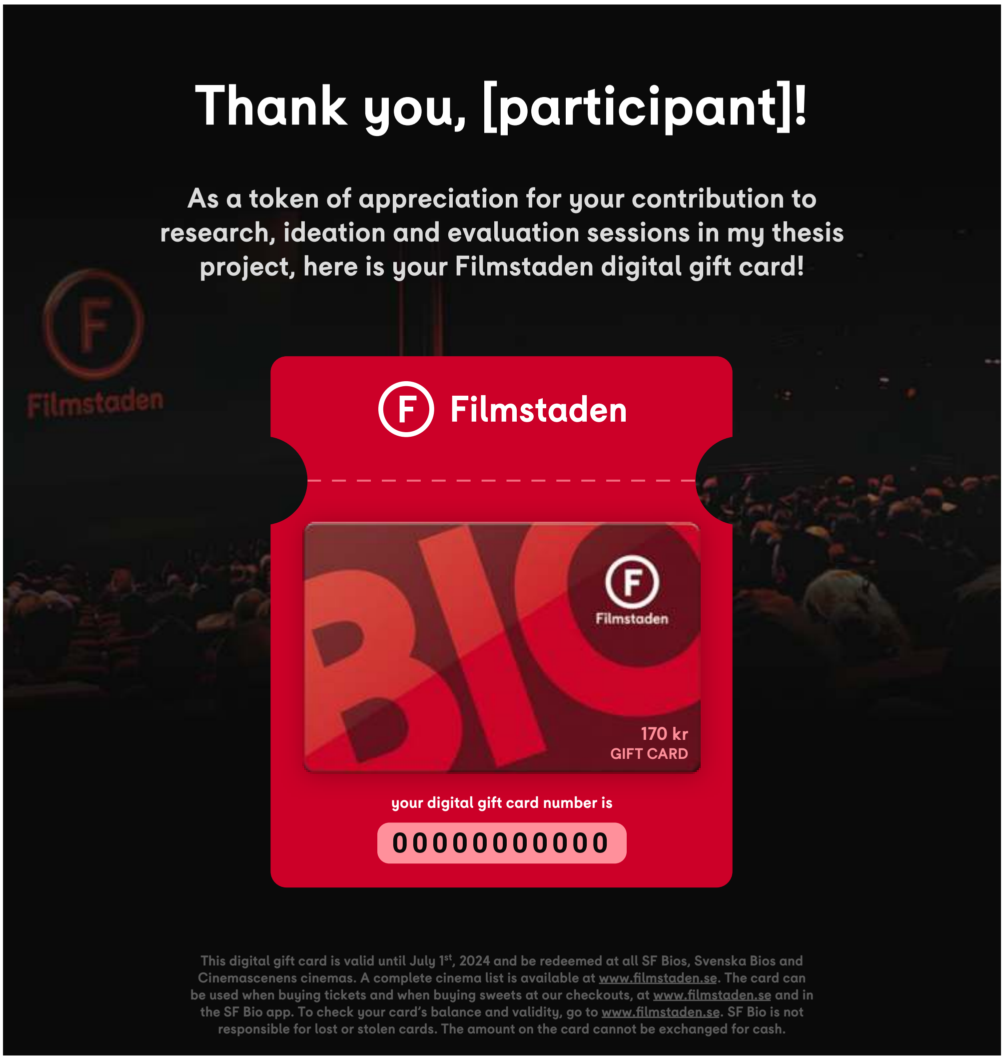

Figure J.1: An example of customized ticket sent out to participants.