Data as a Means

Designing and Developing "Smart" Product Experiences.

MSc Thesis Communication Studies

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Abstract

"Smart" Products have been a popular interest and desire of many researchers and practitioners in the Human-Computer-Interaction field. By their promise to change how people interact with everyday things, "smart" products have the potential to allow for types of user experiences that cannot be reached with other types of systems. Although these products include a strong emphasis on end-users' perceptions and experiences, in-depth research on these user experiences is scarce. Scrutiny of UX research on "smart" products in the HCI-field shows that rather than focused on the needs of end-users, most research is technology-oriented. Therefore, detailed understanding of experiences that are desirable and opportune in "smart" product systems is necessary to guide the design of successful implementations, providing designers with insights on the kind of target experiences that these systems should support. For this reason, the course of this project was to develop a User Experience Framework, to guide the design and development of "smart" product experiences in practice.

Although a shared definition of "smart" products lacks, there is a tension to agree that the nature of these products is centered around data. Often enabled by sensors and inter(net)-connectivity, the usage of data by "smart" products enables them to learn patterns, behaviours, about environments and to act upon these aspects, setting them apart from other interactive products within the HCI-field. Emerging from this differentiation, the UX of "smart" products is also different. Emerging from technology and data, the UX of these products is often distributed among devices, contexts, users, applications and services. Considering system characteristics, contexts of use and the user's internal state is therefore of importance when designing for "smart" product UX. As developing these experiences can be challenging due to confusion in user analysis, the implicitly of "smart" product interaction and challenging task analysis, the development of "smart" product UX should be focused on rapid prototyping and evaluation in short cycles of designing - prototyping and evaluation, together with real end-users in real contexts-of-use.

As the evaluation of the UX insights gathered with real end-users in real contexts-of-use was necessary, a dummy project was conducted together with the Volvo Cars "User Experience Concept Center" where a surrogate "smart" navigation system was designed and developed, on the basis of the UX framework presented. This evaluation showed that the heuristics provided seem to be of practical value when designing and developing for "smart" product UX, by guiding decisions about overall UX and IxD design. However, future work needs to be conducted to determine the value of each heuristic in particular, if the framework needs to be supplied with more heuristics based on studied phenomena in the "smart" product UX domain, in what stage of the design and development process the framework is of the most value and how the role of the designer in the UX design and development process changes when data becomes one of the primary design means.

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Chapter 1

Introduction

Secondary to the rise of the smartphone, seen as the catalyst of the rapid adoption of "smart"[1] technologies, the notion of "smart" has taken on a new meaning in the context of information technology and computing, and has been well adopted within the domain of interactive technologies at large. By equipping products with information and communication technologies as sensors, microchips and wireless chipsets, enhancements in technology empowered products to take a bigger prevalence in the lives of ordinary people. Products like smart thermostats, smoke detectors, smart door-locks, activity trackers and further mobile devices gain ubiquity within everyday environments and are expected to reach a 212 billion by the end of 2020 [1].

To describe the omnipresence of "smart" products within everyday environments, the term "Internet of Things" (IoT) gained a lot of interest among researchers and practitioners in the human-computer interaction (HCI) field. IoT is a term to describe the strategy of enhancing "smart" product systems by connecting devices and sensors to the Internet[2], gaining understanding of system interaction and usage [2]. Contradictory to most technical products, common thread in the conceptions about IoT is that the underlying technology resides in the background, where the interconnection of intelligent objects, big data analysis and cloud infrastructure enable the achievement of user tasks without explicit user interaction [3]. Furthermore, "smart" products induce other paradigmatic changes to the field of interactive products as their context awareness, pro-activity and engagement [4]. A smart thermostat for example, is able to use sensors to determine the presence of a user in a room and to use weather data from the Internet, all to ensure a constant desired temperature by the user. The potential of "smart" products has been widely endorsed within the HCI-field as it "promises to transform the way we interact with everyday things" [5, p.25], which could allow for types of user experiences that cannot be reached with other types of systems [6].

Problem Statement

Although "smart" products include a strong emphasis on end-users' perceptions and experiences, in-depth research on the user experience (UX) of these products is scarce [6], [7]. Scrutiny of the adoption of UX in the HCI-field shows that most research on "smart" products is technology-oriented rather than focused on UX, as many research projects concentrate on how technology can be used, rather than looking at the users' needs [6], [7]. Although user-centered design (UCD) and its resulting pleasurable experiences are becoming important competitive factors in the

[1] "Smart" is placed between quotation marks, primarily to avoid the self-description of this term that the industry self produces for their own goods by placing their products on the wave of the "smart" hype.

[2] The term "the Internet" is understood as the interconnection of networks

services offered by "smart" product systems [6], only a very small amount of research focuses on the subjective user experiences that "foster deep understanding of how these systems are experienced" [6, p.395]. Moreover, detailed understanding of experiences that are desirable and opportune in "smart" product systems is necessary to guide the design of successful implementations, providing designers of these systems with insights on the kind of target experiences that these systems should support [6]. Rather than concentrating on the "core technical workability" of "smart" products, research on these products should shift its focus to the value for end-users [8].

This research aims to address these limitations by providing understanding of the UX of "smart" products, focusing on the unique capabilities of these products, the perception of these products by end-users, their differentiating, subjective user experiences and development and evaluation processes consequentially. As designers of "smart" products can benefit from insights on the kind of target experiences that these systems should support [6], this research will subsequently present a practical UX framework for the design, development and evaluation of "smart" product systems, to guide the design of these systems in practice. In general, this research aims to answer the following research questions:

1. [**RQ.1**] What is the User Experience of "smart" products?
    - [**RQ.1.1**] What are "smart" products?
        - [**RQ.1.1.1**] How can "smart" products be defined?
        - [**RQ.1.1.2**] How do "smart" products work and interact?
    - [**RQ.1.2**] What is User Experience?
        - [**RQ.1.2.1**] How can User Experience be defined?
        - [**RQ.1.2.2**] How can User Experiences be designed and developed?
    - [**RQ.1.3**] How do end-users perceive "smart" products?
    - [**RQ.1.4**] Is the User Experience of "smart" products different from that of other interactive products?
    - [**RQ.1.5**] How can Smart Product experiences be designed and developed?
2. [**RQ.2**] What are the heuristics for the design and development of "smart" product experiences?
3. [**RQ.3**] Is the UX framework of value for practitioners within the HCI-field?

Chapter 2

Methodology

Before an integrated UX framework for the design and development of ”smart” products can be constructed and presented, understanding of the concepts of UX and ”smart” products independently is vital. As both concepts have been researched thoroughly within the domain of HCI, existing literature is used to introduce and clarify these concepts, as outlined in chapter 3. After both concepts are clarified, chapter 4 focuses on the desired UX of ”smart” products specifically. As this research belongs to the multidisciplinary field of HCI, the focus of this chapter is on humans and their reactions and behavior in interaction with technology. Consequentially, by outlining the role, perceptions and subjective experiences of end-users when interacting with ”smart” products, together with the unique nature and capabilities of these products and the unique challenges in the development and evaluation processes of the UX, specific heuristics are provided to guide the design and development of the UX of ”smart” products in practice. The use of pre-established guidelines or heuristics has been widely adopted within the HCI-field, providing practitioners with a comprehensive basis to evaluate usability [9]–[12], aesthetic design [13], emotional design [14], interaction design [15], [16] and user experience [17], [18]. Consequentially, the heuristics provided are incorporated in a framework that serves as a practical tool for designers in the field to use when designing for ”smart” product” UX. As ”smart” products may differ widely in the exact form they take, from ”smart” toothbrush to ”smart” car, the framework provided concentrates on the reuse of the design and development methods throughout the entire ”smart” product domain. Thereby, the framework shoulders the central responsibilities in a ”smart” application but also provides ways to customize the framework for specific needs [19].

To increase the validity of UX findings of ”smart” products found, user studies in real contexts with real users are necessary [6]. Therefore, together with the ”User Experience Concept Center” of Volvo Cars Corporation in Copenhagen, the framework is used as a base for a dummy project. In this project, a surrogate ””smart” product system, within the in-car environment, was designed, developed and evaluated using the framework together with real end-users in real contexts of use. By using the UX framework in a dummy project, the practicality of this framework for the design and development of UX of ””smart” product systems could be tested and evaluated in practice.

Chapter 3

The Foundations of ”Smart” Products & UX

Plenty of research has been conducted to describe the domains of ”smart” products and UX independently. Although many research projects focused on clarifying their concepts, conclusions often contradict providing no clear instantiated understanding nor any shared agreement among researchers how these concepts should be defined. To provide somewhat clarity in the scope of this research, this section aims at introducing both the concepts of UX and ”smart” products. First, Section 3.1 will introduce the concept of ”smart” products, elaborating on the construction of its concept and how these products work and interact. Next, section 3.2 will introduce the concept of UX, clarifying its definition, attributes and influencing dimensions. Subsequently, section 3.3 will focus on UX development specifically, looking at UX prototyping and evaluation methods. To conclude, section 3.4 will give a short summary about the insights presented in this chapter.

3.1 ”Smart” Products

Although ”smart” products and IoT are hot topics nowadays because of their promise to induce radical changes within various domains, their concepts are not entirely new. Already at the beginning of the 21th century Kevin Ashton [20], seen as one of the pioneers who emphasized the promise of ”smart” products, laid the foundation for what would become our current understanding of this term. According to Ashton, if all objects in daily life were equipped with identifiers and wireless connectivity, these objects could communicate with each other and their operation could be controlled and managed by computers. More specifically, Ashton wrote in an online article [20]:

> *“If we had computers that knew everything, there was to know about things—using data they gathered without any help from us we would be able to track and count everything, and greatly reduce waste, loss and cost. We would know when things needed replacing, repairing or recalling, and whether they were fresh or past their best. We need to empower computers with their own means of gathering information, so they can see, hear and smell the world for themselves, in all its random glory. RFID and sensor technology enable computers to observe, identify and understand the world—without the limitations of human-entered data.”*

Although provoking, Ashton’s vision could not be adopted at the time due to the absence of sufficient technological infrastructure. How different is that today. ”smart” products in the areas of wearables, building and home automation, ”smart” cities, health care, ”smart” manufacturing, and automotive are predominant today [21] and show the diversity in kinds of ”smart” products available.

As Ashton envisioned, emerging from the usage of "smart" products within logistic environments, more and more daily objects were equipped with identifiers and wireless connectivity's and became available for ordinary people, taking a growing presence in everyday environments. Consequentially, more and more research on "smart" products within the HCI-field focused on these products as being consumer-centered. However, based on Ashton's notion that computers should be equipped with sensor and wireless connectivity technologies "so they can see, hear and smell the world for themselves", most researchers phrase their definition of these products around the technological, failing to address the interaction of these products with the social lives of ordinary people. Consequentially, "smart" products are cast as the inevitable consequence of a technological juggernaut with a life of its own, acting entirely outside the social. Furthermore, most articles on the subject of ""smart" products" commence with an effort to define them. This suggests that a reasonable definition of these products has not been achieved yet. The argument here is that a standardized, shared definition of ""smart" products has not been found because researchers continue to view it as a technological object [6], [7]. The inadequacy of this view forces researchers to return to the same ground over and over again. Therefore, efforts should not focus on how these products should be defined, but what specific abilities they should possess to be called "smart".

3.1.1 Classifying "Smart" Products

Instead of using a specific definition to describe a "smart" product, the level of intelligence of a product can be used to describe how "smart" that product actually is. Rijsdijk & Hultink define [22] a set of "smart" product abilities and use these to classify the level of product intelligence: the more capabilities a product has, the more it can be referred to as being intelligent:

- **Adaptability.** The ability of an intelligent product to learn and improve the match between its functioning and its environment. A conversational agent for example may learn that certain user queries are related to certain environmental conditions;
- **Autonomy.** The extent to which an intelligent product is able to operate in an independent and goal-directed manner without user interference. Example is an intelligent vacuum cleaner, that cleans the room by itself when a user is not at home;
- **Cooperation.** The ability of an intelligent product to cooperate with other devices to achieve a common goal. Example is a weather-station that communicates with a "smart" thermostat, that rises the inside temperature when the outside temperature drops;
- **Human-like Interaction.** Concerns the degree to which the intelligent product communicates and interacts with a user in a natural, human manner. A conversational agent for example communicates and interacts with a user via speech;
- **Multi-functionality.** Refers to the phenomenon that a single product fulfills multiple functions. An example of the multi-functionality of an intelligent

product is the "smart"phone. It is not only capable of calling, but also of browsing, taking pictures, sending messages etc;

- **Personality.** Refers to the intelligent product's ability to show the properties of a credible character. The old Microsoft Office Paperclip for example suggested that it assisted the user;

- **Reactivity.** Refers to the ability of an intelligent product to react to its environment in a stimulus-response manner. A "smart" thermostat for example may increase the inside temperature when it senses the presence of someone in the room, but may decrease it when the user leaves the house.

Beside the efforts of Rijsdijk & Hultink, other researchers also [23], [24] make a classification of the level of product intelligence, based on:

- **Information handling.** An intelligent product should at least be able to manage its own information, given by sensors, RFID-readers and other techniques. Without this capability, it can hardly be called intelligent. When an Intelligent Product is only capable of information handling it is not in control of its own life, as full control of the product is external or outside the product.

- **Problem notification.** A more intelligent product is a product which can notify its owner, when there is a problem. Such a problem could be that the temperature is too high, there is traffic on the way to work etc. Still the product is not in control of its own life, but it is able to report when there are problems with its status or the action that need to be performed.

- **Decision making.** The most intelligent product is the product which can completely manage its own life and is able to make all decisions relevant to this by itself, without any external intervention. In this case, the product has full control over itself and there is no external control of the product.

Although a unified definition of a "smart" product lacks, it is evident that its concept is built on the usage of data to be used in processes of information handling, communication and interaction, and decision-making between product and user, environment or between other products or systems. However, some of the abilities of these products, as multi-functionality and reactivity, may not be unique for these products. Other interactive products available may possess one or more of these abilities as well. Consequentially, setting "smart" products apart from other interactive products available can be challenging. Therefore, the subsequent section will outline the key differences between those kind of products.

3.1.2 Differentiating "Smart" Products within the HCI-domain

In order to better recognize the nature of "smart" products, it is important to understand the key distinctions between Web-based environment products, often "normal" computers", and "smart" products based on an IoT-environment. As shown in the previous section, the abilities that make products "smart" emerge from the use of data. This also forms the base in which these products set themselves apart from their Web-based counterparts. Weinberg [25] mentions several distinctions between these two types of products, based on this data usage:

Data-entry

Users in a Web-based environment actively manipulate devices to interact directly with the web. For example, a user may use a laptop to surf the web for a particular product, ending up buying it online. This entire process consists of user initiated interactions, as clicking through webpages and entering transaction information. Although users can interact with IoT-based products, in many cases they do not enter the data themselves. Rather, the devices monitor and retrieve relevant data from the environment. For example, a "smart" thermostat can monitor and analyze temperature conditions and user behavior and use pre-defined preferences to learn and optimally manage the temperature in house. A user does not have to actively participate in this process of data-gathering, as the device is able to do this on its own.

Data-sharing

Consumer information related to Web behavior is typically shared internally within an organization or with other third-parties. In an IoT-environment though, data is not only shared with the vendor but also with other devices. For example, a "smart"phone or "smart"-car equipped with location tracking technology may share a user's location and arrival time to a "smart" thermostat at home. This would enable it to set the right temperature based on the preferences of the user, ensuring the house is heated or cooled down when the user arrives.

Learning

Providers, marketers and other interested parties may learn about their users based on their behavior within the digital-world, e.g. shopping online and using social media. This behavior may be recorded through the use of cookies or transactional information. On the other hand, intelligent products learn about their users by observing their habits, tendencies, preferences and environments. This learning is based on behavior and phenomena occurring in the natural, physical world as opposed strictly to the online world in which users behave within a Web-based environment.

Decision making.

Marketers and providers use Web-related data to make decisions to engage and serve users with a better experience. Decisions are not necessarily made in real-time, but are mostly consequences of analyzed online behavior over time. On the other hand, "smart" products are constantly monitoring their environment through sensors and are dynamically making decisions and associated changes in real-time, based on environmental conditions or users' preferences. For example, a "smart"watch may monitor the user's heart rate and may alert the user if it falls to a critic level.

The use of data for sharing, learning and decision-making processes makes that "smart" products possess a unique interaction model in their operation, which is broken down and discussed in the subsequent section.

3.1.3 The Working of "Smart" Products

To gain better understanding of the continuous interaction between the core components of a "smart" product within the working of a device, a model is used to show the specific interaction model of "smart" products (see figure 3.1) which is explained in the following.

The **input** needed is given by data-entry through either implicit (e.g. data from other devices, data from sensors) or explicit (e.g. user entry, user defined rules or preferences) interaction. Next, this data is **analyzed** on the device itself or on e.g. a server to determine what data should be used for the decision-making process.

images/framework.png

Figure 3.1: Flowchart of the Working and Interaction of "smart" Products

Furthermore, this data can be shared (e.g. send to a remote server of the company) to not only give a company a good view on overall system and data use, but also to use this data to let the algorithms involved **learn**, leading to better decision-making in the future. When the data is analyzed, the system will make the **decision** what action to perform. This decision will lead to the **output** as prompting the user, heat the house, open the door etc. The data of this whole process (input data, analyzed data, decision making and output) can also be used to optimize the system for future use, since if the output is accepted the process of interaction is sufficient for future use. Therefore, this will be logged and used by the system on the device itself or by remote servers, to learn and optimize the decision making process for a next interaction alike.

"Smart" products continuously work within a framework of data-input, learning and decision-making and are interacting with users accordingly. However, this understanding of the concept of "smart" products still takes a technology-oriented view, rather than focusing on the new kind of experiences for end-users these products could enable, one of the key problems of "smart" product research within the HCI-field [6], [7]. Therefore, traditional methods of human factors need to be adapted to these contexts, because the potential of experiential design deserves to be explored [6]. To introduce this way of thinking about experiences, the subsequent section will introduce the concept of user experience design.

3.2 User Experience Design

The concept of UX has been well adopted among researchers and practitioners within the HCI-field. As the previous narrow focus on interactive products as tools did not capture the variety and emerging aspects of the technology in use [26], UX has become the term to describe how the user experiences the system in real contexts as necessity for system acceptance [6], and a quality attribute and important success factor of any technology [6].

While the consensus among researchers and practitioners within the HCI-field is that UX is something desirable when designing interactive products, a unified definition of the concept itself is missing. UX is often associated with a wide variety of meanings [27] and is therefore perceived as being vague and unclear for many researchers and designers [28]. According to Law et al. [29] there are three reasons why it is so hard to come to such a definition. First, UX is associated with a broad range of fuzzy and dynamic concepts, including emotional, affective, experiential, hedonic and aesthetic variables. Second, the landscape of UX research is fragmented and complicated by diverse theoretical models with different foci such as pragmatism, emotion, affect, experience, value, pleasure, beauty, hedonic quality etc. Third, the unit of analysis for UX is too malleable ranging from a single aspect of an individual end-user's interaction with a single application to all aspects of multiple end-users' interactions with a company and its merging of services from multiple disciplines. Researchers especially seem to struggle with how the concept of UX is related to that of usability. Usability focuses primarily on the instrumental, utilitarian aspects of the interaction between the user and a product or system, as efficiency and effectiveness [29]–[31]. Although measures of these aspects, like task performance and completion time, are important factors in analyzing user-product interactions, some researchers state that UX should not be equaled to usability or user interface simply [32], as usability alone can only achieve a limited level of UX [28]. While considering pragmatic system qualities as usability and efficiency is crucial [7], UX goes beyond these aspects [26] shifting its focus to user affect, sensation and the meaning as well as the value of such interactions in everyday life. Hassenzahl & Tractinsky [26, p. 91] point out that due to maturing technology "interactive products became not only more useful and more usable, but also fashionable, fascinating things to desire". Accordingly, the classic notion of usability was replaced by the more holistic term "User Experience", although both concepts tend to agree that attributes beyond effectiveness and efficiency play an important role in the acceptance and appeal of interactive products. Therefore, both terms are often used interchangeably as their aspects form quite some overlap [33]. This led to several approaches to the relation of usability and UX, where UX encompasses usability, complements usability or is just one of several components constituting usability [34]. Researchers seem to follow this path as research on both fields is heavily distributed among these three different approaches.

While UX is seen as a vague and fuzzy concept without any form of shared agreement on what it exactly means, the definition of UX is an initial and crucial step towards an integrated framework of UX [29]. As this research aims to provide such a framework, the concept of UX should be enclosed and defined.

3.2.1 Towards a definition of UX

Although a shared agreement on the definition of UX among researchers is lacking, efforts have been conducted to standardize its concept. One of these efforts is the ISO-9241 definition of UX, which reads:

> *"A person's perceptions and responses that result from the use or anticipated use of a product, system or service."*

The ISO-9241 definition focuses on the immediate consequences of use (perceptions and reactions) and the concept of anticipated use of a product, system or service. In an effort to clarify the definition of UX, Law et al. [29] compared this ISO-9241 definition with views on UX from researchers and practitioners in the HCI-field and concluded that indeed the immediate consequences of use and the anticipated use of a product, system or service seem to be important factors of a UX definition [29]. Furthermore, there seems to be a tension to agree on a concept of UX as dynamic, context-dependent and subjective, in line with research conducted by Buchenau, who states that an experience is a "very dynamic, complex and subjective phenomenon" [35, p.424]. However, due to their different backgrounds, actual shared agreement between the participants on the concept of UX lacks. Law et al. [29] therefore stated that inclusion and exclusion of particular variables within UX definition seems arbitrary, depending on the participant's background and interests. This may indicate that the nature of UX is actually dynamic and subjective, what means that using a specific UX definition within a study depends on the contexts and the phenomena this study is trying to addresses. Therefore, it seems arbitrary to use a definition of UX that covers the subjects studied. Hence the following definition is used to describe the understanding of UX in this research:

> *"All the aspects of how people use an interactive product[3]: the way it feels in their hands, how well they understand how it works, how they feel about it while they're using it, how well it serves their purposes, and how well it fits into the entire context in which they are using it."* [15]

The definition of UX as formulated by Alben [15] covers the understanding of UX in this research best as it is focused on interactive products and the interaction between these products and its user(s), which are central to this particular study. Furthermore, it addresses the user's needs to use the product and the contexts of product usage; important aspects of "smart" product UX (see 4.3). Or, a simple way to think about what influences an experience is to think about the components of a user-product interaction, and what surrounds it [36]. More and more studies emphasize this non-instrumental attributes of UX and delve into understanding of the physio, socio, psycho and ideo needs of human beings [37], [38], as addressed in the next section.

[3] A product that is able to foster interaction with a user through elements like aesthetics, motion, sound, space, etc.

3.2.2 The Attributes of User Experience

In contrast to the concept of usability, UX is often used to cover a broad set of users' experiences based on instrumental (pragmatic) and non-instrumental (hedonic) system qualities [26]. However, the focus on utility and other hard attributes central to usability, turned out to be insufficient [39], as product use does not only fulfill a pragmatic, utilitarian function but also emotional wants [26], [32]. Therefore, a second, hedonic dimension was added to the concept of UX to describe the aspects that go beyond the utilitarian. Since HCI is traditionally a task-oriented discipline, and therefore pragmatic product attributes have always been the focus of attention, the explicit consideration of hedonic attributes, was a revolutionary step. Consequentially, many of the available models of UX broadly distinguish between utilitarian, task-oriented, pragmatic and self-oriented, hedonic attributes of interactive products [see 26]. The hedonic dimension of UX captures intangible and subjective product attributes, built on the emotive and fantasy aspects of one's experience with a product [39]. Fantasy refers to the self-constructed reality in accordance with one's ideal self with the help of a product, so the quality derived from this hedonic consumption is built on what consumers desire reality to be, i.e. how they want to be [39]. Although the importance of hedonic quality for the positive experience of interactive products may seem surprising due to the strong focus of i.e. task-fulfillment in the interaction between system and user, there are several reasons why especially hedonic attributes are crucial for product experience: (i) the close relation of these attributes to universal human needs and the user's Self, (ii) their role as motivator, directly contributing to positive affect and (iii) their prior impact on the formation of product evaluation [40]. This perspective on the distinction between pragmatic and hedonic dimensions of product use is related to the distinction of do-goals (instrumental tasks) and be-goals (i.e. how people want to be), which was introduced by Carver and Scheier [41] and then adopted and adapted to the domain of UX in the HCI-field [42], [43]. Pragmatic attributes have to do with the product's perceived ability to support the achievement of *do* goals, such as "making a telephone call" or "finding a book in a book-store". But people do things for a reason: "making a telephone call" should not be regarded as being an end in itself but serves higher-level (hedonic) goals such as "being related to someone" or "being stimulated when bored." These hedonic attributes summarize the product's perceived ability to support the achievement of these *be* goals "and thus can be regarded as the essential reason for product interaction" [40].

Taken together, the pragmatic and hedonic qualities of product experience suggest a "motivation-hygiene model" [see 44]. Hedonic quality serves as "motivator", with the ability to create a positive experience, while pragmatic quality acts as a "hygiene" factor, with the ability to prevent negative experience only. Mano & Oliver [45] find that hedonic quality is directly linked to positive affect, whereas pragmatic quality is only related to negative affect. Similarly, Chitturi et al. [46] find a correlation between hedonic benefits and promotion related emotions as cheerfulness and delight at one hand, and a correlation between pragmatic benefits and prevention related emotions as security and prevention on the other hand. Also Hassenzahl et al. [43] support a "motivation-hygiene model", as they find a direct link between hedonic quality and positive experience, but only an indirect link between pragmatic quality and positive experience. Furthermore, there is a different attitude of expectation towards hedonic and pragmatic quality. As Hassenzahl et al. [43] point out, especially in the domain of interactive products a certain level of pragmatic quality may be taken for granted. For example, a decent quality of a mobile phone's speaker is expected. If the phone fails to deliver this quality, this will be experienced as negative. On the other hand, decent speaker quality is expected and will not lead to a more positive experience when this criterion is met. Furthermore, hedonic quality, such a beautiful design, is able to directly evoke positive emotions and desire and can thus more easily impress by exceeding expectations. Finally, hedonic attributes have a more continuous influence on product experience, influencing a user's perception and attention more direct. On the other hand, pragmatic attributes are experienced over time while the user is actually using the product. Altogether, research shows that hedonic attributes are more relevant for positive experiences and pragmatic attributes more relevant for avoiding negative experiences. In general, the tension is that the concept of UX is mainly formed around the hedonic attributes of a product. Although pragmatic attributes as usability are still very important, they only act as gatekeepers against negative experiences. However, one may argue that the pragmatic attributes of UX are the base of building positive user experiences as before these positive experiences can be designed, the possibilities of negative experiences should be avoided.

3.2.3 Types of Experiences

As shown, the distinction between pragmatic and hedonic aspects of motivation in product experience have been widely discussed within the HCI-field. Borrowed from these insights and research conducted by others [47], [48], two different non-exclusive types of UX can be defined:

1. **Pragmatic** experiences focus exclusively on the fulfillment of the user's need or intention of use, without considering other UX dimensions as emotional state or context of use. This type of experience would correspond with a purely functional application that uses the most common and straightforward way of interaction with a user, e.g. using a touch screen on a mobile phone.

2. **Hedonic** experiences focus on the fun and enjoyment when using an application. Beside the fulfillment of the user's need, other aspects as usability, aesthetics and fun are considered in the design process. This results in an application that is not only intuitive to use, but is also enjoyable to use.

Emerging from these two types of experiences, UX encompasses several distinct dimensions, which are used by UX designers to design for product experiences. These dimensions are described in the subsequent section.

3.2.4 The Influencing Dimensions of UX

Three influencing dimensions of UX are often suggested in review literature: user, product and interaction. Or, as Forlizzi & Ford [36] suggest, a simple way to think about what influences an experience is to think about the components of a user-product interaction, and what surrounds it. Approaches to UX design are heavily distributed among these three dimensions. Forlizzi and Batterbee [27] find that some approaches take the perspective of the user, others attempt to understand experience as it relates to the product and a third group tries to understand UX through the interaction between these two. However, these dimensions turned out to be insufficient to cover the complexity and diversity showed by these terms [32]. Therefore, extended lists of dimensions influencing UX are presented, emphasizing the **user's internal state** consisting of the *user's* needs, resources, emotional state, experiences, expectations [49] and *cognition* [32]; the *physical, social, temporal and task* [49] **contexts of use** [29], [32], [35], [49], [50]; and the *products, objects, services, people, infrastructure* [49] and *usability* [32] involved in the **system**. Based on the work of [26] and others, the following dimensions as influencers of UX are distinguished:

1. **The User's Internal state** consists of the user's expectations, mood, emotions, meaningfulness of the activity and prior knowledge and the intentions of use, composed by the user's needs and motivations. The user's needs that an application should fulfill may be seen as the most fundamental aspect of UX [51].

2. **Context of Use** includes the social, temporal, physical, technological and task-specific aspects of the context a product is used in.

3. **System Characteristics** consist of the functionality, usability and complexity of a system.

Designers often use one or more of these dimensions in their effort to design for product UX [4]. In their efforts, they use specific development methods to address each dimension individually and thoroughly, as discussed in the next section.

3.3 User Experience Development

Hedonic and pragmatic attributes and the dimensions that influence the UX form important aspects to consider in the design process, as UX designers aim to design for the best experience possible. To achieve this, the use of User-Centered Design (UCD) methods is widely adopted within the HCI-field, because of the focus on the central role of the user in the entire design process. UCD is a design philosophy where the needs and requirements of end-users are in focus at each stage of the design process [52], emphasizing (i) explicit understanding of users, their tasks and contexts of use, (ii) driving and refining the design by user-centered evaluation, and (iii) addressing the whole user experience. Prototyping and evaluation together with end-users has become a prominent way of evaluating the UX by reflecting on the hedonic and pragmatic attributes of the UX designed. This section will outline several UCD methods used in practice, showing how both UX prototyping and evaluation methods are incorporated and can be approached during the UX development process.

[4]In this research the use of designing *for* an experience is used deliberately as designers can only design for an experience that they think is best. This experience in practice however, when the user is actually using the product, may be influenced by other external factors that were not emphasized by the designers and therefore are not following the designer's intent. Therefore, designers can only design *for* an experience and cannot design *an* experience.

3.3.1 Current approaches to UX Development

UCD methods based on experiential design thinking, as Agile, Lean or Scrum, have become the prominent trend in HCI [6] and are preferred over other methods by designers in the field [53]. Originating from the field of software development, the integration of user experience design and Agile-like methods has caught the attention of Agile researchers and practitioners alike [32]. Methods as Agile, Lean and Scrum consist of an environment in which system requirements and solutions result from the collaboration between self-organizing, multidisciplinary teams in rapid iterative cycles. These methods are based on the focus on the user during the whole development process, the collaboration with end-users during this process and quick adaption to change during the process itself. Taken together, Agile, Lean and Scrum consist of the following principles [54]–[56]:

1. **Focus on the user.** The highest priority is the satisfaction of the user, so everything that does not add value for the user should be eliminated;
2. **Learn from the user.** Short iterative cycles in cooperation with users should be used to gain more knowledge about the desired objective. User input should be used during the whole development process to evaluate on design choices made;
3. **Decide as Late as Possible.** The team should decide as late as possible based on the gained insights from user feedback;
4. **Deliver as fast as possible.** By delivering products as fast as possible their feedback can be used within the next iteration. Implementing just-in-time delivery by using tools as user stories and scenario's can improve time and effort stimulation;
5. **Empower the team.** Build the development process around motivated individuals, give them the environment and support they need and trust them to get the job done;

UCD methods as Agile, Lean or Scrum consist of many iterative development cycles: sprints. In the beginning of the project the product backlogs and specifications for the final product are defined. These are seperated in multiple, graspable user stories. Next, the set of user stories is incorporated in different sprints, which each have a specific time-frame (usually two to three weeks). In the end of a sprint, the outcomes and feedback are presented and used as input for the next iteration. At regular intervals, the team reflects on how to become more effective, discussing the progress of each team and individual and discuss new goals and tasks.

3.3.2 User Experience Prototyping

To evaluate one's design and choices made together with end-users, prototyping is of significant value and is seen as a key activity within the development process of interactive products [35], as they allow designers to "demonstrate, evaluate or test an evolving design with minimal efforts" [57, p.254]. Prototypes can fulfill different functions [58], can have different fidelity levels [57], [59] and can target different audiences. Buchenau & Suri [35] specifically considered prototyping methods with active participation of end-users to generate relevant subjective experiences. This so called "Experience Prototyping" (ExP) enables "design team members, users and clients to gain first-hand appreciation of existing or future conditions through active engagement with prototypes" [35, p.424]. They find that ExP contributes to the design process in three ways:

1. The exploration and evaluation of ideas, generation of specific requirements and making design choices must be done in an early phase of designing. Low fidelity prototypes are especially suitable for this. ;

2. Communicating ideas to different audiences as other designers, users, developers or clients. The level of fidelity corresponds to the current design and development phase.;

3. Helps to foster understanding about the essential factors of an existing application and its context. To achieve this, high fidelity prototypes are necessary.;

As can be seen, the fidelity levels of the prototypes within the ExP method needs to raise to be able to gain sufficient insights according to the time of product release [35]. However, as efforts in time, cost and work-force are high for the creation of high-fidelity prototypes [57], the use of low-fidelity prototypes in fast iterative design processes as Agile, Lean or Scrum are more common in industry. Some examples of these kind of prototypes and the way these prototypes relate to the domain of "smart" products are discussed below [57], [60], [61], based on their level of fidelity.

Moodboards & Visualizations

Low-fidelity prototypes as moodboards or collages are often used in the initial phase of the design process to discuss ideas and concepts and to discover potential problems. Visualizations as collages are tools for the creation of semi-realistic mockups that help non-experts imagine unfamiliar devices in an early stage of the design process [61]. The visualizations can be rough and imperfect and usually consist of a collection of photographs of existing applications or renderings. In the domain of "smart" products, considering the use of low-fidelity prototypes in the initial design phase is important to gain sufficient understanding of the components of a product and its inter-operability with other systems.

Wireframing & Paper Prototyping

Wireframing is used to define a layout of a graphical user-interface (GUI) of a specific device, e.g. a "smart"phone app or website [62], visualizing structural aspects, terminology and navigation. Wireframes can be created e.g. on a piece of paper or on a whiteboard, serving as prototypes of low-fidelity. Similarly to wireframes, paper prototypes are used for creating visualizations of structural aspects and navigation. In contrast to wireframing, paper prototypes are used to gain understanding of dynamic interaction aspects such as navigation and workflow [62]. By "playing the role of the system", designers simulate how the interface would behave by manipulating the paper prototypes [62], gaining understanding of realistic interactions between user and product [57]. As for wireframing, paper prototypes are meant to be rough and should be able to be created within a limited time-frame. Main benefit of prototyping with paper is that changes to the interaction flow or interface can be made quickly, requiring no technological efforts. On the other hand, paper prototypes are not suitable for gaining insights in the technical feasibility of a product and design choices as colors and fonts. Due to their visual nature, wireframes and paper prototypes are not very suitable for prototyping ”smart” product systems, as most of the interactions of these products occur in the background [3]. However, paper prototypes are suitable when a ”smart” product has a user-interface or when paper is used to make scale models of objects or scenery [60].

GUI Prototyping

Evolving from a wireframe or paper prototype, software can be used to create a digital prototype of an interface or object. Although creating digital prototypes increases efforts in time and costs, they can provide a better understanding of the actual interaction by the ability to evaluate a prototype on the desired device itself.

Scenario’s and Storyboards

Scenario’s tell ”a short story about people, situations, and how products introduced into that situation change people’s experience” [60]. The goal of writing scenario’s is to create a detailed story of the UX, by focusing on people, time, space, objects and context [60]. Scenario’s enable designers to understand everyday practices of users [57], share understanding with them and mediate concept experiences to clients and end-users [60]. Storyboards elaborate on the created scenario’s, visualizing sequences and transitions in interactions by the use of images of people, objects and environments, and diagrams and symbols [61]. The creation of scenario’s is especially useful in the concept generation [57], [61] phase of ”smart” products, as, due to the space for imagination, it provides a means for discovering future uses and interactions. Due to the space for imagination, users should be actively involved in the creation of scenario’s, to gain more understanding of their behaviors when interacting with or acting within the context of a ”smart” product. On the other hand, storyboards, due to the addition of visual aspects, make active user involvement challenging as it provides more restrictions. Therefore, getting valuable user feedback on storyboards is difficult [57].

Rapid Video Prototyping

Video prototypes are mostly used to communicate and demonstrate concepts in action and enable the quick exploration of ideas without considering technical details [60], [61]. By rapidly creating video prototypes, the efforts in time, cost and workforce can be reduced. Rapid video prototyping has the advantage over live enactment that the experience can be edited afterwards, and can be used to mediate the concept to a bigger audience, e.g. clients. However, as the audience is not actively involved in the creation of the video prototype and the experience is predefined, their feedback may not be always valuable since they don’t have a subjective experience. Therefore, the use of rapid video prototyping for ”smart” products may only be useful to limited extent or in early stages of the development process.

Wizard-of-Oz

Wizard-of-Oz is a technique in which a person (the Wizard) observes the input of a system (e.g. by a user) and simulates the system's responses in real-time [57]. The Wizard-of-Oz technique enables the simulation of complex interactions such as speech or gesture input or the interaction with a "smart" product system. The effectiveness of this way of prototyping depends on the level of understanding and skill of the Wizard to control the system [57]. Unfortunately, due to the complex and multi-modal interactions of "smart" products (see 4.3.2), high-fidelity implementations of these products are challenging and are complicated further by the difficulty of testing these prototypes in the context of use, as human perception of these contexts is limited.

Functional Component Prototyping (FCP)

FCP is a way of creating high-fidelity prototypes to make the experience of specific capabilities or functional components available. By using specific tools, as microcomputers, high fidelity prototypes can be created to simulate a near-real experience. However, due to the high efforts in creating these prototypes, often only components of systems are prototyped. Prototyping an entire "smart" product system would require even higher efforts due to the diversity of contexts and according functionality, and would not be suitable in rapid iterative design processes. Therefore, the use of functional prototyping of "smart" products for UX design seems inadvisable with conventional tools for technical prototyping.

Each of the prototyping methods mentioned above serves its own goal and is, based on its level of fidelity, of use in a different stage of the development process. Low-fidelity prototypes as moodboards or scenario's are suitable in early stages of the process, providing understanding of the product the UX is designed for and formulating detailed UX stories and scenario's that will provide common understanding of the UX goals among designers and developers. Techniques as wireframing and user-interface protoyping can be used later on in the process to design and develop the individual UX of components of a product. However, for "smart" products it is challenging "to provide an early, low-fidelity improvisation prototype of sufficiently robust nature that they can have an experience in a naturalistic context without supervision" [35, p.432]. The heterogeneous and dynamic contexts wherein "smart" products (inter)act make it challenging to generate and predict scenario's and potential problems. Furthermore, as UX is highly subjective [35], the prediction of users' behaviour within these contexts is difficult as well [57]. Therefore, to increase the validity of UX findings of "smart" products, user studies in real contexts with real users are necessary [6].

3.3.3 User Experience Evaluation

To test the UX designed, evaluation is key. In the following a short introduction is given of the most common methods used in UX evaluation as found by [6] and others.

Questionnaires

Questionnaires can be used after the interaction of a user with a prototype. Questionnaires can aim for quantitative or qualitative data or can use a combination of both. They are easy to distribute and standardize but offer little insight when compared to e.g. interviews.

Interviews

Interviews can take place in a one-on-one or in a group setting [60]. The structure of an interview may differ between a structured, semi-structured or open approach, regarding the level of user recognition and data outcomes preferred. Evaluation of the interviews conducted may be challenging depending on the desired level of details.

Logging

Logging of system metrics is done to gather quantitative data. To extract meaning, an UX expert is needed to process, analyze and interpret the data.

Observation

Observation is usually conducted to analyze how a user interacts with a given product. This observation may be done in direct presence of a user, hidden behind a "magic mirror" or recorded by audio or video.

Diaries & Probes

Diaries & probes are long-term studies conducted by the participants themselves [60]. The participants are asked to document on e.g. the activities, emotions, impressions and many more aspects in a diary. An additional probe, as a prototype, can be provided to the participant to act as research material. Close on-going contact between researcher and participant is necessary to ensure correct execution and handling of the probe, ensuring validity of the research.

Forums & Blogs

The use of digital platforms, as forums and blogs, where users can provide feedback and ask for help with problems is a popular approach in industry. Several companies use their employees as help-desk, as they react on inquiries by users, e.g. on a problem or new feature. The gathered user feedback from these platforms can be used to develop a specific further.

In general, in the UX/HCI-field, experiential, UCD based methods have become the prominent way of developing experiences [6]. Central to these approaches are the focus on and collaboration with end-users during the entire design process. Short sprints are used to create a quick, continuous loop of designing, prototyping and evaluating, ensuring that user feedback is gathered and incorporated in subsequent iterations. Only by working according to this procedure, active user involvement in the design process is ensured. For ”smart” products specifically, this is important as user studies in real contexts with real users are necessary to increase the validity of UX findings [6].

3.4 Towards ”Smart” Product UX

As shown in this chapter, although ”smart” products and UX independently have seen wide adoption within the HCI-field, a shared, standardized definition of both concepts is still lacking. However, there is a tension to agree among researchers and practitioners that ”smart” products are centered around the use of data, that enables specific ”smart” product abilities that are used to determine the smartness of a product, although this view is not predominant. Furthermore, although UX is still seen as a vague and fuzzy concept, the common understanding of UX among researchers and practitioners is that UX is rather subjective and context-dependent and that the nature of UX development, by focusing on user-centered design, tries to address these aspects. The insights on ”smart” products and UX presented in this chapter are used to come to a common understanding of ”smart” product UX and are discussed in the next chapter.

Chapter 4

Designing & Developing Smart Product UX

Now that the concepts of "smart" products and UX have been introduced, this chapter will converge both concepts, focusing on providing specific heuristics to guide the design and development of the UX of these products in practice. As "deep, detailed understanding of experiences that are desirable and opportune for "smart" products is necessary to guide the design of successful implementations" [6, p.385], this chapter will kickoff by elaborating on the specific nature of UX of these products, outlining how end-users perceive "smart" products, how the nature of UX is different for these products compared to other interactive products and what the influencing dimensions of "smart" product UX are. Next, challenges to the UX development process of "smart" products are outlined. Subsequently, based on the insights presented, specific heuristics for the design and development of "smart" product UX are presented.

4.1 The Experience of "Smart" Products

Before heuristics can be defined, it is important to provide understanding of how end-users perceive these products and how the nature of UX is different compared to other interactive products, shifting the focus from a technology-oriented view to deep understanding of how these systems are experienced. This is important as UX studies "need to take a broad spectrum of human experiences into account to provide guidance for design and experiments for ubicomp and similar systems due to the novel and versatile technology involved" [6, p.385].

4.1.1 The End-User Perception of "Smart" Products

With the rise of the amount of "smart" products available, interest has increased in how users perceive these products. By researching "smart" products currently available on the market, different researchers [22], [63] have studied the influences of the "smart" dimensions of these products (see 3.1.1) on the perceptions of end-users. Derived from the work of Rijsdijk & Hultink [64] the following will outline these influences, regarding the individual dimensions.

Autonomy.

The autonomy of a "smart" product increases the advantages that users perceive in this product [64], as products with higher levels of autonomy deliver savings in time and effort [65]. Products with higher levels of autonomy that take over a complex *cognitive* task from the user are also perceived as less complex. This is in contrast to *physical* tasks, as perceived complexity increases as consequence of autonomy [64]. As such, product autonomy that takes over cognitive tasks is perceived as decreasing complexity and, through that, increases the probability of product adoption. On the other hand, as with all "smart"ness dimensions, autonomy increases the risk consumers perceive [22], [64].

Adaptability.

The adaptability of a product according to the context or user's needs has its advantages in that it increases the perceived levels of compatibility and observability. A product that is adaptable is likely to better fit with users' needs, acting as one of the primary drivers of value perception and perceived emotional value [63]. However, adaptability also increases complexity and perceived risk. Alpert et al. [66] found that users of user-adaptive interface had difficulty to understand how the interface worked.

Reactivity.

Researching the use of smartphones, Park & Lee [63] found that reactivity positively influences the perceived emotional value a user has of a product. This may be different for other products though. Therefore, the art of creating reactive products appears to be to develop latent functionality that remains unnoticed as long as needed. As it becomes necessary, reactive functionality should require little user involvement. As a result, this functionality will be perceived as advantageous and not complex.

Multi-functionality.

The multi-functionality of a product increases the complexity and risk that consumers perceive. Beside the complexity that will be perceived at first, users also may perceive complexity in "smart" products in later phases of use. Due to the nature of "smart" products, most of their functionality is hidden inside a black box [67]. Many users have difficulties understanding and using these products [67]. As technology has advanced, we have understood less and less about the inner workings of the systems under our control [68]. This is partly because users don't receive feedback in the form of movements or noise when using these products. On other cases, users give up on using certain functions because their operation is too difficult [69]. However, Park & Lee [63] found that multi-functionality is one of the primary antecedents of functional and experiental utility, which may be due to the fact that they researched the use of smartphones specifically. Because of all the functions "smart"phones have, multi-functionality as primary driver of functional utility may not be that surprising. However, Rijsdijk & Hultink [22] found that there appears to be a maximum level of multi-functionality that consumers appreciate.

Ability to Cooperate.

As with all other smartness dimensions, the ability to cooperate positively influences the observability and complexity of these products. Furthermore, the ability to cooperate generally has a negative impact on compatibility and only affects relative advantage in a limited way. When users have a relatively negative attitude towards products that cooperate with other products, designers may want to clarify these cooperation and emphasize the benefits that this cooperation delivers.

Human-like Interaction.

Park & Lee [63] found that human-like interaction is positively related to the perceived emotional value of a product.

4.1.2 Separating "Smart" Product UX in the HCI-domain

Designing for experiences of "smart" products comes with a bunch of challenges due to the unique capabilities of these products and the lack of research that focuses on the subjective user experiences these products may enable. How complex these challenges are in the actual design process depends on [61]:

- The maturity of the technology involved;
- The context of use or expectations users have of the system;
- The complexity of the service (e.g. how many devices the user has to interact with).

The nature of "smart" products differs on several points from that of their non-intelligent counterparts. This means that the UX of these products is also different. There are several key distinctions between the UX of "smart" products and the UX of other digital services, as outlined below [61].

IoT is All About Data

As mentioned, "smart" products use a lot of data to learn and to make decisions. Essentially, information has become a design material. Designers have to take this in mind when designing intelligent products, so that it is clear for users what data is collected for what purpose. Aspects as security and privacy are key to this. As shown earlier, the use of data sets "smart" products apart from their Web-based counterparts and may be seen as one of the most important aspects of the UX of "smart" products. All of the following distinctions emerge from this data usage.

Functionality may be distributed across multiple devices.

"Smart" products come in a variety of different devices, all with their own characteristics. Some of these devices may use screens to interact with a user, others may use only a blinking LED to communicate or some may have no input or output capabilities at all. Interactions can also be handled by separate "smart"phone apps. For users, it is important that they need to feel as if they are using a coherent service, rather than a set of separated user interfaces (UI) of different devices. Therefore, for designers it is important to consider not just the usability of each separate UI but the *inter-usability*: distributed user experiences across multiple devices.

The focus of the UX may be in the service.

When discussing "smart" products, the focus is often on the device itself. However, the behavior of the device might be generated by a program that lives on another device, e.g. on a server where a dedicated agent is running [70]. This means that the service around a "smart", connected product is often as critical in delivering the UX, if not more so, than the device itself. For example, an iPhone comes with a bunch of service-oriented apps for cloud-storage and music, book and film subscription/storage. The services these apps provide are important influencers of the overall UX of the iPhone itself.

We don't expect Internet-like glitches in the real world.

It is frustrating when a webpage on a computer loads very slowly or fails to load at all. However, users accept these frustrations because they are part of the nature of the Internet. By contrast, objects presented in the real-world often respond immediately and reliably. When interacting with a "smart" product over the Internet, e.g. interacting with a "smart" thermostat at home from the office, this interaction is subject to the same latency and reliability issues as any other Web-based interaction. This could make the real world start to feel broken: imagine turning on the lights and having to wait for a few minutes before they respond.

"Smart" products are largely asynchronous.

When users interact with desktops, "smart"phones and tablets they tend to assume that they all have constant connectivity. User expect that an interaction on one device transfers smoothly into an interaction on another device. For example, if they delete an e-mail on their smartphone, they expect that that same e-mail is deleted on their tablet as well. However, this same flow will not always occur in IoT systems. One characteristic of a "smart" product is that it is connected to the Internet. However, this networking consumes a lot of power. Therefore most of these devices only connect intermittently, which means that parts of the system may be out of sync with one another, creating a discontinued UX. For example, when raising the indoor temperature from a mobile application, it can take several minutes for a "smart" thermostat to go online and check for new instructions. This discontinuities won't always be noticed though, as sometimes the delays are very short or the user won't notice the delay at all because it turns its attention to something else. So, the UX may feel synchronous, even it isn't sometimes. This may not form always a problem but when a user does notice a delay, the UX may feel incoherent.

Devices are distributed in the real world.

The shift from desktop to mobile computing means that computers are used in a wide variety of contexts. Consequentially, mobile design requires a greater emphasis on understanding the user's needs in particular contexts of use. Because computing is embedded in more and more objects and environments, the social and physical contexts in which these devices can be used are more complex and varied.

Remote control and Automation are programming-like activities.

As discussed in section 3.1.2, one characteristic that sets a "smart" product apart from its non-intelligent counterpart is the way data-entry is handled. Web-based products or other products that use screens, often use a user-interface based on the principle of *direct manipulation* Direct manipulation depends on visual representation of objects and actions of interest, physical actions or pointing instead of complex syntax, and rapid incremental reversible operations whose effect on the object of interest is immediately visible [71]. This strategy can lead to user interfaces that are comprehensible, predictable and controllable [71]. Ever since, the use of direct manipulation has been the prevailing trend in UX design. Direct manipulation is so successful because interface actions are aligned with the user's understanding of the task, as they receive immediate feedback on the consequences of their actions. In contrast, "smart" products create the potential for interactions that are misplaced in time and space: configuring things to happen in the future, or remotely. For example, a user may set up a home automation rule to cool down the house, enable the security camera and raise the alarm when a motion sensor detects that the house is unoccupied. Or a user may set up a rule that his car will heat automatically the next morning, based on the weather conditions. These examples both break the principles of direct manipulation, as a user needs to anticipate on its future expectations and needs and need to translate them in a set of logical actions. This is basically programming [72]. This doesn't have to be a bad thing, but it may be inappropriate for some users as it impacts overall usability and accessibility.

Complex services can have many users, multiple UI's, many devices, many rules and many applications.

Although a simple IoT service may consist of just two devices communicating with each other, the connected nature of these products enables them to act in a much bigger IoT-environment. This adds more ways to coordinate with one another. For example, a user may set up his alarm system to go off when a motion sensor and security camera detect presence in the house. To frighten the intruder, the user may set up the lightning system in his house in such a way that all lights will turn on when the alarm system goes off. Or, a user may connect the house's heating system to the alarm system so it uses information from the motion sensor and security camera to know if the house is empty and can be pre-heated. However, if the family consists of four people, who are not intruders obviously, the user has to set up a rule that the motion sensor and security camera won't trigger the alarm system when their presence is detected. To add more complexity to the puzzle, all these devices have their own user-interfaces, with their own options and own configurations. What started as a straightforward system and user goal has become a complex web of interrelationships. For a user, understanding all the different devices and their role in the overall system will become more and more complex when more devices and services are added.

As shown, "smart" product UX differs significantly from the UX of other interactive, Web-based products. This brings new challenges for designers when designing for "smart" product UX. However, these are not the only aspects they have to take into account. The next section will introduce some additional aspects related to the unique nature of "smart" product UX and will provide a general outline for this UX.

4.1.3 The Influencers of ”Smart” Product UX

This section provides a general outline for the UX of ”smart” products by elaborating on the UX dimensions mentioned in section 3.1.3. This section provides details concerning the UX of these products regarding the Intention and Context of Use and specific aspects of UX and Interaction Design (IxD) that originate from the system characteristics and unique capabilities of ”smart” products. Consequentially, specific heuristics will be presented for the UX design of ”smart” products.

User's Internal State

As mentioned in section 3.1.3, many aspects of the internal state of a user are highly subjective. Aspects as the user's expectations, moods, emotions and prior knowledge are dynamic factors of the interplay between the user's personality, the product itself and the context of use. Based on the capabilities of ”smart” products, the uniqueness of the UX of these products and its perception by end-users, the following Intentions of Use of ”smart” products, as a consequence of the user's internal state, can be distinguished.

1. **Efficiency** of user's resources. Not only can ”smart” products facilitate in a more efficient use of energy (e.g. ”smart” thermostats), these products also deliver savings in time and effort of users due to their multifunctional and autonomic nature. Consequentially, users have more time to do other things in their lives;

2. **Empowerment.** ”smart” products could allow for types of user experiences that cannot be reached with other types of systems [6] and enable users to do things they thought were never possible. For example, they can facilitate in the cure of loneliness among elderly or help children to learn a language (e.g. by social robots);

3. **Convenience and Comfort.** Due to the autonomous and adaptable nature of ”smart” products they can take over routine tasks, increasing convenience and comfort. An experience can be transferred easily from one device to another (e.g. controlling a ”smart” thermostat with a ”smart”phone from a remote location). ”smart” products are able to adapt to user activities, e.g. changing the colour of the lights and are able to take over complex cognitive tasks, enabling more convenient and comfortable user experiences;

4. **Security and Safety** of the user can be enhanced due to the monitoring and surveillance capabilities of ”smart” products. A camera and motion sensor for example can monitor a user's house constantly for abnormal activity. This enables a more secure and safe feeling of the user.

It is important to note that users' needs as well as the purposes of ”smart” products can converge with multiple intentions of use, mentioned above. For example, a ”smart” door lock, enabling security and safety, also brings a more convenient and comfortable experience, as a user can use a ”smart”phone to check the status of these locks at any time from any place. On the other hand, the intentions of use are highly subjective. The routine of a task is highly dependent on the kind of user. This should be considered when designing for ”smart” product UX.

Context of Use

As mentioned earlier, the context of use forms an important aspect of the overall experience of a ”smart” product. This context is not always fixed, as it can transfer between users, devices and applications and may be used in all kinds of different contexts (e.g. smartphones). Borrowed from research of predecessors [29], [49], the following contextual dimensions are distinguished.

1. **Physical** context, referring to everything a person can see or feel. For example, variables as location, physical surroundings, temperature and humidity form important aspects of the working of a ”smart” thermostat, and therefore of the whole user experience;

2. **Social** context, referring to the expectations and influences other people have on the user and/or the willingness of the user to participate in a social situation, creates challenges for the behavior of ”smart” products. For example, the desired temperature in a room should consider all persons present. Additionally, certain actions of a system may be desirable by one person but may not be desirable when there are other people around, e.g. the use of speech when interacting with a virtual agent;

3. **Temporal** context, referring to the time period that the user is able to dedicate for the system given the context restrictions, can influence the way a system reacts to a user. For example, displaying the current status of a user’s fitness goals on a ”smart”watch may be desired during a run but would be highly inappropriate when in a business meeting;

4. **Technological** context, referred to as the infrastructure of other devices around, should be incorporated in the design of the system when appropriate. For example, the use of multiple devices should be considered when determining the location of a user or its activities. For example, video playback on a smartwatch should be ideally transferred to a smartphone or TV screen when present, due to their bigger screen sizes, to achieve the best possible experience;

5. **Task-specific** context, referred to as the role of the system in the higher-goal the user has in a use case, is an important aspect as well. A sub-task performed by a user can have a big impact on how a ”smart” product should react/interact. For example, a user may get a telephone call in his car from a client that wants to set up an appointment. The user then triggers his virtual assistant, using speech, to set up the meeting. When prompted to set up an appointment, the system should know that the next step should be on what date and time the meeting should take place. Hence the context of a specific task may differ widely between tasks. A system should know how to react and interact in each specific context to provide the best experience possible.

As for intentions of use, the context of use of a system is a mix of the dimensions mentioned above and can never be seen in an isolated way.

System Characteristics

The third dimension of UX [26] is the characteristics of the system involved. As ”smart” products can take many forms, these characteristics can barely be generalized. However, as outlined earlier, general characteristics of IoT systems exist. The specific characteristics of the system developed could influence the overall UX by providing means for specific ”smart” features. For example, a motion sensor on a ”smart” alarm system enables the device to detect presence in a house and thereby can notify a user when an intruder is detected.

As shown above, several aspects of the intentions of use, contexts of use and system characteristics of ”smart” products should be taken into account when developing for ”smart” product UX. Furthermore, the UX development of ”smart” products itself also comes with some unique challenges, which are discussed below.

4.2 Developing ”Smart” Product UX

As mentioned earlier, UCD methods as Lean, Agile or Scrum offer an attractive way to manage the inherent risk of loosing the link to the user in the design processes of ”smart” products [73]. However the unique requirements of these products (such as embracing the contextual changes, implicit interaction and localized scalability) make the existing approaches in UCD inappropriate for ”smart” product systems [57]. A major problem in UCD is how to determine the desired functions and technical features, which would bring new challenges in designing pervasive applications [57]. The heterogeneous and dynamic contexts wherein ”smart” products (inter)act makes it challenging to generate and predict scenario’s and potential problems. Furthermore, as UX is highly subjective [35], the prediction of users’ behaviour within these contexts is difficult as well [57]. These are not the only challenges to the UX development of ”smart” product systems. The following will outline other challenges to the development process of ”smart” product UX.

Confusion in user analysis

In UCD, understanding the users’ individual characters and situations are important tasks, but become a major concern for the design of ”smart” products because the diversity of situations will put varying constraints on the applications, leading to different choices among design means [57]. Development of interactive products usually considered a simple application environment with fixed hardware and straightforward interaction, but this situation is very different for ”smart” products. Due to the attachment of the computation to the user itself or to the surroundings, the application environment becomes complex consisting of uneven hardware, software and human factors, that all have different attributes. Hence it is necessary to combine such complex and dynamic users’ contexts in user analysis in order to design an adaptation strategy [57].

Challenging tasks analysis

In UCD, task analysis is focused on determining the tasks involved in the problems addressed. However, the analysis of tasks in the ”smart” product environment is challenging, as sensing, decision-making, actuation, computation, networking and physical processes are mixed and all function in a context-aware manner (see 4.1.3). As mentioned earlier, ”smart” products are more focused on the context of use, interacting with physical processes within the environment. Although it is essential to analyze these processes, they are often uncertain, uncontrolled and unpredictable within the ”smart” product environment. So, describing the relations between the computation and physical processes for refining the task analysis is still very challenging [57].

User Intent vs. Implicit Interaction

One of the paradigmatic changes of ”smart” products within the domain of interactive products is their shift towards implicit, rather than explicit, interaction [4] (see 4.3.2). In order to make these implicit interactions effective, it is crucial to trace the user's intent for an application, since it is essential to determine which actions of the system would help, rather than distract or disturb the user [57]. This all depends on what the user is trying to achieve. The need to capture the user intent generates a number of new design issues for ”smart” products and brings a greater demand for novel design approaches and technologies. Without a careful design, an application would distract or disturb the user and defeat the goal of invisibility [74].

Rapid Prototyping of Applications

In UCD development methods as Agile or Scrum, rapid prototyping is one of the key principles. Although rapid prototypes can provide the effective means for identifying and tackling core design problems, it is still a critical task to choose the right kind of prototypes to serve a particular purpose in the ”smart” product environment. The implicit input and variety of contexts of these products must be considered in the creation of an appropriate prototype [57].

Long-term, context-dependent evaluations

”smart” products are mostly designed to support one's everyday activities. A good design of these products only has meaning when testing it with real users in their everyday lives during extended periods of time [6], [75]. Although evaluations based on user models to stimulate user tests of ”smart” product systems will take less time and cost to recruit participants and have better control on learning effects, realistic testing environments are essential to transfer the laboratory prototypes into real-world experiments [57]. Situ evaluations, product evaluations in the real context of use, can reduce the number of iterations by helping developers making a better design from a direct observation of users [76].

4.3 Heuristics for ”Smart” Product UX

Based on the insights presented in the previous sections, this section will outline specific heuristics for the UX, IxD and UX development of ”smart” products.

4.3.1 User Experience Heuristics

As mentioned earlier, the UX for ”smart” products differs from that of stand-alone, digital products/services. Based on the described UX of ”smart” products and the work from predecessors, the unique nature of ”smart” product UX:

- [UX.1] **Is dynamic and distributed.** The interaction in an IoT environment can occur over many different users, devices, rules, applications and UI's. Also the functionality can be distributed among devices, which can also be added dynamically to the system at a later time.

- [UX.2] **Depends more on the Context of Use.** In contrast to the UX of other interactive, Web-based products, the context of use of ”smart” products is more dynamic, diverse and complex [57], [60], [61].

- [UX.3] **Can be discontinued.** As the functionality within an IoT environment can transfer from one device to another, drops in connectivity may cause a discontinued UX between those devices, creating a asynchronous and incoherent experience [61].

- [UX.4] **Can be cognitively demanding.** As an IoT environment can consist of many devices, users and applications, connecting and setting up these devices to work together may feel like a complex and cognitive demanding task for the user. Furthermore, the lack of a form of direct manipulation may cause a higher cognitive load when interacting with a ”smart” product system [61].

- [UX.5] **Relies heavily on data.** The functionality of a ”smart” product heavily relies on the amount of data it is able to process. Beside the use of sensors, the data of users of these products are key to providing the most functionality and the best user experience. Furthermore, this can have consequences for topics as security and privacy [61].

- [UX.6] **Can be unpredictable and unforeseen.** As ”smart” products heavily depend on the context of use, preferences or rules set by other users or devices may cause a surprising and unforeseen experience.

4.3.2 Interaction Design Heuristics

The UX heuristics presented also touch the domain of IxD. Incorporating relevant aspects of IxD is important because to come to good understanding of the UX of ”smart” products, aspects affecting UX such as relevant aesthetic and interaction design principles should be linked to the design process [6]. In general, two different kinds of interactions can be distinguished in the domain of ”smart” products: implicit and explicit interactions [3], [61], [77]–[79]. First, a general list of IxD heuristics that are important to consider when designing ”smart” products is presented. Subsequently, the implicit and explicit interactions of these products will be explained and outlined in more detail. Emerging from the unique nature of "smart" product UX as mentioned above, the interaction with a "smart" product in general should:

- [IxD.1] **Consider the inter-usability between devices.** As the functionality within an IoT environment may be distributed among multiple "smart" products, the overall interaction flow should consider the possibility of different kind of interactions of multiple devices
- [IxD.2] **Consider all contexts of use.** As "smart" products can be used in a wide variety of different contexts, functionality and interaction should consider all contexts of use. Different modalities of interaction are preferred in different kinds of contexts
- [IxD.3] **Be available when disconnected.** As "smart" products may lose their network connection, at least a part of the interaction should remain available.
- [IxD.4] **Be transparent and clear to the user.** The process and state of interaction should always be clear to the user so it knows what is happening and what a next step could be. Because "smart" products rely on new kinds of interactions (e.g. speech), the absence of visual feedback and direct manipulation makes a transparent and clear interaction more challenging.
- [IxD.5] **Consider discontinuity in the interaction.** Not all "smart" products are online all the time and the transfer of one device to another may cause a discontinued interaction flow. This flow needs to remain stable.
- [IxD.6] **Consider differences in users' interests and preferences.** As the use of "smart" products can be distributed among different users with different interests, rules and preferences, the device should know and make clear what kind of interests, rules and preferences belong to what user, e.g. by the use of user-profiles.
- [IxD.7] **Consider security and privacy in the interaction.** "smart" products heavily rely on data. The use of this data has consequences on the security and safety of users. These products should consider the use of this data in an ethical way in general and within the interaction.

Explicit Interactions

In explicit interaction, the user tells a device in a certain level of abstraction (e.g. UI, speech or gesture input) what he/she expects the device to do [78]. Thus, it is based on the direct intention of the user to manipulate the system. Examples are the use of a keyboard and mouse when interacting with a computer, the touchscreen of a "smart"phone or speech-interfaces. Derived from the general system characteristics and the UX and IxD aspects of "smart" products, the explicit interactions with a "smart" product specifically should:

- [IxD.Ex.1] **Consider the context of use.** Although the concept of "smart" products "promises to transform the way we interact with everyday things" [5, p.25] the form of interaction chosen should be meaningful within the context of use. The use of speech within a car may be desirable as it is safer than the use of physical buttons or touchscreens. On the other hand, the use of speech may be less meaningful within contexts with more people involved.

- [IxD.Ex.2] **Be appropriate for the technology used.** "smart" products can use many forms of technology as base for interaction. The technologies chosen should suit the ways of interaction desired. For example, the use of speech may be inappropriate as primary form of interaction when the device is equipped with a display and physical buttons.

- [IxD.Ex.3] **Be straightforward and clear.** The interaction with a "smart" product should be straightforward and clear. It should be clear for the user when to use what mode of interaction (e.g. when speech, when UI) when interacting with a device. Furthermore, it should be straightforward what form of interaction should be used primarily. For example, the interaction with a "smart"phone is straightforward due to the presence of a big screen and the interaction with a voice-controlled virtual assistant is clear due to the absence of a screen.

- [IxD.Ex.4] **Not be cognitively demanding.** As mentioned, the use of "smart" products can be distributed among different devices with different forms of interaction. The interaction itself should be clear and not cognitively demanding. Struggling with what to say when using a speech-interface is undesired and may deliver a negative UX. For example, most speech-interfaces in cars today use standardized phrases to provoke certain functionalities. To trigger these functionalities, the user *has* to use these exact phrases. It may be very cognitively demanding for users to remember these exact phrases.

Implicit Interactions

Implicit interactions are actions performed by the user that are not primarily aimed at interacting with a system but what such a system uses as input [78], as the change of location or certain behavior. Implicit interactions are one of the paradigmatic changes "smart" products bring [4]. These kind of interactions are mostly used by context-aware-systems as "smart" thermostats, security systems and cars, but also by stand-alone applications on smartphones, usually enabled by sensors. Implicit interactions with a "smart" product specifically should:

- [IxD.Ix.1] **Consider the entire context of use.** As mentioned, the nature of implicit interactions relies on the context of use of user and system. To deliver the best experience, all contextual dimensions (see section 4.1.3) should be considered by the system to appropriately interpret the context.

- [IxD.Ix.2] **Provide a feeling of control.** The nature of implicit interactions is that users are basically out of the loop of the interaction. However, to provide them a feeling of control the system should communicate what is happening and why or this should be easily to find out by the user.

- [IxD.Ix.3] **Be clear about data-use.** As context-aware products heavily rely on gathered data from the specific context, it should be clear for the user what data is used and where it is stored. It should also be easy for the user to delete this data and, consequentially, an overview of broken functionality should be given.

- [IxD.Ix.4] **Not distract or disturb.** The everyday actions and behavior of users should not be disturbed or distracted by the system due to the gathering of data or the monitoring of the context.

4.3.3 UX Development Heuristics

Based on the challenges on the UX development of "smart" products and the analysis of UX prototyping and evaluation mentioned in 3.3.2 and 3.3.3, the guidelines for the UX development process of "smart" products are:

- [Dev.1] **Work in rapid development cycles.** As the evaluation of user intent and their understanding of the system(interaction) are key to the development of "smart" products, designers should work in rapid, continuous development cycles of designing, prototyping and evaluating, similar to the approaches of Agile and Scrum.

- [Dev.2] **Involve real end-users in the development process.** In the process of designing, prototyping and evaluating, end-users should be involved early and during the entire design process to assure that users' requirements are met and they have sufficient understanding of system(interaction) [6].

- [Dev.3] **Prototype in real contexts-of-use.** As the context-of-use is key to the actual use of a "smart" product, prototyping should be done in real contexts-of-use to capture the users' intent in specific environments and validate UX findings [6].

- [Dev.4] **Use lightweight prototyping and evaluation methods.** Not every method of prototyping and evaluation is preferred when developing "smart" products. Actionable and lightweight techniques to elicit qualitative experience feedback from end users are needed [6]. Low-fidelity prototypes as collages or scenario's may be suitable in early stages of the design process as ideation and concept generation and techniques as wireframing can be used to design and develop the individual UX of components of a "smart" product.

- [Dev.5] **User studies should focus on the intention of use.** Due to their nature, interacting with "smart" products can be complex and may differ between contexts. By focusing on the intentions of users when they are interacting with product, insights in overall product use and interaction can be gained.

- [Dev.6] **Prototype only components of the "smart" product.** The interaction between different components of a "smart" product and its interoperability with other devices in the environment, can complicate the user's understanding of a specific function. To measure the specific, subjective UX of one of its features or design elements, designers should only prototype a specific component of the "smart" product to be able to gain insights on its specific UX.

- [Dev.7] **Direct observation in user-studies.** When studying users in prototype evaluation, designers should use direct observation to gain insights in product use, understanding and interaction. Situ evaluations can reduce the number of iterations by helping developers making a better design from a direct observation [76].

Chapter 5

A User Experience Framework

The heuristics on UX design and development and IxD presented in the previous chapter serve as a guideline for designers in the HCI-field to consider when designing and developing for ”smart” product UX. Because these heuristics are still quite distributed and therefore challenging to grasp, this chapter presents a practical and hands-on framework for designers to use in the field.

UX & IxD Design:	
UX.1	**The UX is dynamic and distributed.**
- IxD.1	The interaction should consider the inter-usability between devices.
UX.2	**The UX depends more on the Context of Use.**
- IxD.2	The interaction should consider all contexts of use: • Physical; • Social; • Temporal; • Technological; • Task-specific.
- *IxD.Ex.1*	The explicit interactions should be appropriate for the context of use.
- *IxD.Ix.1*	The implicit interactions consider the entire context of use.
UX.3	**The UX can be discontinued.**
- IxD.3	The interaction should be available when disconnected.
- IxD.5	The interaction should consider discontinuity in the interaction.
UX.4	**The UX can be cognitively demanding.**
- IxD.4	The interaction should be transparent and clear to the user.
- *IxD.Ex.3*	The explicit interactions should be straightforward and clear.
- *IxD.Ex.4*	The explicit interactions should not be cognitively demanding.

- *IxD.Ix.2*	The implicit interactions should provide a feeling of control.
UX.5	**The UX relies heavily on data.**
- IxD.6	The interaction should consider differences in users' interests and preferences.
- IxD.7	The interaction should consider security and privacy in the interaction.
- *IxD.Ix.3*	The implicit interactions should be clear about data-use.
UX.6	**The UX can be unpredictable and unforeseen.**
- IxD.4	The interaction should be transparent and clear to the user.
- *IxD.Ix.4*	The implicit interactions should not distract or disturb.
UX Development:	
Dev.1	**Work in rapid development cycles.**
Dev.2	**Involve real end-users in the development process.**
Dev.3	**Prototype in real contexts-of-use.**
Dev.4	**Use lightweight prototyping and evaluation methods.**
Dev.5	**User studies should focus on the intention of use.**
Dev.6	**Prototype only components of the "smart" product.**
Dev.7	**Direct observation in user-studies is preferred.**

Table 5.1: UX Framework for the Design & Development of "smart" Products

Chapter 6

Evaluation of the UX Framework

To increase the validity of UX findings of "smart" products found, user studies in real contexts-of-use [76] with real users are necessary [6], [75]. Therefore, the UX framework presented is used as a base for a dummy project. This chapter will outline the process of this project and its outcomes.

6.1 Dummy Project

Together with the "User Experience Concept Center" (UXCC) of Volvo Cars Corporation in Copenhagen, the UX framework developed was used as a base for a dummy project. In this project, a surrogate "smart" product system, within the in-car environment, was designed, developed and evaluated using the UX framework together with real end-users in real contexts-of-use. By using the UX framework in a dummy project, the practicality of this framework for the design and development of UX of "smart" product systems could be tested and evaluated in practice. This section will outline the design of the project and its outcomes, by elaborating on the project goals, methodology and insights gathered from the project itself.

6.1.1 Project Goals

As "to understand how well the system enables the experience goals and what its experiential facets in the overall system quality are, the developed system should be evaluated against the experience targets" [6, p.398]. Only by evaluating the system, deep understanding of the experiential qualities of the system can be formed. Such understanding will support the further development of the system [6]. Main goal of this project was to evaluate the UX framework purposed in practice. Thus, if the UX framework is suitable to guide the UX design and development of "smart" products in practice. Consequentially, this goal was broken down in several sub-goals:

1. [**PRQ.1**] Is the UX framework of value for practitioners within the HCI-field??
    - [**PRQ.1.1**] → [**UX.1 - UX.6, IxD.1 - IxD.7**] Are the UX and IxD heuristics provided in the framework sufficient to guide the UX design process of "smart" products in practice?
    - [**PRQ.1.2**] → [**Dev.1 - Dev.7**] Are the UX development heuristics provided in the framework practical and valuable for practitioners to guide the UX development of "smart" products?
    - [**PRQ.1.3**] Are there any additional insights that are important for the UX design and development of "smart" products in practice that are not mentioned in the UX framework provided?

6.1.2 Methodology

In the UX/HCI-field, experiential, UCD based methods have become the prominent way of developing experiences [6]. Central to these approaches is the focus on and collaboration with end-users during the entire design process. The involvement of real end-users in "smart" product UX processes in particular is of importance as user studies in real contexts with real users are necessary to increase the validity of UX findings [6]. In this project, the UCD approach (see 3.3) to UX development and the unique challenges to this approach for "smart" products (see 4.2) were used, ending up with a loop of short sprints of designing, prototyping and evaluating.

Together with real end-users a "smart" navigation system was designed based on the current navigation system available in Volvo cars today (XC90, V90 & S90 specifically). This system is called "Sensus Navigation". The design and development of this system, on the basis of the UX framework provided, consisted of several phases as outlined below.

Phase 0: Explanation

The working of the UX framework and the heuristics specifically were presented to the other two designers contributing in this project.

Phase 1: Ideation

Based on the smartness abilities of the Sensus Navigation System and the future modalities of this system (as automation, prediction and human-like interaction) low-fidelity prototypes were created to set out the specific functions and UX the system had to possess. First, a group discussion was conducted to start the ideation phase (Act.1.1), elaborating on the current functions of Sensus and its level of "smart"ness, based on the abilities of "smart" products as defined by [22]. Next, a brainstorm session about the future "smart" functions of the Sensus navigation system was conducted (Act.1.2). Based on the current functions of Sensus and its future functions collected in the brainstorm sessions, scenario's were written (Act 1.3). Scenario's tell a short story about people, situations, and how products introduced into that situation change people's experiences [60]. The goal of writing scenario's was to create a detailed story of the UX, by focusing on people, time, space, objects and context [60]. Scenario's enable designers to understand everyday practices of users [57], share understanding with them and mediate concept experiences to clients and end-users [60]. To conclude the ideation phase, specific UX goals for the system were formulated (Act.1.4), based on the scenario's written and the UX heuristics provided in the UX framework.

Phase 2: Concept Generation

Based on the scenario's and UX goals created, specific storyboards were made (Act.2.1). Storyboards elaborate on the created scenario's, visualizing sequences and transitions in interactions by the use of images of people, objects and environments, and diagrams and symbols [61]. Next, when the specific ideas and functions of the "smart" Sensus system and how these interact were outlined, the individual components of the Sensus System were prototyped (Act.2.2). Using low-fidelity prototyping techniques as wireframing, specific components of the functions and interactions of the "smart" Sensus System were evaluated. An example was the inter-operability between a "smart"phone and the "smart" Sensus System. Specific questions for users were formulated to guide the evaluation with real end-users (Act.2.3), focusing specifically on the intention of use.

Phase 3: Evaluation

After the prototypes were made, they were evaluated with employees from UXCC and students from the universities of Aarhus and Twente (Act.3.1). These evaluations were conducted using the Wizard-of-Oz technique. This technique is commonly used within the automotive research community for the design and study of automotive user interfaces and related interaction-models [see 80]–[85]. As direct observation is key to the evaluation of "smart" products, the usage of the Wizard-of-Oz technique was very suitable for his particular project.

The steps mentioned above were conducted in short sprints of designing, prototyping and evaluating together with real end-users in real contexts-of-use. During the project, all three designers involved were asked to write down any relevant reflections on the working of the framework or on the heuristics specifically. At the end of the project, all information was gathered to be able to evaluate on the working of the UX framework in practice.

6.1.3 Project Summary

This section will provide a summary of the project conducted, breaking it down in specific descriptions of each phase of the project process (explanation, ideation, concept generation and evaluation) and their corresponding conducted actions.

Phase 0: Explanation

Before the project was started, I gave a short presentation about the UX framework and the specific heuristics to the team-members.

Phase 1: Ideation

The following will outline the activities conducted in this phase.

Act.1.1: Examining current functions of Sensus Navigation

A short examination of the current Sensus Navigation system features and workings was conducted. Afterwards, these functions were compared to the smartness abilities as defined by Rijsdijk & Hultink [22] to determine the smartness of the current Sensus system:

- **Adaptability.** The current Sensus Navigation system is not really adaptable in a sense that it doesn't learn and improve its own functionality. Although the system presents the user with environmental conditions as traffic jams and roadwork on the map, it doesn't adapt to these conditions pro-actively; still requiring the user to notice and act on these presented conditions.

- **Autonomy.** The Sensus Navigation system doesn't provide any form of autonomy, requiring the user in every step of the interaction.

- **Cooperation.** The Sensus Navigation system does work together with Volvo On Call (VOC). VOC is a telematics service system that provides Volvo car users with several services [86]. Concerning navigation particularly, users can use the VOC "smart"phone app to send a destination or route to the navigation system in the car, so it will be presented the next time they enter the car. Furthermore, the Sensus Navigation system uses Volvo's servers to check for traffic information, presenting users with this information accordingly.

- **Human-like Interaction.** Users of the Sensus Navigation system are able to prompt the system using voice commands. For example, users can stop or start navigation. Although speech is a mean of human-like interaction, the Sensus Navigation system is only capable of reacting on pre-defined queries. This mean that the conversation between car and user is not very human-like, although using speech.

- **Multi-functionality.** The Sensus Navigation system has multiple functions that can be used. Examples are finding the current location on the map, searching for a destination, changing the route etc.

- **Personality.** The Sensus Navigation system doesn't show any characteristics of a human-like character with a specific personality.

- **Reactivity.** Sensus Navigation is not able to react to environmental conditions by itself. Although it prompts users, for example when there is a traffic jam on their way, it doesn't suggest a new route or changes the route by itself.

Based on the smartness abilities of Sensus Navigation, one can conclude that it is an information-oriented product [87] focused solely on information handling and problem notification [23], [24], leaving decision-making processes out of scope [23], [24]. Furthermore, the small amount of intelligence of Sensus Navigation is not located in the car itself but is supplied by external servers outside the physical object, e.g. VOC and traffic information. Therefore, the intelligence of Sensus Navigation is supplied through network, rather than located at the object [88].

Act.1.2: Brainstorming about future functions of Sensus navigation

Based on the lacking smartness of the current Sensus navigation system, a brainstorm session was conducted to examine future "smart" functions of this system, to enhance the overall UX:

- Prediction of user destinations, based on data gathered;

- Support human-like interaction, through the use of speech in a contextual way (physical, social, temporal, technological and task-specific);

- Connect with third-party suppliers to provide additional information and services (e.g. the prices of gas or the availability of parking spots);

- Surprise the user by presenting unknown places and destinations that could be of interest to the user (based on data about user preferences);
- React to the environment by avoiding traffic jams and present the user with the best time to go to a certain destination (e.g. it is usually pretty crowded in the supermarket at 3 pm.);
- Adapt to the media needs of users. Especially when the car is driving itself, a user may prefer a longer route to be able to watch an entire video, listen to an entire album etc.

Act.1.3: Writing scenario's based on current and future functions of Sensus Navigation.

Before the actual scenario's were written, a session was conducted with all team-members to define and distinguish the nature of the different scenario's. As the scope of the project was to develop a future Sensus navigation system, the possibility of autonomous driving by the car on highways was incorporated. Based on the current and future functions of the Sensus system and insights on the spending of time by end-users when in autonomous driving mode provided by Volvo, the following scenario's were distinguished:

- **The Daily Commute** This scenario was based on the normal, daily commute of a user when driving from home to work. Important aspects of this scenario were time-efficiency, relaxation during the trip, getting things done in the real-world (e.g. making shopping lists, planning activities during the day) and media/audio consumption;
- **The Solo Leisure** This scenario was based on activities conducted by users in their free-time. Important aspect of this scenario was the car as a "get-away" vehicle, that would facilitate in the planning of user activities in the real-world during their free-time (hobbies), enabling a more engaging driving experience, as the focus was not on the optimization of time. Furthermore, the social/sharing aspects was important in this scenario, were users would be able to gather to conduct certain activities together (e.g. sports);
- **The Family Trip** This scenario was based on the family going out together, for a small break or holiday. Important aspect of this scenario was the ability to explore, were the car would facilitate in the trip-planning of the holiday based on the individual preferences of all family members, optimizing time, book hotels or restaurants and informing the family about interesting places to visit.

Before writing the scenario's, three different phases in the interaction between car and user during the scenario's mentioned above were distinguished: (i) pre-entering the car, (ii) the commute and (iii) leaving the car. The following will present three different scenario's for the daily commute, solo leisure and family trip.

The Daily Commute

John is on the road often as he is an outside consultant. He visits clients of the company he is working for every day, travelling across the country. On Monday morning, John receives a "smart"phone notification that there is some traffic on the way to his first appointment and has to leave in 10 minutes to be on time. As John wants to travel comfortably, he set the system so he will always arrive 30 minutes early at his destination. John packs his stuff and gets a new notification: the traffic situation has become worse, time to go! John leaves the house and enters his car. When starting the car, the navigation system shows a prediction of the destination of the first meeting. John acknowledges that that is the place he wants to go by a simple tap and the navigation shows the different routes John could take. As John will join a business conversation in the car that will lasts about 30 minutes, the navigation system suggests that he will take a longer route to be able to attend the full meeting. John acknowledges that he wants to take this route by a simple tap and the system starts navigating.
John is on his way to work. Unfortunately, the traffic situation has become worse. The navigation system prompts John with a notification that this is the case, and asks John if he wants to take another route. By simply tapping this notification, John acknowledges that he wants to take another route. The navigation system starts calculating and changes the route.
Finally, John is close to his destination. John usually parks his car at the same parking place. However, the navigation system prompts that there are no parking spots available anymore and asks John if he wants the system to change the route to another parking place nearby. John acknowledges the system to do so. The system changes the route to the parking place. John arrives at the parking place and parks his car. As this parking place is in another neighbourhood where John is not familiar, the navigation system asks if John want to receive turn-by-turn walking directions on his phone for the last kilometres he needs to walk. John tells the system he wants to receive this instructions with a simple tap. He leaves the car, takes his phone out of his pocket and a notification on his phone is already up. John taps the notification and the system provides him with turn-by-turn walking instructions.

The Solo Leisure

Sarah is a 29-year old girl who likes to play sports during the weekend. As she is living quite close to the coast, Sarah loves to surf when there are high waves. It is Friday evening and Sarah doesn't have any plans for Saturday yet. On Saturday-morning, Sarah receives a notification on her "smart"phone. It is an invitation of her friend Linda to go surfing this afternoon. Sarah confirms the invitation and this information is shared with the Volvo on Call app. In the afternoon, Sarah receives a notification on her "smart"phone that it is time to go. She enters the car and is presented with the route on the center display. Sarah starts the car and starts driving. After some minutes, notification comes up on the center display of the car. John wants to join the surfing trip. That's cool! As John doesn't have a car he needs to be picked up. The car asks Sarah if she wants to pick up John, which will cost her 5 minutes extra. Sarah confirms that she wants to do so and John pops up on the map and the navigation changes the route.

The Family Trip

The family Johnson, consisting of man and wife and two children, has a week off and wants to make a family trip together. They're planning to go to a part of the country they have never been to. On an evening, the family gathers together on the couch and explore the different destinations they can visit on their trip. When agreed on these destinations, they use a tablet to let Google Maps calculate a route with all the preferred destinations. As this family has an electric car, range is an important factor of their trip. As the tablet is connected to the car, Google Maps asks if it is allowed to use this information. The family allows the tablet to do so and information about the battery capacity of the car is shared with Google Maps. Google Maps asks the family how many people will join the trip and uses weather information from the internet, all to calculate the necessary stops within the trip where the family needs to re-charge the car. When the trip is ready and the family evaluated the trip they use the "Send to Car" button in the application.
As the trip is not for today but will be conducted in a few weeks, the system knows that it doesn't have to bring up the route the next time someone enters the car. Instead it uses the time, GPS location and information from the seat sensors to determine when the family is set up to leave for the family trip, showing the route on the system and asking if they want to start the route. The family acknowledges they're ready t start the trip and the system starts navigating. As the night falls, and the family is still driving around, it is time for dinner. As the surrounding is not known to the family, they decide to ask the navigation system for a suggestion. As the family loves Italian food, and the Sensus navigation system knows that, they decide to go with that option. The dad taps the speech button on the steering wheel and asks: "Show me all restaurants nearby". The system shows all Italian restaurants nearby, providing them with reviews from Yelp. The family decides to go to restaurant "Mario". The dad speaks out loud: "Lets go to Mario!". The system knows that in this specific context, the dad means the Mario Restaurant and changes the route to the restaurant accordingly. As the Sensus system knows that the restaurant can be quite busy around that time it asks the family if it should initiate a call so the family could make a quick reservation. The dad confirms this action and the system initiates a call.
Arrived at the restaurant, the family parks the car. Unfortunately, this is a paid spot. The car asks the family if it should pay for the first hour automatically. The dad confirms this action and the family leaves the car. As the pizza's are so delicious and the family has a great time, they completely forget the time. Luckily, the car knows that the family is still in the restaurant and books some extra time for the parking sport automatically.

Act.1.4: Formulating UX Goals.

Based on the future functions of Sensus Navigation, the written scenario's and the UX framework the following UX goals for the system were formulated:

1. The Sensus System should be efficient in use;
2. The Sensus system should consider activities in the physical world of the user;
3. The Sensus System should consider the social life of users;

4. The Sensus System should offer a continuous functionality between the system itself and an external device;
5. The Sensus System should provide the user with a feeling of control;
6. The Sensus System should provide the user with a feeling of comfort;
7. The Sensus System should not distract or disturb the user;
8. The Sensus System should be predictable in its actions;
9. The Sensus System may surprise the user by providing relevant destinations;

Phase 2: Concept Generation

The following will outline the activities conducted in this phase.

Act.2.1: Making storyboards.

Due to time-restrictions, this activity was skipped. As we had good understanding of the functions and UX desired, making storyboards was not a critical step in the development process of the system.

Act.2.2: Formulating, choosing and prototyping specific components of the system.

As the development of "smart" product UX requires that only specific components of the "smart" product are prototyped (Dev.6), we focused solely on the scenario of the daily commute during the development of the prototypes. Furthermore, as autonomous driving (AD) capabilities of a future car may be of significant importance to a future navigation system, we focused on spending time during AD as primary driver for the prototype. Main goal for the prototype was to examine the understanding of "experience-driven" routing. This meant that the participant was presented with four different modes that would change the behaviour of the car as well as the way the navigation was presented and which functions were core to these specific modes (see below). Each of these four modes (Work, Relax, Entertain and Explore) had its own dedicated view and would change the layout and functions of the navigation system accordingly. By letting the system ask the participants how they would like to spent their time during AD, the specific experiences became the primary driver for the overall UX during the route. In other words: the car would adapt to what the user wanted to do during the AD time. Instead of presenting the user with a standard view of the route, the displayed route would adapt to the mode chosen. So, the mode "Work" for example, showed the route from A to B separated in chunks of tasks, derived from the agenda of the user, a user could do during AD time. Some of the activities had designated times, as a specific Skype-meeting. The "Relax" mode showed the route based on time of mediation a user could do during AD time to relax. The "Entertain" mode showed the time a user could watch video's, films or listen to music. To conclude, the "Explore" mode showed relevant points-of-interest (POI) on the map, based on gathered data about user interests.

Overall, the prototypes were based on the adaptation of the entire Sensus navigation system on the mode chosen, as how users wanted to spend their time during AD. The idea behind this was that users wanted to do other things while the car was driving itself and that the navigation system could adapt to this need, by presenting relevant information based on AD time. Thereby, the idea was that users could like to opt for a slightly longer route (in time) based on what they wanted to do. For example, the car may opt for a slightly longer route to a chosen destination if the user wanted to watch a certain film or listen to a specific playlist that lasted for a certain amount of minutes. Furthermore, users could like having a slightly longer route to a destination when having a business-conversation in the car, so they would not be interrupted during the actual call by a change in driving mode (from AD to manual) or a other driving task that required their attention (e.g. parking). As this "experience-driven" approach to navigation is quite unique, we wanted to test only the overall UX of the prototypes, focusing on the UX heuristics from the framework specifically and leaving the IxD heuristics out of scope. The idea was that these IxD heuristics would be used after the evaluation of the prototypes to drive, refine and describe the overall interaction of the future system.

As lightweight prototyping methods should be used when developing for "smart" product UX, the prototypes were made just using paper and pencil, as shown below.

images/image1.jpg images/image2.jpg images/image3.jpg

images/image4.jpg images/image5.jpg

Act.2.3: Formulating questions to guide the evaluation of the prototypes with real end-users.

As rapid development cycles are preferred when designing and developing "smart" product UX (Dev.1), the prototyping process consisted of a continuous loop of designing - prototyping - evaluating. So, each time the screens presented on the previous page were evaluated, the user feedback was used to change the prototypes and evaluate them with the users, over and over again. As user studies should focus on the intention of use (Dev.5) and the presented "experience-driven" routing was quite new, we decided to stick with evaluating the overall design and UX of the prototypes at first. Therefore, the following questions were formulated to guide the evaluation with participants:

1. Do you understand what you're seeing?
2. What do you expect from what you're seeing?
3. What do you think about what you're seeing?
4. Do you see any problems with what you're seeing?
5. What would you change or add about what you're seeing?

The questions aside, a small introduction scenario was written that was read to the participants before presenting them with the screens in the evaluation:

Imagine: you have a future car with a navigation system that has access to your personal data, as your calendar, hobbies and interests, and is able to drive autonomously on certain roads. It is Monday-morning, you're at home and you'll leave soon for a long 3-hour trip to Aarhus. You receive a notification on your "smart"phone that you should leave to be on time at your destination. You leave the house, get into the car and are presented with the following screen on the central touch display.

Next, screen 1 with the different modes was presented and the questions asked. Next, the participant was asked to choose one of the modes (every mode was treated once) and the questions were asked again.

Phase 3: Evaluation

The following will outline the activities conducted in this phase.

Act.3.1: Evaluate the prototypes with real end-users in real contexts-of-use.

Although the evaluation of "smart" product UX should be conducted in real contexts-of-use (Dev.3), the low-fidelity of the actual prototypes made their use in real cars unnecessary. As real end-users had to be involved in the development process (Dev.2), a total of 5 people, one from the Volvo office in Copenhagen and 4 students from the universities of Aarhus and Twente respectively, were asked to participate in the experiment. In total, three rounds of evaluation were conducted with each participant, consisting each of a continuous loop of designing - prototyping - evaluating the prototypes made. The following describes their feedback and the changes made to the prototypes accordingly.

In the first round the following feedback was given, which led to the following changes:

- **Unclear why I'm presented with these 3 modes** → Clarifying what is presented and why
- **Unknown if I can access other functions of the car, e.g. climate** → Add option to skip or modify modes later, giving direct access to critical functions of the car
- **If I have chosen one of the modes, can I change them later?** → Add back button, or modifier in menu
- **Relaxing mode is unclear, is watching video's not relaxing?** → Change mode names, re-categorize them
- **Car should only present proposal for the route with option to change it** → Add ability to modify route activities
- **What do the question marks mean in the "Explore" mode?** → Change presentation activities in Explore mode
- **Why is there no information about when I will arrive and the actual route?** → Change map representation
- **What is the "auto" mode and why would I need it?** → Change/remove "auto" mode
- **What do the hearts mean in the "relax" mode?** → Clarify representation of hearts
- **I expect in "entertain" mode that the car presents how long I can watch videos or listen to music in total, not per activity** → Clarify representation of "entertain" mode
- **I don't know what will happen if I press one of the icons on the map, will give me that some extra information?** → Clarify icon representation
- **I would like to have an overview of the route with ETA's so I can quickly switch between modes, before choosing one. So more information from the start** → Change representation of modes in navigation
- **I would like to have an overview of the route with ETA's so I can quickly switch between modes, before choosing one. So more information from the start** → Change representation of modes in navigation
- **I expect the actual route when I enter the car, would give me more familiarity as I see the destination I will go represented** → Change first screen

Based on the feedback of the participants, the changes were incorporated in the prototypes and let to the following re-designs:

images/image6.jpeg images/image7.jpeg images/image8.jpeg

images/image9.jpeg images/image10.jpeg

After the re-designs were made a second round of evaluation was conducted, which led to the following feedback and changes:

- **Would like to edit route in a specific mode before I start the route** → Add edit option
- **ETA is presented twice: one in bar and second by the flag, is unnecessary** → Remove one of two ETA's presented
- **Still don't know how to change modes when driving** → Make changing modes more clear and intuitive
- **I would like to see a whole map with POI's displayed on it in "Explore mode", no text** → Change text in icons
- **Explore POI's are unnecessary, want to explore myself** → Remove explore POI's

- **Why is manual driving not represented in the individual modes?** → Add manual driving

The changes mentioned on the previous page let to the following re-designs:

images/image11.jpeg images/image12.jpeg images/image13.jpeg

After the re-designs were made a last, third round of evaluation was conducted. Unfortunately, due to time-restrictions, not all re-designs could be tested. Therefore, we had to drop the "Explore" and "Sleep" screen for the third evaluation round. The re-designs led to the following feedback and changes:

- **Would like to have a whole map blurred, with selected route highlighted** → Change overall map view
- **Would like to have always interesting POI's shown on the map** → Change map POI view
- **Not clear how to edit route** → Make route editing more prominent

Act.3.2: Based on evaluation, describe IxD heuristics from UX framework

As mentioned, the initial focus of the evaluation phase was to get feedback about the UX created. Therefore, it was decided to, after useful feedback about the UX was gathered, shift the focus to how the IxD of the Sensus system should be designed to reach this UX. Therefore, the IxD heuristics from the framework were evaluated against the prototypes made, based on the insights about the overall UX.

Regarding the IxD, the future Sensus navigation system:

- [IxD.1] **Should consider the inter-usability between devices.** As users use a "smart"phone application to set up their route, give access to their calendar or receive a "smart"phone notification that it is time for them to leave, the first screen shown in the car should provide a familiar feeling. So, the screen needs to show the route to the destination the user has set up so the overall UX flow from "smart"phone to car is continuous. The inter-usability between these two devices should be familiar and recognizable.

- [IxD.2] [IxD.Ex.1] [IxD.Ix.4] **Should consider all contexts of use.** The "smart" Sensus system should consider all contexts of use where it is used in: the location of the car and the user (physical), who is attending the trip and is in the car (social), the time and progress of the ongoing route (temporal), the availability of other data, e.g. content to be used for entertainment (technological) and the task the user is doing or wants to achieve, e.g. relaxing, working, watching films or listen music (task-specific). The interaction with the Sensus system should change according to these contexts. For example, a user doesn't want to be presented with all kinds of interesting POI's when he has indicated that he wants to relax. Then, the map should be as clean as possible, showing only the ongoing route. Furthermore, the system should adapt its mode of interaction to individual user preferences and the presence of other people in the car.

- [IxD.3] **Should be available when disconnected.** Although the "smart" Sensus system relies heavily on data about the car and user location, preferences and interests, most of the functionality should be available when the car is not able to fetch this data. The user still has to be able to go to its destination, making use of the different modes.

- [IxD.4] [IxD.Ex.3] [IxD.Ex.4] [IxD.Ix.2] **Should be transparent and clear to the user.** Because the "smart" Sensus system uses data to make a proposal for specific activities that can be done during the route, e.g. based on the user's calendar, and all of this happens in the background, it should be clear for users why they're presented with specific activities and where that data comes from. Furthermore, the overall interaction should be clear, straightforward and not cognitively demanding, always providing a feeling of control.

- [IxD.5] **Should consider discontinuity in the interaction.** As the connectivity of the car can get lost during the trip, an ongoing interaction between user and car, e.g. watching a movie, can be interrupted. This interruption should be considered, for example by downloading the entire movie before the user sets off.

- [IxD.6] **Should consider differences in users' interests and preferences.** A car is usually used by multiple people. As the "smart" Sensus system is able to use individual user data for route planning and activity proposal, it should consider differences in users' interests and preferences in making decisions about what route to plan and what data to use to make a proposal for route-planning activities.

- [IxD.7] [IxD.Ix.4] **Should consider security and privacy in the interaction.** The "smart" Sensus system should always secure the data it is using, be clear about what data is used and from what sources and provide information about how users can opt-out of the system. Overall, the system should not use more data than necessary and never share this data with other parties without explicit permission given by the user.

Act.3.3: Evaluate overall project

After the dummy project ended, an evaluation was conducted to evaluate the overall project and the working of the UX framework. Starting with the evaluation of the overall development of the UX of "smart" products in general, the UX development heuristics provided in the framework were valuable in guiding the development of "smart" product UX [PRQ.1.2]. The use of rapid development cycles in the form of designing - prototyping - evaluating turned out to be a good and practical way for designers to quickly test their prototypes and change them based on user feedback [PRQ.1.2.1]. By involving real end-users in the development process [PRQ.1.2.2] and by using a lightweight prototyping technique [PRQ.1.2.4] (paper prototypes) quick iterations let to valuable feedback by real end-users about the direction the design of the UX of the "smart" Sensus system should take. As the prototypes only represented actual screens, the evaluation was not conducted in real contexts-of-use. In this particular project, this didn't form a problem but when the fidelity of the prototypes increases, when testing actual interaction between user and car, prototyping in real contexts-of-use may be of value as these contexts will resemble how this interaction will take place in the real world, when the product is delivered [PRQ.1.2.3]. However, this need to be tested in the future. The use of lightweight evaluation methods, in this case interviews, were of value in this particular project as well [RQ.1.2.5]. The use of interviews let to quick design iterations, getting quick and qualitative feedback from users when testing general design ideas. The focus of the project was on the intention of use by elaborating how users would use the product and if they understood what they were presented with. This focus let to qualitative feedback about how and if the users would use of the product [PRQ.1.2.6]. As only interviews were used, the value of direct observation in the evaluation of the prototype was not tested [PRQ.1.2.8]. This was due to the focus on the intention of use and the use of low-fidelity prototypes. The practical value of the use of direct observation is imaginable when higher fidelity prototypes are used in real contexts-of-use as the focus of the evaluation phase is more on the actual interaction between human and car. By prototyping only a small component of the system, the different modes of navigation and the presentation of the routes, the project took a clear approach and had a clear focus on what was tested and evaluated [PRQ.1.2.7]. As a navigation system can be quite complex, due to all its features, prototyping only a small component of this system let to feedback only focused on this particular feature, leaving the rest of the navigation system out of scope. This let to practical, valuable feedback only focused on the particular feature that was prototyped, leaving less valuable feedback, based on the rest of the navigation system, out of scope. Overall, the use of the UX development heuristics from the framework was of practical value in this project and let to a narrow focus on prototyping and evaluation of a component of the "smart" Sensus system, which let to qualitative feedback of real end-users that was of value in the rapid development process of designing - prototyping and evaluation.

As mentioned, the focus of the prototypes and evaluation was on the intention of use. Thereby, the focus was on getting general feedback from end-users about the overall UX. So, the prototypes were designed and evaluated based on only the UX heuristics from the framework, leaving the IxD heuristics out of scope. However, this formed a major drawback of the project. By designing prototypes that resembled actual in-car screens, the focus of the evaluation with end-users quickly shifted to the overall aesthetics and interaction of the screens themselves. By asking users if they understood what they were seeing, if they had any problems what they were seeing and how they would address these problems themselves, users answered these questions based on what they were actually seeing. Hence by the appearance of elements of the screens, e.g. icons, buttons and text. This shifted the focus from the evaluation of UX to a focus on IxD, by elaborating on how they would interact with the product. This set the scope for the rest of the development process as the screens were re-designed based on this feedback. Then, leaving the IxD heuristics out of scope was a big fault as this completely undermined the use of the framework: when designing and evaluating aspects of interaction, the IxD heuristics should be used. Using the IxD heuristics after the project was conducted let only to an analysis of how the product should work, according to the feedback given. By actually incorporating these heuristics in the development process itself, way more valuable feedback could have been generated. Hence it is advisable to actually incorporate these heuristics when evaluating aspects of IxD. Overall, the use of UX heuristics from the framework was of value when designing "smart" product UX [PRQ.1.1]. However, what turned out was that both the UX and IxD heuristics could not be separated from each other and must be used in conjunction with each other when designing and developing "smart" product UX.

Looking at the use of the framework in the project, it is still not really clear in what phase the framework could have been of value and should have been used. In the particular project, the use of the framework was initiated when starting the concept generation phase, leaving the ideation phase out of scope. However, as the ideation phase dealt with the creation of scenario's that described the overall UX, the framework might also be of value in this phase as it provides heuristics for the overall UX of the "smart" product system. However, this needs to be tested in the future.

So, is the UX framework of value for practitioners within the HCI-field? [PRQ.1]. This question is hard to answer, looking at the problems mentioned above. Although the UX development heuristics were of value in the actual development process, the use of the UX and IxD heuristics was a lot more problematic. Although the UX heuristics were used in the concept generation phase of the project, it may be advisable to also use them earlier when the UX of the "smart" product is discussed, described and incorporated in scenario's. By not doing so during the project the framework was undermined, which forms a drawback of this project. Furthermore, the UX and IxD should be combined when designing prototypes as they could not be separated from each other when evaluating aspects of "smart" product IxD. Hence there is a clear indication that the framework may be of value for practitioners in the field. However, more research is needed to come to a clear conclusion about how the framework can be used in the design and development of "smart" product UX, if the heuristics provided are sufficient or that more heuristics are needed.

Chapter 7

Discussion

This research aimed at presenting a practical UX framework for the design and development of "smart" products to be used by designers in the HCI-field, by providing understanding of the nature of "smart" product UX.

As emphasized by other researchers [6], [7], this research showed that in-depth research on the UX of "smart" products is scarce and is therefore still in its infancy, which may be due to the strong technology-oriented view on these products [6], [7]. In their efforts to define "smart" products, most researchers phrase their definition around the technological, without providing any clarity on the perceptions and experiences of end-users of these products nor any shared agreement about an actual definition itself [RQ.1.1.1]. However, there is a tension to agree that the concept of "smart" products heavily relies on the usage of data, acting as the prominent enabler in the way "smart" products work and interact [RQ.1.1.2] and as the primary differentiator of "smart" products within the HCI-domain [25]. With data as enabler, specific "smart" product abilities are used within the HCI-field to describe what a product should possess to be able to be called "smart" [22]–[24], although this approach is not predominant. In the dummy project conducted in this research, this approach showed to be a good way to describe the smartness of an existing product however.

Deviating from the technological-oriented view on "smart" products, towards a focus on end-user needs, perceptions and experiences, the lack of shared agreement about a definition turned out to be non-exclusive for "smart" products as the concept of UX is also seen as vague and unclear, due to its diverse characteristics and overlaps with other concepts, as usability. However, the tension to agree is that UX is rather dynamic, subjective and context-dependent [35] and therefore the inclusion and exclusion of particular variables within UX seems arbitrary, depending on the participant's background and interests [29]. As a definition was an initial and crucial step towards an integrated framework of UX [29], this research adopted the definition given by [15], who included the user's needs and the context of product-usage in its understanding of UX [RQ.1.2.1], because these factors turned out to be central to the nature of "smart" product UX. Based on the usage of data, the UX of "smart" products turned out to be unique [RQ.1.4], in the way functionalities and experiences of these products can be distributed among many other devices, users, applications and contexts [61]. Although this can cause an incoherent UX, due to data-connection and latency issues, and can be cognitively demanding for users, due to the automation and remote-control activities they have to conduct, most end-users emphasize the advantages that the automation, adaptability, multi-functionality, cooperation and human-like interaction of "smart" products bring [RQ.1.3]. Taken together, all these factors of "smart" product UX fit well in three exclusive categories of UX as emphasized by many researchers [26], [29], [32], [35], [49], [50]: the **user's internal state** consisting of the *user's needs, resources, emotional state, experiences, expectations and cognition*; the *physical, social, temporal and task* **contexts of use**; and the *products, objects, services, people, infrastructure* and *usability* involved in the **system characteristics**. Emerging from these UX dimensions, specific heuristics for the Interaction Design of "smart" product systems were formulated, as aspects affecting UX such as relevant aesthetic and interaction design principles should be linked to the design process [6]. These heuristics were formulated to provide designers with practical guidelines when designing for "smart" product UX [RQ.2]. To develop this UX, User-Centered-Design (UCD) methods have been the primary way to go in the HCI-field. UCD is a design philosophy wherein the needs and requirements of end-users are in focus of each stage of the design process [RQ.1.2.2]. By adopting and adapting this approach to the development process of "smart" product UX, by emphasizing unique guidelines as the focus on the user's intention, the rapid prototyping of components of the "smart" product system and the challenging task analysis, specific guidelines for the development of "smart" product UX were formulated that focused on rapid prototyping cycles together with real end-users in real contexts-of-use, in line with [6] [RQ.1.5].

In consonance with the common way to design and evaluate UX [17], [18] and its components [9]–[16], the process of formulating specific heuristics for the UX design and development of "smart" products turned out to be a good approach to gain understanding of the UX of these products and turn these insights into graspable, understandable components, forming a base to evaluate the dimensions of "smart" product UX in detail. In line with [6] these UX insights gathered were evaluated by conducting a dummy project. By designing and developing a "smart" navigation system together with real end-users in real contexts-of-use, the heuristics formulated and incorporated in the UX framework showed to be of practical value for designers in the field [RQ.3]. By working according to the UX development heuristics formulated, the process of designing and developing "smart" product systems turned out to be of practical value, in the way rapid cycles of designing - prototyping and evaluation together with real end-users provided valuable feedback to be used for subsequent iterations, making quick changes to the design of the system possible and easy to evaluate. Furthermore, the heuristics on the UX from the framework showed to be of value for designers as they gave a clear and practical understanding and guidance to the design. However, emerging from the dummy project, it is not entirely clear in what stage of the design and development process the UX framework should be used. In the project conducted, the framework was only used from the actual design phase of the "smart" product system. Furthermore, the IxD heuristics were only used after the overall evaluation was conducted, to set a clear guidance for subsequent iterations that would focus on higher fidelity prototypes and evaluation methods. However, as IxD is such an integral part of the overall UX it is advisable to use these heuristics from the actual design phase as well, to incorporate relevant interaction aspects to be used when designing "smart" product UX. As this was not done in the project conducted, this is a clear limitation of this study.

In general, this study provided clear understanding of the nature of "smart" product UX, something that is lacking in the HCI-field [6], [7], by focusing on the needs, expectations, perceptions and other influencing dimensions of this UX. By transforming these insights into actual heuristics to be used by designers in the field, this research provided a practical and hands-on approach to designers to be able to understand and design for "smart" product UX. The evaluation of these heuristics in a dummy project showed that these insights seem to be of value for practitioners in the field. However, although the heuristics on IxD and UX design and development set a start in research about "smart" product UX, a lot of work needs to be done in the future to gain better understanding of the practical value of these heuristics for practitioners in the field by studying the individual heuristics provided in more design and development settings. Furthermore, more research needs to be conducted on the nature of "smart" product UX to enhance the UX framework provided.

Although not emphasized in the body of this research, the nature of "smart" product UX could also change the role of the UX designer in the actual design process. As the common thread in the conceptions about "smart" products is that the underlying technology resides in the background, where the interconnection of intelligent objects, big data analysis and cloud infrastructure enable the achievement of user tasks without explicit user interaction [3], the role of UX designers could shift from designing the front stage of a product - how to make products desirable and easy to use (physical materials, icons, colours etc.) - to primarily designing the inner workings or backstage of the product, through data and behavioural analysis, to understand the contexts of use better and thereby make better predictions about what impacts the user's behaviour. As the working and interaction of a "smart" product primarily relies on the use of data, platforms such as digital assistants, but also platforms as Google and Facebook, provide an enormous amount of data that could be used by designers and thereby foster new backstage tools to know more about product-usage. This knowledge can be used for increasingly more effective and persuasive designs, influencing the user's internal state on a personal, emotional or even spiritual level. These backstage tools eventually can become the primary tools for UX designers when designing for "smart" product UX, just because of the big reliance of these products on the use of data. As this development in the way UX designers work can also heavily influence the heuristics on UX development provided, more research needs to be conducted to gain better understanding of how the nature of "smart" products, and thereby the use of data, changes the overall UX development process of these products. For this, the role of designers in the UX development of some platforms, as Facebook and other related social media, could be used as case examples for future study. In these cases, UX designers have already acquired sufficient knowledge and mastery of this new UX-skillset of persuasive and habit forming design. For example, one of the UX targets of these ad-based companies is that "as many users should spend as much time as possible with our product" [89]. However, the nature of "smart" products is that, through the use of data, users could be more efficient and effective and thereby have more time to do other things. This contradiction of the targets of UX designers and the personal needs of users could influence the heuristics on UX and IxD provided, as efficiency and effectiveness are important guidelines for "smart" product UX. Therefore, more research needs to be done on the relationship between the needs of designers and users, fostered by the use of data.

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