EXPERIENCE PROTOTYPING FOR AUTOMOTIVE APPLICATIONS

DISSERTATION

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ABSTRACT

In recent years, we started to define our life through experiences we make instead of objects we buy. To attend a concert of our favorite musician may be more important for us than owning an expensive stereo system. Similarly, we define interactive systems not only by the quality of the display or its usability, but rather by the experiences we can make when using the device. A cell phone is primarily built for making calls and receiving text messages, but on an emotional level it might provide a way to be close to our loved ones, even though they are far away sometimes. When designing interactive technology, we do not only have to answer the question how people use our systems, but also why they use them. Thus, we need to concentrate on experiences, feelings and emotions arising during interaction. Experience Design is an approach focusing on the story that a product communicates before implementing the system.

In an interdisciplinary team of psychologists, industrial designers, product developers and specialists in human-computer interaction, we applied an Experience Design process to the automotive domain. A major challenge for car manufacturers is the preservation of these experiences throughout the development process. When implementing interactive systems engineers rely on technical requirements and a set of constraints (e.g., safety) oftentimes contradicting aspects of the designed experience. To resolve this conflict, Experience Prototyping is an important tool translating experience stories to an actual interactive product.

With this thesis I investigate the Experience Design process focusing on Experience Prototyping. Within the automotive context, I report on three case studies implementing three kinds of interactive systems, forming and following our approach. I implemented (1) an electric vehicle information system called Heartbeat, communicating the state of the electric drive and the batteries to the driver in an unobtrusive and ensuring way. I integrated Heartbeat into the dashboard of a car mock-up with respect to safety and space requirements but at the same time holding on to the story in order to achieve a consistent experience. With (2) the Periscope I implemented a mobile navigation device enhancing the social and relatedness experiences of the passengers in the car. I built and evaluated several experience prototypes in different stages of the design process and showed that they transported the designed experience throughout the implementation of the system. Focusing on (3) the experience of freehand gestures, GestShare explored this interaction style for in-car and car-to-car social experiences. We designed and implemented a gestural prototypes for small but effective social interactions between drivers and evaluated the system in the lab and and in-situ study.

The contributions of this thesis are (1) a definition of Experience Prototyping in the automotive domain resulting from a literature review and my own work, showing the importance and feasibility of Experience Prototyping for Experience Design. I (2) contribute three case studies and describe the details of several prototypes as milestones on the way from a an experience story to an interactive system. I (3) derive best practices for Experience Prototyping concerning their characteristics such as fidelity, resolution and interactivity as well as the evaluation in the lab an in situ in different stages of the process.

ZUSAMMENFASSUNG

Wir definieren unser Leben zunehmend durch Dinge, die wir erleben und weniger durch Produkte, die wir kaufen. Ein Konzert unseres Lieblingsmusikers zu besuchen kann dabei wichtiger sein, als eine teure Stereoanlage zu besitzen. Auch interaktive Systeme bewerten wir nicht mehr nur nach der Qualität des Displays oder der Benutzerfreundlichkeit, sondern auch nach Erlebnissen, die durch die Benutzung möglich werden. Das Smartphone wurde hauptsächlich zum Telefonieren und Schreiben von Nachrichten entwickelt. Auf einer emotionalen Ebene bietet es uns aber auch eine Möglichkeit, wichtigen Personen sehr nah zu sein, auch wenn sie manchmal weit weg sind. Bei der Entwicklung interaktiver Systeme müssen wir uns daher nicht nur fragen wie, sondern auch warum diese benutzt werden. Erlebnisse, Gefühle und Emotionen, die während der Interaktion entstehen, spielen dabei eine wichtige Rolle. Experience Design ist eine Disziplin, die sich auf Geschichten konzentriert, die ein Produkt erzählt, bevor es tatsächlich implementiert wird.

In einem interdisziplinären Team aus Psychologen, Industrie-Designern, Produktentwicklern und Spezialisten der Mensch-Maschine-Interaktion wurde ein Prozess zur Erlebnis-Gestaltung im automobilen Kontext angewandt. Die Beibehaltung von Erlebnissen über den gesamten Entwicklungsprozess hinweg ist eine große Herausforderung für Automobilhersteller. Ingenieure hängen bei der Implementierung interaktiver Systeme von technischen, sicherheitsrelevanten und ergonomischen Anforderungen ab, die oftmals dem gestalteten Erlebnis widersprechen. Die Bereitstellung von Erlebnis-Prototypen ermöglicht die Übersetzung von Geschichten in interaktive Produkte und wirkt daher diesem Konflikt entgegen.

Im Rahmen dieser Dissertation untersuche ich den Prozess zur Erlebnis-Gestaltung hinsichtlich der Bedeutung von Erlebnis-Prototypen. Ich berichte von drei Fallbeispielen im automobilen Bereich, die die Gestaltung und Implementierung verschiedener interaktiver Systemen umfassen. (1) Ein Informationssystem für Elektrofahrzeuge, der *Heartbeat*, macht den Zustand des elektrischen Antriebs und den Ladestand der Batterien für den Fahrer visuell und haptisch erlebbar. Nach der Implementierung mehrerer Prototypen wurde Heartbeat unter Berücksichtigung verschiedener technischer und sicherheitsrelevanter Anforderungen in die Armaturen eines Fahrzeugmodells integriert, ohne dass dabei das gestaltete Erlebnis verloren gegangen ist. (2) Das *Periscope* ist ein mobiles Navigationsgerät, das den Insassen soziale Erlebnisse ermöglicht und das Verbundenheitsgefühl stärkt. Durch die Implementierung mehrere Erlebnis-Prototypen und deren Evaluation in verschiedenen Phasen des Entwicklungsprozesses konnten die gestalteten Erlebnisse konsistent erhalten werden. (3) Im Projekt *GestShare* wurde das Potential der Interaktion durch Freiraumgesten im Fahrzeug untersucht. Dabei standen ein Verbundenheitserlebnis des Fahrers und soziale Interaktionen mit Fahrern anderer Fahrzeuge im Fokus. Es wurden mehrere Prototypen implementiert und auch in einer Verkehrssituation evaluiert.

Die wichtigsten Beiträge dieser Dissertation sind (1) eine intensive Betrachtung und Anwendung von Erlebnis-Prototypen im Auto und deren Relevanz bei der Erlebnis-Gestaltung, beruhend auf einer Literaturauswertung und der eigenen Erfahrung innerhalb des Projekts;

(2) drei Fallstudien und eine detaillierte Beschreibung mehrere Prototypen in verschiedenen Phasen des Prozesses und (3) Empfehlungen zu Vorgehensweisen bei der Erstellung von Erlebnis-Prototypen hinsichtlich der Eigenschaften wie Nähe zum finalen Produkt, Anzahl der implementierten Details und Interaktivität sowie zur Evaluation im Labor und in tatsächlichen Verkehrssituationen in verschiedenen Phasen des Entwicklungsprozesses.

DISCLAIMER

Publications and Own Contribution

The work reported in this thesis would not have been possible without the support by the members of the CAR@TUM project "User Experience" and three Media Informatics students. Parts of this thesis are based on papers that have been published at international peer-reviewed conferences. Some of the projects have been supported by Master or Bachelor theses. The following sections will provide further information.

Chapter 5. Heartbeat: An Electric Vehicle Information System
is based on Loehmann, S., Landau, M., Koerber, M. and Butz, A. *Heartbeat: Experience the Pulse of an Electric Vehicle* at AutomotiveUI 2014 [64] where the design (section 5.2), prototypes and study results (sections 5.3 and 5.4) have been published. I supported the team in the design of the experience by implementing and evaluating a preliminary prototype (section 5.3.1) and providing constant feedback on story and storyboard (section 5.2). I implemented both experience prototypes (sections 5.3.2 and 5.4.2). I planned and conducted both user studies (sections 5.3.3 and 5.4.3) in close cooperation with the project team.

Chapter 6. The Periscope: A Mobile Navigation Device
is based on Loehmann, S., Landau, M., Koerber, M., Hausen, D., Proppe, P. and Hackenschmied, M. *The Periscope: An Experience Design Case Study* at AutomotiveUI 2014 [65] where the design (section 6.2), prototypes and study results (sections 6.3 and 6.4) have been published. I supported the team in the design of the experience by implementing and evaluating a preliminary prototype (section 6.3.1) and providing constant feedback on story and storyboard (section 6.2). I supervised two Bachelor students [26, 83] implementing the prototypes described in sections 6.3 and 6.4. I planned both user studies (sections 6.3.3 and 6.4.2) in close cooperation with the students and the project team and supervised the execution and the evaluation of the results.

Chapter 7. GestShare: Experiencing Freehand Gestures in the Car
The GestShare project is a result of the Master thesis of Johannes Preis [82] under my supervision. I constantly provided input and feedback on the context analysis and contributed ideas to the design of the GestShare experience including story and storyboard (section 7.2) and to the implementation of the prototype (section 7.3). We planned and conducted both evaluations in close collaboration (section 7.4). For more details on the design process see [82].

Pictures and Illustrations

Due to the interdisciplinary character of the CAR@TUM project and the support by students, I did not create all images and illustrations of this thesis. In this case, I mention the name(s) of the author(s) in the corresponding caption. I created all pictures and illustrations that are not followed by such a statement. The first two illustrations on the title page are drawn by Marc Landau and the third one by Johannes Preis.

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Some Bachelor and Master students supported me in a great way while I was working on the prototypes described in this thesis. Thank you **Maximilian** Hackenschmied, **Patrick** Proppe, **Clara** Lüling and **Johannes** Preis. Keep up the great work!

I could not have done all this work without my fellow PhD students, post-docs and staff of the Media Informatics Group at the LMU in Munich. **Fabian:** your own company, marriage, a new apartment, a dissertation and a wonderful boy; an impossible challenge, but you managed to turn the corner (get it? ;)). **Sara:** I was so sad that we did not get to spend more time together as colleagues, but we are now making up for it, and this is even better than being colleagues! **Doris:** after ignoring each other for the first five years, we co-authored seven papers, visited four (almost five) conferences together and totally blew the one common research project; you literally moved from the periphery to the center of my attention. **Dominikus:** you 'suffered' a metamorphosis from the grumpy, old but genius dude occupying the neighboring desk to a friend sharing the love for good drinks, deep discussions and honest feedback. **Martin:** We did not only share this difficult experience stuff with each other, but more importantly many great conversations; please keep it that way! **Alina:** you were the best 'roomie' I could ever think of, quiet when I needed quietness and chatty when I needed chattyness; it was a pleasure to hold you in my arms this one time ;) **Ema:** thank you so much for always reminding me that work is not everything that counts. **Raphael:** first I was your HiWi, now I am your buddy, I enjoyed both but like the current state better; and sorry for defending before you did ;) **Hendrik:** it was an honor to be supervised by you and to supervise with you. **AlexDL:** it is great to see how disagreements can disappear over time. **AlexW:** I still don't like you tattling about my awesome project 'Klapperhand', but it was fun to tinker around with you and put colorful sticky notes everywhere. **Henri:** If there even is a cool dude with good taste and a great sense of humor in our group, it must definitely be you! **Sarah:** I still don't know why you wanted to leave our office so badly, but I forgive you now :) **Simon:** Please be nice to Sarah, I know you two actually really like each other. **Julie:** you always reminded me to don't worry, but be happy, even more than this song did. **Max:** I don't know who you can be both, that good and that funny, but it is an awesome combination. **Prof. Hußmann:** I always enjoyed our talks about this difficult topic of Experience Design; thank you for attending this very important meeting with BMW management and for defending our concepts there. **Franziska:** thank you for always helping me when I needed you and for all the interest in the crazy things we do. **Rainer:** you are by far the most important but at the same time most underestimated person in our group, but you are also a great guy; thank you for everything, it was a pleasure to work for you and with you.

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Chapter 1

Introduction

People are the authors of their own experiences.

– Esko Kurvinen, Ilpo Koskinen and Katja Battarbee (HCI Researchers) –

User Experience Designer, User Experience Researcher, User Experience Manager. User Experience seems to be an inevitable element of current job descriptions listed by companies building interactive technology. This is great in many ways, especially because it shows how it became widely accepted that the relationship between technology and the people using it *is* important. On the other hand, did UX not become a buzzword instead of a phenomenon with enormous relevance? When reading the details of these job descriptions, the requirements often suggest that the company is actually looking for a User Interface Designer, Front-End Developer or Usability Engineer. Of course, these professions among others are essential to create successful products with appealing appearance, good performance and a fluid interaction design, leading to satisfied users. However, experience goes beyond usability. Experience Design extends the concepts of effectiveness and efficiency by adding a dimension focusing on the subjective experience people have when using interactive technology. I would like to point out that the goal is not to design experiences per se, but rather to design *for* experiences because after all "people are the authors of their own experiences" [58].

1.1 Motivation

According to Ingelhart's theory of post-materialism, significant value changes occurred in Western cultures since the 1970s. "'Materialist' values, emphasising economic and physical security, were overwhelmingly predominant – but as one moved from older to younger birth cohorts, 'postmaterialist' values, emphasising autonomy and self-expression, became increasingly widespread" [40]. Ingelhart's work supports the hierarchy of basic human needs published by Maslow [70]. Both state that human well-being is based on the satisfaction of these needs, whereas "the appearance of one need usually rests on the prior satisfaction of another, more pre-potent need" [70], meaning that 'lower' physiological needs such as hunger or the need for safety must be fulfilled before a conscious want of autonomy or self-expression can occur. As lower needs are permanently satisfied in Western cultures, post-materialistic values gain influence [40]. People's *experiences* [95] based on their longing for love, esteem and self-actualization [70] become more important than the ownership of materialistic goods. Suggesting a more recent interpretation, I will provide some examples.

Experiences Define our Lives

First example: Music. Music has always been an important part of our culture. Different decades were characterized by different genres, for instance Swing in the 1930s or Rock 'n' Roll in the 1950s, representing a certain way of life or the protest of younger generations. Until recently, people used to own the music they liked. First on tangible media such as records, tapes and CDs, then [76] in digital formats such as mp3 files [77]. Currently, the private ownership is about to be replaced by accessing music using streaming services such as Spotify[1]. While music collections decorated shelves and whole living rooms in the past, they are now stored in the cloud or on mobile devices, offering instant and location-independent availability. Music became omnipresent in our lives. Thus, we associate certain music or even single songs with personal moments and events, which is referred to as music-evoked autobiographical memory [94, 44]. The materialistic values of owning music in the form of physical media shifted to post-materialistic values of associating music with meaningful experiences (e.g., reminding us of a beautiful day at the beach with our loved ones).

Second example: Lifelogging. "Sebastian is happy :) at Space Needle." He just posted a picture on Facebook, taken from the view deck and showing the beautiful sunset over Puget Sound. "Doris was out running. She tracked 10.15 km in 1h:02m:23s." She just finished the city run in Munich and proudly posts her results on Endomondo. People love to upload pictures to Instagram, submit their little anecdotes to Twitter and document their year by shooting 365 selfies. When following friends' profiles on social networks, I can get a good overview about the things happening in their lives. The lifelogging culture and the willingness to share personal data online shows that people increasingly define their lives by the great experiences they make. They express themselves, feel close to people they share content with and increase their self-esteem when people like and comment their posts.

[1] https://www.spotify.com/ (accessed 01/02/2015)

Interactive Technology Mediates Experiences

These two examples show how we move from focusing on the things we own to defining our lives by the experiences we make. This change would not be possible without relevant enabling technology. In this case, it is the smartphone. It allows us to be always online and thus to access and download our data and to create and upload content on social platforms. With its compact size and easy-to-use touchscreen, it allows mobile interactions wherever we are and whenever we want. But, is it the smartphone itself or are the possibilities created by this technology the driving factors triggering positive experiences? Experience Design argues that interactive products are "mediators of experience" [30, p. 2]. The smartphone is without doubt a great piece of technology with its touchscreen allowing for direct interaction and a flexible way of visualizing large amounts of content. But only the various kinds of applications using this underlying hardware make it exciting. Skype or FaceTime allow us to feel close to our loved ones because we can hear and see them even if they are far away. Spotify or iTunes let us listen to our favorite music 24/7, going along with the important events in our lives. We share these experiences on Instagram and Twitter, where likes and comments show us how well we did and that we influence others.

Experience Design and Experience Prototyping

Thus, interactive technology is defined by the experiences it creates. Having realized this, User Experience needs to be considered as an important factor beyond usability. The subjective experiences of the people interacting with our products including emotions, feelings and affect, needs to be kept in mind when designing and building interactive technology and applications. Experience Design is an approach following this goal. Before designing and implementing the product, the definition of the experience itself plays an important role in the process. This experience, which is for instance represented by a story and a storyboard, is then a fixed point of reference throughout the development of the product. By deriving requirements from the story, the team can ensure that the experience does not get lost due to technological constraints or other design decisions on the way to the final product.

The preservation of the experience is the main purpose of Experience Prototyping. Prototypes are an important tool to translate experiences defined in a story and a storyboard into interactive representations. With their help, it is now possible to involve users into the interaction and to evaluate whether they are able to relive the designed experience. If this is the case, the prototypes can be refined in an iterative process until they reach the intended degree of maturity. In other words, prototypes bring experiences to life by communicating the essential parts of the story to people who are involved in the interaction.

Automotive Experience Design

The automotive domain is an especially complex field for the design of experiences. Developers of in-vehicle information systems have to pay attention to a enormous number of constraints and requirements that mainly arise from safety issues. Usability and ergonomics play a crucial role in the attempt to keep the driver, his passengers and all other traffic participants safe. It is important to support the driver to concentrate on the primary task of driving with minimal distraction. At the same time, reliable technology and excellent engineering are not the only reasons for customers buying a new car. From the point of view of the driver and the passengers, spending time in a vehicle does not only fulfill the purpose of driving from A to B. The car also offers a place for meaningful conversation [7] or the collaborative exploration of the environment [55]. Drivers and passengers recognized that it is actually possible to enjoy cars in other ways than merely being transported to a destinations. Slogans such as "Sheer Driving Pleasure"[2] or "Technology to Enjoy"[3] show that meaningful experiences connected to a car are a unique selling proposition influencing customer decisions. Furthermore, advanced driver assistant systems such as automatic cruise control keeping the car at a certain speed or defined distance to another car without the involvement of the driver, make room for secondary tasks, which are not directly related to driving. Thus, similar to smartphones, cars now offer a permanent connection to the Internet and thus access to social networks and multimedia content. However, conflicts arise between pragmatic and entertaining tasks both for manufacturers designing in-car interactions as well as customers constantly being confronted with new applications and a rising complexity. For these reasons, it becomes more and more important to focus on the emotional aspects and to consider the conscious design of experiences when developing in-vehicle infotainment systems.

Synopsis

In this thesis I report on an Experience Design process for automotive applications with a focus on the role of Experience Prototyping. The process has been developed by an interdisciplinary team of designers, psychologists, engineers and experts on Human-Computer Interaction in the course of a three-year project. The goal was to provide tools and methods for the design, implementation and evaluation of interactive systems in the car that trigger positive emotion and thus meaningful experiences. In the first part of this thesis, I introduce the theoretical background of the topic and derive definitions for the terms User Experience and Experience Design. Furthermore, I elaborate the importance of prototyping for the successful development of interactive systems leading to a definition of Experience Prototyping. In the second part, I describe three case studies providing details on design, iterative implementation and evaluation of in-vehicle applications with a focus on the interaction experience. In the third part, I derive best practices for Experience Prototyping based on insights gained in the case studies.

[2] http://www.bmw.com/ (accessed 12/21/2014)

[3] http://www.seat.com/ (accessed 12/21/2014)

1.2 Research Objectives and Research Questions

Within a three-year project analyzing User Experience in the automotive domain, I filled the role of an expert in Human-Computer Interaction. On the one hand, I brought human-centered and iterative characteristics to the design process. On the other hand, I applied my technical skills to translate experiences into interactive prototypes. Due the interdisciplinary nature of my HCI education, I worked in close collaboration with an industrial designer to design and create experiences and concepts for the interactive prototypes as well as a psychologist to conduct user research and evaluations analyzing implemented experiences. During my research in the course of the three-year project, I focused on the following objectives:

Objective 1: Define the Role of Prototyping in an Experience Design Process

As a team, we developed a process for creating positive experiences during the interaction with in-vehicle interfaces. According to the human-centered design cycle [88] we followed the phases of analyzing the context, designing experiences, implementing interactive representations and evaluating these prototypes before iterating them based on the results. With the focus on triggering meaningful interactions and thus positive emotion, it was my goal to integrate Experience Prototyping into the design process. To do this, it was important to answer the following research questions:

R1: Is prototyping an appropriate approach to translate designed experiences into interactive representations of the envisioned product?

R2: At which stages of the design process does prototyping need to be applied?

Objective 2: Gather Insights on Experience Prototyping

To be able to develop an Experience Design process, we had to create exemplary interactive in-vehicle infotainment systems. In three case studies, we designed and implemented several experiences as proof of concept. In each case study, we implemented several prototypes and evaluated them to find out whether it was possible to trigger the designed experiences during interaction. Thus, in the course of the projects I gathered valuable insights on Experience Prototyping to answer the following research questions:

R3: Which prototyping tools and methods are suitable to implement and to communicate envisioned experiences?

R4: Which characteristics should prototypes possess at different process stages in terms of fidelity, resolution and interactivity?

R5: Which study setups and procedures are suitable to evaluate whether designed experiences can be relived during interaction even in early development stages using early prototypes?

1.3 Research Approach

Based on the research questions formulated above, I pursued the following approach.

Literature Review and Definitions
To establish a theoretical basis for the analysis of prototyping in an Experience Design process, it was first of all necessary to study the relevant related literature covering the topics User Experience, Experience Design and Experience Prototyping. In a next step, I derived working definitions for these terms.

Exploration
To establish an Experience Design process and to gain insights into the role of prototyping within this process, I applied various tools and methods known from user-centered design and the field of Human-Computer Interaction. I created various prototypes in three case studies implementing three designed experiences with the help of the project team and several students. To cover a broader spectrum of insights, I focused on different types of interactive systems.

Evaluation
To analyze whether interactive representations allow for the communication of the design experience, we evaluated each single prototype. In several user studies, we asked participants to interact with these prototypes, complete especially designed questionnaires and to report on their experiences in semi-structured interviews. In an iterative manner, we subsequently adjusted the concepts and enhanced the prototypes based on study results and feedback.

Retrospective
In the course of this exploratory approach and the three-year project incorporating twelve man-months, I documented the tools and methods used for prototyping as well as results of the corresponding evaluations. In this thesis, I introduce the resulting Experience Design process and report on the details of the case studies with a focus on the translation of designed experiences into interactive representations. Finally, I derive and formulate best practices for Experience Prototyping in the automotive domain.

1.4 Contributions

The research questions and the research approach mentioned above led to several contributions relevant for the field of Human-Computer Interaction and especially for practitioners interested in Experience Design.

Contribution 1: Relevance of Prototyping within the Experience Design process
Results of our studies show that prototypes are an appropriate method to preserve the designed experience throughout the development process. A constant evaluation of new prototypes protect the experience from interfering influences caused by technological constraints or the integration into the context of use.

Contribution 2: Examples for Automotive Experiences
As proof of concept, I contribute three examples for experiences triggered by three different interactive systems in the car. I provide details on the design, implementation and evaluation of (a) an information system communicating the state of an electric vehicle to the driver in an exciting and comforting way, (b) a mobile navigation device for exploring the environment and sharing discoveries with others in the car and (c) an interface allowing for the communication with other drivers using gestural interaction.

Contribution 3: Best Practices for Experience Prototyping in the Automotive Domain
Based on the case studies including various prototypes and evaluations, I derive best practices for building Experience Prototypes for in-car applications. These findings will help Experience Design teams to choose a suitable amount of fidelity, resolution and interactivity in various stages of the process to be able to explore, communicate and evaluate envisioned experiences.

1.5 Thesis Structure

I divided this thesis into three parts. In the first part, I provide an overview of the related work in the fields of User Experience, Experience Design and prototyping and derive definitions for these terms. Additionally, I introduce the CAR@TUM project "User Experience" that I was involved in while doing research for this thesis. In the second part, I introduce three case studies and provide details about the iterative design, implementation and evaluation of several experience prototypes in the automotive domain. In the third part, I list best practices for Experience Prototyping derived from the results and insights gathered in the case studies. I conclude the thesis by stating limitations to my work and providing an outlook into future work. The three parts contain the following chapters.

Chapter 1: Introduction
I open my thesis by stating that the focus on positive experiences needs to move into the focus of HCI research. I provide examples showing that we nowadays tend to define our lives by meaningful experiences instead of the things we own. Additionally, I provide details about the motivation for doing research on Experience Prototyping, formulate research questions, present a research approach, state my contributions to the field and give an overview about the contents of the thesis.

Part I: Setting the Stage for Experience Prototyping

Chapter 2: Experience Beyond Usability
In the second chapter I summarize related work about User Experience and Experience Design. I define the term User Experience and list important characteristics and properties. Then, I describe an approach to Experience Design and its underlying psychological theories about hedonic quality, be-goals, psychological needs and positive emotion. Additionally, I give examples for automotive experiences as well as a first Experience Design Process.

Chapter 3: Experience Prototyping
In chapter three I provide related work and a definition of Experience Prototyping. Then, I elaborate why prototyping is important when developing interactive systems and how it is useful for exploring, communicating, implementing and evaluating design ideas. Subsequently, I explain characteristics of prototypes such as fidelity, resolution and interactivity and describe different approaches to prototyping.

Chapter 4: CAR@TUM Project "User Experience"
I introduce the purpose and the goals of the interdisciplinary CAR@TUM project "User Experience" in chapter four. I provide an overview of the different roles in our design team and list the six phases of the resulting Experience Design process providing a structure for the following studies describing the case studies we conducted in the course of the project.

Part II: Case Studies for Experience Prototyping

Chapter 5: Heartbeat: An Electric Vehicle Information System
In chapter five I describe the first out of three case studies which represent the main part of the thesis. Heartbeat is an interface in an electric vehicle communicating the state of the electric drive and the state of charge of the batteries. Heartbeat provides visual and tactile feedback ensuring the driver that the car is ready to go and whether a recharge is needed to reach today's destinations.

Chapter 6: The Periscope: A Mobile Navigation Device
In chapter six I report on the Periscope, a mobile navigation device. It can be used by the passengers to explore points of interest along the road, triggering a stimulating experience. Discoveries can also be shared by physically handing over the Periscope, leaning to an experience based on the need for Relatedness.

Chapter 7: GestShare: Experiencing Freehand Gestures in the Car
GestShare is the last of the three case studies introduced in this thesis. Using freehand gestures, a driver can connect to others in cars nearby my pointing into a specific direction. The other driver can accept the request by waving his hand or decline by performing a stop gesture. When a virtual connection is established, drivers can grab the music currently played in the other car and drag it into the own vehicle. Thus, other drivers move into an arm's reach.

Part III: A Retrospective on Experience Prototyping

Chapter 8: Best Practices for Automotive Experience Prototyping
In chapter eight I provide a summary of the results and insights derived from the case studies. To answer the research questions listed in chapter one, I relate these insights to each other and describe the overarching perspective on Experience Prototyping. I conclude with best practices that will help interdisciplinary teams to integrate prototyping into their design process.

Chapter 9: Limitations and Future Work I conclude my thesis in chapter nine by providing a summary of the contents of the preceding chapters. Then, I will elaborate some limitations to my work that readers should keep in mind when applying described prototyping methods and tools. Finally, I will provide starting points for future work in the area of Experience Prototyping to encourage interdisciplinary teams to explore further case studies in different application areas.

I

Setting the Stage for Experience Prototyping

Chapter 2

Experience Beyond Usability

Technology should bring more to our lives than the improved performance of tasks: it should add richness and enjoyment.

– Donald A. Norman (Design Thinker and HCI Researcher) –

In the field of Human-Computer Interaction (HCI), usability is a major concern when designing and developing interactive products. Indeed, when we use technology in our everyday life we want to solve our tasks successfully, with low effort and in a reasonable amount of time. ISO, the International Organization for Standardization, thus defines effectiveness and efficiency to be important characteristics for usability [41]. Nielsen and Norman define quality components of usability[1], such as the number of errors made and how the interface supports users to recover from these errors, the learnability of basic tasks for first time users or the ability to memorize how to use the system. Without doubt, the concept of usability and its application in HCI research had an immense positive impact on the quality of interactive products in our daily lives.

The ISO standard contains one more characteristic of usability next to effectiveness and efficiency. Satisfaction is described as "freedom from discomfort and positive attitudes towards the use of the product" [41]. In his interpretation, Jordan [45] concludes that it is the goal of usability to avoid negative feelings instead of trying to create positive ones. Thus, usability fails to settle Norman's claim for emotional design [79].

[1] http://www.nngroup.com/articles/usability-101-introduction-to-usability (accessed 08/14/2014

Companies such as Starbucks[2] or Apple[3] as well as researchers such as Norman and Hassenzahl [30] point out that there is more to a successful attachment of users to a product than an effective, efficient and satisfying interaction. Despite the fact that all of them use different approaches to tackle this issue, there is a common understanding that *experience* is the key factor.

But what is an experience and what are influencing factors? How can we design for and develop products that trigger experiences? Before elaborating the practical realization and implementation of experiences in the car, which is the focus of this thesis, the following chapters establish the theoretical basis by providing an introduction to the areas of User Experience and Experience Design and associating them to the automotive domain.

2.1 User Experience

In 1996 Alben [2] provided her criteria for a successful interaction design. Despite the aspects we know from the definition of usability, she added the term *aesthetic experience* to her list, meaning that the use of a product shall be "aesthetically pleasing" and "sensually satisfying" [2]. Without further explanation she made the first step towards defining a concept going beyond usability with its goals of effectiveness and efficiency. Alben calls for a careful design of the look and feel of interactive products by addressing different senses such as vision or touch with the goal to create a pleasing and satisfying experience. To be able to understand experiences in more detail, it is necessary to look at literature picking up and extending Alben's concept.

2.1.1 Aesthetics and Emotion

With his thoughts on aesthetics of interactive technology, Norman concludes that "attractive things work better" [79, p. 17]. He argues that users act more creatively when they find a product attractive and thus are more likely to find a good solution to their actual task, which has a direct influence on perceived usability. This phenomenon is described by the Aesthetic-Usability-Effect stating that "aesthetic designs are perceived as easier to use than less-aesthetic designs" [60, p. 20]. Besides the influence of aesthetics on usability, Jordan [45] stated that appearance strongly affects the users' pleasure while interacting with the product and that a product perceived as not attractive even causes displeasure. As most important aspects of appearance he identified style and shape.

Furthermore, Jordan [45] concluded that pleasurable interactions induce users to associate *positive emotions* such as excitement or pride with the corresponding product. Vice versa,

[2] http://www.starbucks.com/about-us/our-heritage (accessed 09/04/2014)

[3] http://www.apple.com/environment/ (accessed 09/04/2014)

displeasurable interactions cause negative emotions such as frustration and anxiety. Norman links these resulting positive emotions to the design of "real experiences" by explaining three levels of human cognitive processing [79, p. 37]. The first level, *visceral processing*, is concerned with the look and feel of a system. Visceral processing happens pre-consciously and is thus responsible for forming important first impressions. The second level, *behavioral processing*, is related to functionality, performance and usability of the product. It focuses on how people use a system and whether it supports them in successfully solving their tasks. Behavioral processing is therefore responsible for changing the affective state in a positive or negative way and thus, in a positive case, adds value to the system in use. But it is the third level described by Norman, *reflective processing*, which is responsible for feelings and emotions that users associate with an interactive product. Reflective processing forms the overall impression of the product [79, p. 88] and due to interpretation and reasoning about the interaction influences self-image, satisfaction and memories. Since visceral, behavioral and reflective levels influence the overall experience with a product, Norman concludes that the design of "any real experience involves [the adherence] of all three" [79, p. 39].

McCarthy and Wright [72] moved emotion even further into the center of attention when talking about experiences. In their model they introduced four threads of experience [72, p. 80]. According to Norman's visceral level of processing they begin with the Sensual Thread as a pre-reflective visceral percipience of a situation through the human sense organs. The Spatio-Temporal Thread specifies interactions to happen in space and time, the Compositional Thread describes "relationships between single parts and the wohle of an experience" [72, p. 87]. The essential part in their model is the definition of an Emotional Thread [72, p. 83]. Similar to Jordan [45] they point out that emotions are directly linked to the character of the experienced event.

2.1.2 From Experience to User Experience

Hassenzahl [30] continued Norman's [79] as well as McCarthy and Wright's [72] work by recognizing that "emotion is at the center of experience" [30, p. 3]. In his definition, he refers back to Forlizzi and Battarbee [17], who describe three types of experience. As *experience* itself they consider a "stream of 'self-talk' that happens when we interact with products" [17]. With their example of walking in the park they show that experiences happen constantly in everyday life and are influenced by people, products and the environment. In contrast, *an experience* is more concrete since it can be named and has a clearly defined beginning and end, such as a ride in a roller coaster. Since people are conscious of this particular experience, it results in behavioral and emotional change. This definition of an experience is clearly related to Norman's description of the behavioral level of cognitive processing [79, p. 37]. Additionally, Forlizzi and Battarbee mention the *Co-Experience* [17] and define it with the collective creation of emotion while using a product together with others or by sharing an experience with others.

Hassenzahl reuses this definition of *an experience* by stating that *User Experience* "is not much different from experience per se. It simply focuses our interest on interactive products." [30, p. 8] Thus, he utilizes interactive technology "as mediators of experience" [30, p. 2].

2.1.3 Defining User Experience

It remains difficult to trace the origin of the nomenclature *User Experience*. Donald Norman coined the term as he stated via Twitter: "In 1993 Apple's UE team = me, Tom Erickson, Harry Sadler–1st use of 'user experience' (I think). We said UE. I don't know who made it UX."[4] In literature, various definitions for User Experience exist. The respective ISO standard defines a "person's perceptions and responses resulting from the use and/or anticipated use of a product, system or service" [41]. Nielsen and Norman have a more general view on the factors shaping UX by stating that it "encompasses *all aspects* of the end-user's interaction"[5]. Alben specifies these aspects as "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" [2]. With "how they feel about it" Alben hints at the emotional results of User Experience, which Hassenzahl extends by stating "a momentary, primarily evaluative feeling (good-bad)" [29]. In the notes accompanying their standard, ISO mentions "emotions, beliefs, preferences, perceptions, physical and psychological responses, behaviours and accomplishments" as parts of User Experience [41]. The standard adds a temporal aspect by stating that user experiences "occur before, during and after use" [41]. Taking all mentioned perspectives and their different aspects into account, I propose the following definition for further elaborations in this thesis:

> **A User Experience** summarizes a person's emotions, feelings, perceptions and psychological responses resulting from the interaction with a product, system or service that can occur before, during and after use in a specific context.

2.1.4 Properties of User Experience

With this definition in mind, User Experience can be further characterized. Hassenzahl lists five key properties describing the nature of User Experience [30, p. 29]. First of all it is subjective, meaning that it is transformed by a psychological process depending on individual factors such as prior experiences or cultural background. This implies that there is no guarantee that an experience we design for is going to be successful due to its subjective nature. This conclusion was already included in McCarthy and Wright's model, who stated that "We

[4] https://twitter.com/jnd1er/status/360031085935075328 (accessed 08/10/2014)

[5] http://www.nngroup.com/articles/definition-user-experience/ (accessed 08/10/2014)

do not perceive an objective representation of the world; rather, we perceive a unique version colored by our unique desires and values as experienced in the situation we are engaged in" [30, p. 85]. Second, a User Experience is holistic, integrating people's actions, motivational factors and cognitive processes into "a meaningful whole" [30, p. 29]. This links to Norman's reflective level of cognitive processing [79, p. 38]. As a third property User Experience is situated and thus always depends on temporal and local factors, implying that "no two experiences are exactly alike" [30, p. 31]. This supports McCarthy and Wright's statement that "different people's experiences with the same system, or even the same people's experiences of a system at different times and in different activities [can be] radically different" [72, p. 85]. The fourth property states that a User Experience is dynamic [30, p. 31], meaning that events and single moments significantly influence the holistic experience. For the design of a successful experience, the order of events therefore needs to be defined and timed. As the last and most important property, a User Experience must be positive. By positive, Hassenzahl does not simply mean fun, he rather stresses the terms worthwhile and valuable [30, p. 31]. Norman supports this definition by stating that "it should add richness and enjoyment" [79, p. 101].

2.1.5 Time Spans of User Experience

When collecting users' experiences with pleasurable products, Jordan [45] found that these experiences do not only happen during interaction, but also prior to and after using the product. In their User Experience White Paper [89] a group of experts on User Experience research under the direction of Roto, Law, Vermeeren and Hoonhout provided a model to show how the interaction with a product can be experienced over time (see figure 2.1). *Anticipated UX* happens before usage. It is influenced by prior experiences with other products or by the brand image of the manufacturer. An example for anticipated UX is the online purchase of a tablet computer due to a commercial on TV or positive impressions the user had with a smartphone by the same manufacturer. *Momentary UX* happens during usage and is similar to Forlizzi and Battarbee's definition of a constant stream of self-talk happening during the interaction with a product [17]. Hassenzahl defines Momentary UX as *experiencing* (as a verb) [30, p. 1]. Considering the tablet example, Momentary UX describes the actual moments when using the tablet depending on the tablet's properties such as size and weight, environmental factors such as direct sunlight or noise and other people that might be involved in the interaction such as a child sitting on the user's lap.

In contrast to experiencing, Hassenzahl defines the actual User Experience, which can be named and which has a beginning and an end [30, p. 1]. Roto et al. [89] divide this type of User Experience into two depending on the defined time span. *Episodic UX* describes a relatively short interval of interacting with a product. Usually, several episodic experiences happen with the same product and are interrupted by periods of non-use. Episodic UX is formed after usage by reflecting on the interaction. An example for an Episodic UX is using the tablet to play a game for one hour. Concluding, *Cumulative UX* is formed during the interaction with a product over time including all Episodic User Experiences.

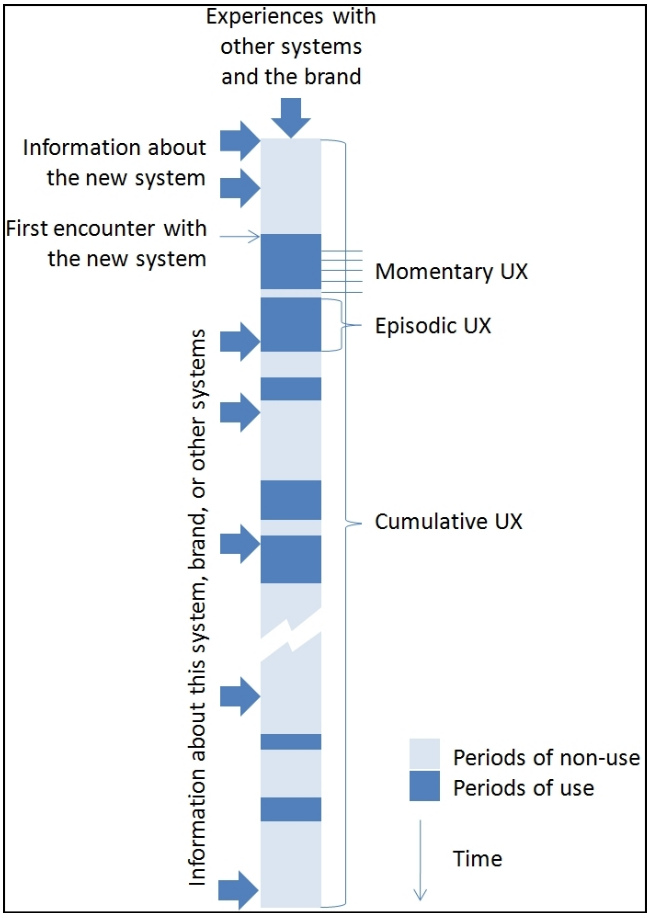

Figure 2.1: The time spans of User Experience. [89]

It focuses on the system as a whole and refers to Hassenzahl's holistic property of User Experience [30, p. 29]. The user of the tablet experiences a Cumulative UX after having interacted with the tablet multiple times for different tasks over several weeks or months. Roto and colleagues [89] underline that it is important to specify the time span that is in focus when designing or reporting on a User Experience.

2.1.6 Factors affecting User Experience

Referring to Hassenzahl's property describing User Experience to be situated [30, p. 31], Roto and colleagues [89] collected three groups of factors influencing interactions with a product and the resulting experiences. The first group of factors emerge from the user himself. Her physical prerequisites influence how she holds the tablet in her hands, her mental resources determine the amount of attention she directs to the interaction, her mood affects her patience towards the way she uses the tablet to work on a task and her expectations influence how satisfied she is with the performance and appearance of the device. As McCarthy and Wright put it, "the quality of experience is as much about the imagination of the consumers as it is about the product they are using" [72, p. 12]. The second group of influencing factors is determined by the interactive system being used. Most notably are the designed properties, such as size, weight or color of a tablet. Furthermore, some of these properties can be added (e.g., a protecting case or plug-ins) or changed (e.g., ring tone or background image) by the user. Finally, interactions with other products of this brand may also influence the overall experience. The third and last group of factors derives from the context of interaction. Examples include the social situation, i.e. other people that are present and the kind of relation the user has to them, the kind of task which has to be executed or the physical situation, e.g., interacting with the tablet while walking. Roto et al. [89] suggest to use this list of influencing factors to define or describe the situation in which a person is supposed to feel a particular user experience.

2.2 Experience Design

According to Jordan [45] usability is an important factor influencing the pleasure or displeasure arising while interacting with a product. While methods for ensuring and evaluating efficiency and effectiveness [41] of interactive systems are well established (e.g., [69]), it remains a challenge to define and measure experiences during interaction. As McCarthy and Wright stated critically: "Employing the phrase 'user-experience design' as a reminder or motivator to designers to pay attention to people's experience of technology is one thing. Employing the phrase to indicate that a particular user experience can be designed is another thing altogether." [72, p. 9]

In his book, Hassenzahl [30] answered that the product itself is not an experience, but interacting with it can trigger and influence experiences. He notes that "without a clear understanding of experience, the interactive products we design will never be able to properly shape experiences, let alone, to create novel experiences" [30, p. 3]. His thoughts lead to the postulation "experience *before* product" [30, p. 63], coining the discipline of *Experience Design* [30]. Taking these considerations and my definition of User Experience on page 16 into account, I propose the following definition.

> **Experience Design** builds on basic psychological principles and provides methods to design, create and evaluate user experiences that arise during the usage of interactive technology. Thereby, the actual design of the experience happens before building interactive prototypes without taking implementation details into account.

In the following sections I will provide an overview of basic psychological principles that Experience Design builds on. Furthermore, I will link Experience Design to the automotive domain and provide insights into an Experience Design process by Knobel [52] who suggested a collection of methods to design, implement and evaluate experiences.

2.2.1 Hedonic and Pragmatic Product Quality

In 1982 Hirschman and Holbrook [35] described two differentiating views on product consumption. In the traditional view, a user defines a product as an object that he can use to "maximize utility, where utility typically is measured as some function of the product's tangible attributes" [35]. In terms of usability, the product needs to facilitate effectiveness and efficiency. Next to this well established product quality, Hirschman and Holbrook define *Hedonic Consumption*, which they define as "those facets of consumer behavior that relate to the multisensory, fantasy and emotive aspects of product usage experience" [35]. By multisensory they refer to the experience of "tastes, sounds, scents, tactile impressions and visual images" triggering historic images recalling past events as well as fantasy imagery evolving in the user's mind. These images lead to emotional arousal including feelings such as joy or fear. They conclude that "sensory-emotive stimulation seeking and cognitive information seeking are two independent dimensions" [35].

Hassenzahl picks up this concept and confirms how people perceive interactive products along two quality dimensions. He and his colleagues compared software systems [33] and visual display units [27] differing in design and interaction style and found that two scales delivered independent results. *Ergonomic quality (EQ)* measures dimensions related to usability and *hedonic quality (HQ)* refers to dimensions such as originality, innovativeness and beauty. They conclude that both were perceived as independent quality concepts. Both EQ and HQ "almost equally contribute to the judgment of APPEAL", which is defined as a subjective measurement of users, e.g., expressing sympathy for the interactive system [33]. In his later work (starting with [28]) Hassenzahl uses the term *pragmatic quality (PQ)* instead of ergonomic quality.

Hassenzahl, Diefenbach and Göritz "collected over 500 positive experiences with interactive products" [31] to further investigate the relationship between both HQ as well as PQ and the positive affect arising during interaction. They conclude that "hedonic quality was more strongly related to [positive affect] than pragmatic quality" and consider HQ as a "motivator capturing the product's perceived ability to create positive experiences" [31]. Furthermore, they identify PQ as a "hygiene factor [...] removing barriers but not being a source of positive experience in itself" [31] supporting Hassenzahl's idea that "pragmatic quality contributes indirectly via making fulfillment more easy and likely" [29].

2.2.2 Be-Goals and asking the Why?-Question

In his three level model on the hierarchy of goals [30, p. 12], Hassenzahl further explores the concept of Hedonic Quality as an independent quality of products. In this model (see figure 2.2), he defines three kinds of goals that users have when interacting with objects. *Do-goals* describe the need for tools in order to successfully solve a task. An example is the goal to call somebody on his smartphone and the successful accomplishment depends on the phone itself and its functionality as well as accordance to usability aspects. *Motor-goals* are caused by do-goals and describe *how* the task of making a phone call can be accomplished. Dialing a number by pressing buttons on a touchscreen and a final use of the call button are examples. Reflecting on both do-goals and motor-goals influences the product design and interaction design of the smartphone from a designer's point of view. The Pragmatic Quality of interactive technology is mainly concerned with the achievement of do-goals.

Concerning Hedonic Quality, Hassenzahl attributes special attention to the third level of his model, the *be-goals* (see figure 2.2). These goals are answers to the question *why* users want to achieve a do-goal. Calling somebody on her smartphone can for instance be important because a person wants to hear the partner's voice while he is absent. "Being close to others" is the underlying be-goal in this example, others might be "being admired" or "being competent" [30, p. 13]. By reflecting on be-goals and the question why users have certain do-goals, Experience Designers are able to identify and design for aspects influencing the Hedonic Quality of a product. Hassenzahl concludes that fulfillment of be-goals is the driver of experience [29] and postulates to "design for the 'why' (including the 'what' and the 'how') rather than for the 'what' and 'how' only" [30, p. 15].

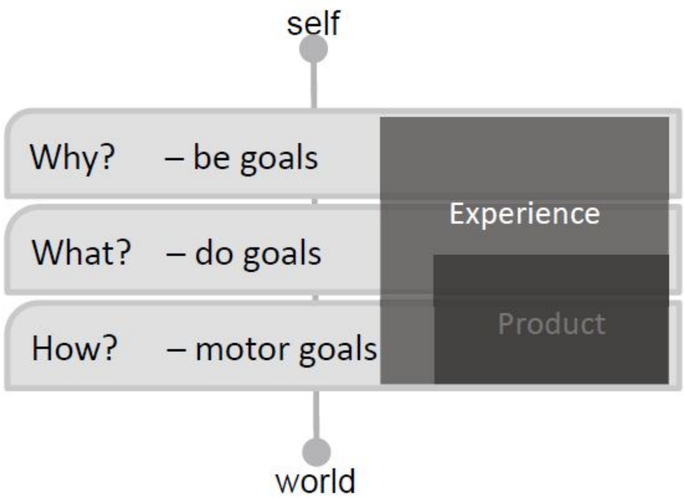

Figure 2.2: The three level hierarchy of goals [30, p. 12]. Be-goals answer the question *why* people perform certain actions and provide them with meaning.

2.2.3 Psychological Needs as Drivers for Experience

One important aspect of investigating be-goals and therefore the factors influencing the Hedonic Quality of interactive products is the understanding of how people express these goals. McCarthy and Wright stated that "because we are always involved in experience, there is no God's-eye view or privileged position of neutrality or authority" [72, p. 50]. Thus, there is a need for a common understanding of be-goals. Hassenzahl observed that "although actual experiences may occur in an infinite number of variations, they share a common, defining core" [30, p. 57]. To define this common core, he suggests "universal psychological needs [...] as important constituents of experience" (see table 2.1) and that "it is the fulfillment of those needs which creates emotion and meaning in interacting with a product" [30, p. 57].

In literature, several need theories were presented. Maslow [70] introduced a hierarchy of basic needs. He considers these needs to be the reasons for humans being motivated. As a starting point, Maslow names *physiological needs* as the lowest group in the hierarchy, including the wants for food, sleep or sex. As long as these "lower" needs are not satisfied, there is no striving for "higher" ones. But as soon as physiological needs are met, the needs for *safety* (e.g., securing the own body or the family), *love* (e.g., friendship or intimacy), *esteem* (e.g., self-confidence or being respected) and *self-actualization* (e.g., being creative or solving problems) become important motivators.

Gaver and Martin [18] presented several conceptual design proposals for supporting emotional communication by interactive technology. They listed six values they aimed to address. Gaver and Martin called the first value *Impressionistic Displays*, describing "people's desire for attention to and variety in the aesthetics of devices" [18]. Furthermore, they list desires for *Diversion* from normal patterns of behavior, *Influence* over environmental factors, *Intimacy*, *Insight* into their individual self and the world, as well as *Mystery* in terms of exploring the unknown.

Jordan [45] interviewed users of interactive products exploring their pleasure and displeasure during interaction. He collected, analyzed and categorized responses and presented a list of pleasurable feelings hinting at psychological needs that need to be addressed by interactive technology. Jordan identified Security, Confidence, Pride, Excitement, Satisfaction, Entertainment, Freedom and Nostalgia [45].

In the course of their Self-Determination Theory Ryan and Deci defined a basic need as "an energizing state that, if satisfied, conduces toward health and well-being but, if not satisfied, contributes to pathology and ill-being" [91]. They identified competence, relatedness and autonomy as essential for personal well-being and state that these psychological needs "must be satisfied across the life span for an individual to experience an ongoing sense of integrity and well-being" [91].

Sheldon et al. confirmed this conclusion when "testing 10 candidate psychological needs" to identify "which are truly most fundamental for humans" [95]. Agreeing with Ryan and Deci [91], the needs for autonomy, competence and relatedness (see table 2.1) were rated among the top needs by people describing events within their live they considered to be most satisfying. Additionally, they found self-esteem to be "important, whereas self-actualization or meaning, physical thriving, popularity or influence, and money-luxury were less important" [95].

Psychological Need	**Items describing the need** ("During this event I felt...")
1. Autonomy	...that my choices were based on my true interests and values. ...free to do things my own way. ...that my choices expressed my "true self."
2. Competence	...that I was successfully completing difficult tasks and projects. ...that I was taking on and mastering hard challenges. ...very capable in what I did.
3. Relatedness	...a sense of contact with people who care for me, and whom I care for. ...close and connected with other people who are important to me. ...a strong sense of intimacy with the people I spent time with.
4. Self-actualization-meaning	...that I was "becoming who I really am." ...a sense of deeper purpose in life. ...a deeper understanding of myself and my place in the universe.
5. Physical thriving	...that I got enough exercise and was in excellent physical condition. ...that my body was getting just what it needed. ...a strong sense of physical well-being.
6. Pleasure-stimulation	...that I was experiencing new sensations and activities. ...intense physical pleasure and enjoyment. ...that I had found new sources and types of stimulation for myself.
7. Money-luxury	...able to buy most of the things I want. ...that I had nice things and possessions. ...that I got plenty of money.
8. Security	...that my life was structured and predictable. ...glad that I have a comfortable set of routines and habits. ...safe from threats and uncertainties.
9. Self-esteem	...that I had many positive qualities. ...quite satisfied with who I am. ...a strong sense of self-respect.
10. Popularity-influence	...that I was a person whose advice others seek out and follow. ...that I strongly influenced others' beliefs and behavior. ...that I had strong impact on what other people did.

Table 2.1: Psychological needs and the respective items describing each need [95].

2.2.4 From Need Fulfillment to Positive Experience

In their studies on the fulfillment of basic psychological needs during experienced interactions, Sheldon et al. found that need fulfillment is positively correlated to positive affect [95]. Hassenzahl et al. confirmed this result in a similar study collecting and analyzing 500 positive experiences concluding that there exists "a clear relationship between need fulfillment and positive affect" [31]. Furthermore, Hassenzahl refers to his three level model of goals [30, p. 12] (see section 2.2.2) and argues that "the fulfillment of be-goals (i.e., basic human needs) is the driver for experience" and that "Hedonic quality, thus, contributes directly to the core of positive experience" [29]. This implies that all experiences people have while using interactive products can be categorized by assigning them to the psychological need they address [31]. Kim et al. [50] suggested a more graduated classification by defining 16 *Experience Patterns*. These categorizations help designers to understand the essence of experiences [50] and in turn allow for the design of meaningful interactions by focusing on one psychological need or experience pattern [30].

Since psychological needs are "more often unconscious rather than conscious [70, p. 389], Sheldon et al. used descriptions starting with "During this event I felt ..." when asking participants about their experiences instead of simply asking for a specific need. For instance instead of asking "Did you feel related to others?" they used three items such as "During this event I felt close and connected with other people who are important to me." [95], which participants rated on a five item Likert scale. With these items (see table 2.1), Sheldon et al. provided a way to describe, define and express each of the ten psychological needs. This paved the way for psychological needs being a reference point in Experience Design.

2.3 Experiences in the Car

After introducing the basic principles of User Experience Design, the following sections will draw a line to the automotive domain. Traditionally, in-vehicle information systems (IVIS) are driver-centered [49] and their design and implementation is concentrated on usability and safety aspects. With emerging research in the field of Experience Design, its focus moved to interactive systems in the car [46, 53]. As a result, experiences while driving became more important and increasingly play a role for car manufacturers. Slogans such as "Sheer Driving Pleasure" (BMW)[6] or "Technology to Enjoy" (SEAT)[7] show that they have recognized pleasurable and enjoyable experiences as a unique selling proposition. But to integrate the methods of Experience Design into development processes that have evolved over decades is nontrivial. The following section provides an overview of pioneering work tackling this challenge.

2.3.1 Social Life on the Road

In his work Oskar Juhlin [46] studied the social aspects of driving. He did not only think about *how* people drive and *what* they do while driving ("use their time in traffic to make phone calls to their family") but also asked *why* they do it that way ("enjoy the journey as a means of escape from a stressful work life") [46, p. 5], a first step towards identifying be-goals and psychological needs of drivers (see section 2.2.2). Juhlin thereby challenges the idea of an isolated and secluded driver and instead focuses on social experiences with passengers in the car, other drivers on the road, traffic participants on foot or bikes and other

[6] http://www.bmw.com (accessed 08/21/2014)

[7] http://www.seat.com (accessed 08/21/2014)

objects or technology in the environment and calls this concept "The Interactive Road" that becomes more "meaningful, aesthetic, fun, and safe" [46, p. 13]. Juhlin calls for a use of technological advances such as mobile devices, infotainment systems and advanced driver assistant systems [93] to overcome the issue of drivers "being enclosed in the shell of a vehicle" [47].

2.3.2 The Design Space of In-Car Interfaces

Naturally, car manufacturers and automotive research primarily focused their work on the driver. It is the driver's first priority to maneuvering the car in a safe way and he is therefore not only responsible for himself and other passengers, but also other drivers, pedestrians and cyclists. Thus, to support the driver's complex tasks, usability, a manageable mental workload and safety should always remain in the focus when developing automotive interfaces.

A Driver-Centered Design Space

Driving a car can be divided into three groups of tasks [21, 101]. *Primary tasks* concern the driving itself and include using the acceleration and braking pedal to control the car's speed as well as steering to move into the desired direction. *Secondary tasks* include all functions directly increasing safety, such as using turn signal and windshield wiper. Controlling IVIS is summarized in the last group, namely *tertiary tasks*.

Kern and Schmidt [49] divided the design space for automotive interfaces into input and output modalities independent from the kind of task. Examples for the former are buttons with haptic feedback, sliders or pedals. Examples for the latter are analog speedometers, indicator lamps or digital displays. Furthermore, they stress the positioning of input and output devices in the driver's interaction environment and identified six areas: windshield, dashboard, center stack, steering wheel, floor and periphery. The position of the input device also determines the body part interacting with it, e.g., right or left foot or hand.

Considering other Passengers

Recently, automotive research increasingly extends the design space for in-car interfaces to areas that are out of reach and out of focus of the driver but consider other passengers in the car. Studies on the collaboration of and interaction between individuals in the car provide important insights to inform the design of future IVIS. Forlizzi et al. [16] observed collaborative navigation strategies with teenage children, partners and unacquainted people as co-drivers. They conclude that due to the importance of communication, future navigation systems should facilitate "some characteristics of human-to-human collaboration" [16]. Brown et al. [7] recorded and analyzed trips of drivers and co-drivers in their cars. They report on the car being a place where people with different relationships, e.g., colleagues or family members, are assembled resulting in a "new form of social relationships" [7]. Conversations are moved from the living room or the office into the car, and cars can even be "a good place for some of our most serious conversations on matters of life, love and death" [7]. These observations indicate that interactions between driver and co-drivers form a new kind of driving experience and an additional group of tasks for the driver and should therefore be considered when designing interactive systems for the car.

Inbar and Tractinsky [39] built on this idea and suggest that passengers should be able to see trip-related information and control parts of the IVIS. They argue that this involvement can "potentially improve travel safety and experience" by helping "drivers to concentrate on their primary task by sharing the load of information and reducing distractions" [39]. Eckoldt et al. provide an example supporting this idea in their *Shared Speed* concept [11]. On a display visible to both driver and co-driver, the current speed of the car and the relation to the allowed speed on this road is displayed. This triggers conversations about the driving style possibly including concerns as well as praise, increasing the driver's awareness of his speed.

Wilfinger et al. [111] suggest to extend this design space of driver and co-driver to passengers on the rear seat. They collected pictures, drawings and notes made by children and their parents during a four week probing study in the families' cars. Basically, they identified three kinds of activities for passengers in the back. One is reducing boredom by listening to music or playing a game independently. A second is collaborative activity such as gaming with the other people in the back. For the last activity children "want to contribute to and support their parents' tasks" [111] and generally like to do things together with the rest of the family such as looking for a restaurant in the next city. They conclude that the design of future IVIS should take the passengers in the rear and their special needs into account.

Moving Outside of the Car

One area that Wilfinger et al. [111] identified as relevant for the backseat was interactive technology for gaming. Juhlin presented a concept for a game for the backseat experience [46]. The player can use a mobile device including GPS functionality and a compass to aim at objects in the environment that can be seen through the window. During this activity, the player needs to find virtual hidden objects which are then integrated into a story that is told during the game. With this concept, Juhlin extends the design space to the environment and the objects that are placed outside the car.

With a Concept called *Sound Pryer*, Östergren and Juhlin [81] include the communication with passengers in other cars that are close to the own car into the design space. Drivers are not only able to enjoy their own music, but can also listen to the music played by other drivers right now. To enhance the experience and enrich the interaction between drivers, Sound Pryer shows a visual representation of the other car, so that drivers can actually spot where the music is coming from.

2.3.3 Automotive Experience Design

After extending the classic driver-oriented design space including different modalities for input and output to other passengers and even objects and vehicles in the direct environment of the car, the concept of need satisfaction as a basis for creating experiences (see section 2.2.3) can now be considered. Eckoldt and colleagues [11] show how six psychological needs are relevant for experience design in the car based on the design space derived in section 2.3.2. *Competence* is important for drivers, especially when managing difficult driving situations or parking the car in a narrow spot. With emerging automated driving or partial automation through advanced driver assistant systems (ADAS), these experiences building on the need for competence are reduced. As an example, they mention how navigation systems indicate each single turn even though the driver usually knows whole parts of the route from prior experience. As a concept considering these thoughts, they introduce *Minimal Navigation*, a system that provides subtle tactile cues in case the driver is lost, "creating the feeling of knowing a route and driving proficiently while being guided" [11] at the same time.

In a similar manner, Eckoldt et al. [11] suggest to make use of the needs for *Stimulation* which can be addressed by discovering interesting places in the environment and for *Security* by providing information on the trip lying before the driver and thus making it predictable. Furthermore, a feeling for *Autonomy* can be created by making use of the fact that the car is a closed and private space and a symbol for freedom in general. *Popularity* can be achieved by enabling positive interactions with others, e.g., shown in a system by Knobel et al. [54] praising a driver for being a Gentleman and giving way to other drivers in different traffic situations. The last psychological need Eckoldt et al. identified as relevant for the automotive domain is *Relatedness*, "regular intimate contact with people who care about you rather than feeling lonely and uncared for" [95].

2.3.4 Feeling Related in the Car

As already stated by Forlizzi [16] and Brown et al. [7] the car provides a physical space for people spending time together while being on holiday trips, shopping tours or when simply sharing the car for the way to work. This social setup offers opportunities to design for relatedness experiences. Knobel and colleagues introduced *ExplorationRide* [55], an interactive IVIS supporting a group of friends while exploring the countryside during leisure rides. A digital map visible to all passengers shows a vague representation of the surroundings that becomes clearer as soon as the car moves along. The whole group is integrated into the choice of a new direction and possible destination. Next to the stimulating character of the system in terms of exploring the environment in an enjoyable way, the interaction also fosters the feeling of relatedness between the members of the group.

With their concept *Together Alone*, Eckoldt et al. [11] aimed for relatedness experiences between friends driving different cars, for instance while driving to or home from work. The systems simply displays if a friend is in his car as well and how much more time they will both be driving, independent from their location or destination. The friends can use this time for talking on the phone, which "provides the feeling of undertaking at least a part of individual journeys together" [11].

Extending his concept of ExplorationRide [55], Knobel introduced *Clique Trip* [53], an IVIS supporting the feeling of relatedness between groups of friends in different cars while driving to a destination together. When the cars are located in the same area, Clique Trip provides a shared channel so that the groups can talk to each other. As soon as the distance between the cars increases, this type of communication is replaced by a display showing the location of the other car, so that one group still has a feeling for the distance to the other. Results of an in-situ study show that the members of both groups felt "as part of one big group even though being in different cars" [53] and how Clique Trip helped to create a relatedness experience.

2.4 An Experience Design Process

After introducing the theoretical basis for experience design and applying it to the automotive domain, the question remains *how* we can actively design for experiences. A first attempt has been made by Knobel [52] who describes methods and tools defining an Experience Design process for interactive systems in the car (see figure 2.3). This process basically follows the user-centered design (UCD) cycle by iterating the four activities of interaction design, namely analysis, design, prototyping and evaluation [88, p. 168]. However, Knobel underlines that "the experience has to become the focus of the design in every design step" [52, p. 25] rather than the system itself with its requirements and functionality. In several case studies [53, 54, 55] he applied UCD methods to Experience Design and suggested a process that I will introduce in the following sections.

To illustrate a given method or tool, I will summarize how Knobel used it during the design and implementation of *Clique Trip* [53], an interactive system that supports communication between groups of friends in different cars while driving to the same destination (see section 2.3.4).

2.4.1 Analyzing Past Experiences

As a basis for designing new experiences, collecting past experiences is the first step in Knobel's approach [52, p. 26]. The method of choice is the *narrative interview* that is used to induce people to tell stories about experiences they once had in a certain context. After recording such a story, *episodic interviews* can be used to ask for more specific details such as "the motivation of the experience, the resulting emotions, and the detailed single course of actions within an experience" [52, p. 27].

After collecting experiences in the form of stories, they need to be structured and analyzed. One way to provide a structure is to sort experiences according to the underlying psycholog-

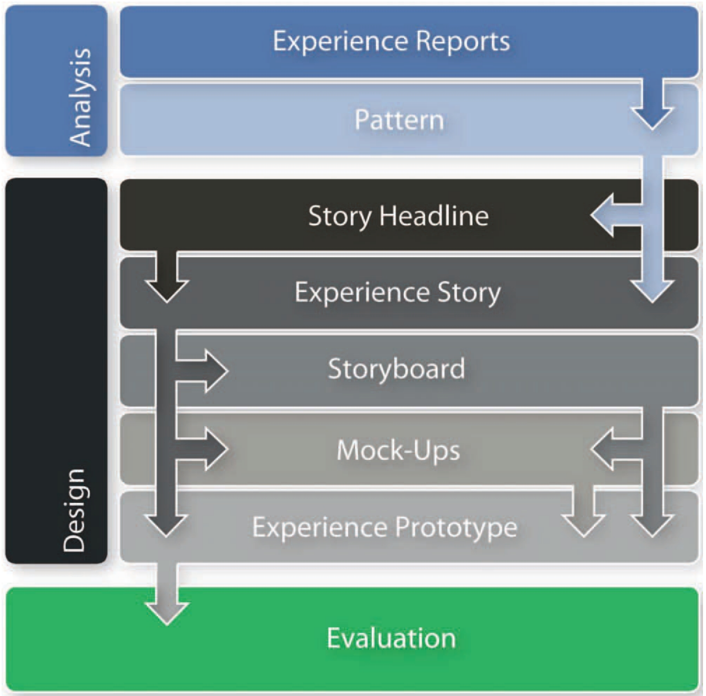

Figure 2.3: Steps of the Experience Design process for designing Clique Trip, an in-car interactive system supporting the communication between groups traveling together in different cars [53].

ical need (see section 2.2.3). A convenient tool is a questionnaire such as the one provided by Sheldon et al. [95], which identifies the psychological needs (see table 2.1) addressed by a particular experience. In a similar way, the PANAS [109] questionnaire can be applied to analyze positive and negative emotions (see section 2.1.1) that were triggered during the experience. The final goal of structuring and analyzing all collected stories is the identification of experience patterns [30, 50]. Each pattern, together with a particular psychological need it represents, summarize the essence of a number of experiences and thus offer a starting point for Experience Design.

When designing Clique Trip, Knobel and his colleagues interviewed participants about situations in the car in which they felt close to others or as part of a group. They collected 26 experiences which fulfilled the need for relatedness (see section 2.3.4) and triggered positive emotions. Out of four of these experiences they identified the "motorcade pattern" describing it with "heading together to the same destination [...] but in different cars" [53]. This pattern is characterized by a limited communication between both cars and thus offers potential for designing interactive technology supporting this kind of experience.

2.4.2 Designing Experiences

After identifying a specific pattern representing collected experiences, the next step is the actual design of the experience without considering technical solutions yet.

Experience Stories

The method of choice is the *experience story*. It describes ideas and concepts in form of a written text. Everybody should be able to understand the essential aspects only by reading the story, which makes it an important communication tool in and outside of the design team [84]. Important parts of a story are the characters, their interactions and the resulting experiences and positive emotions [53]. According to Hassenzahl it is essential to "set the story straight before we start thinking about how we can create this story through a technology" [30, p. 63].

For his Clique Trip application, Knobel started out with a story headline describing the idea for a potential experience design derived from the motorcade pattern. It summarizes the concept as "being one group even when being in different cars" and focuses on "a communication channel, which is restricted and needs some effort to be established" and states that Clique Trip "plays with the tension between the feeling of separation and closeness" [53]. The resulting experience story is the following. Note how feelings and emotions such as "being separated" and "relaxed" are included.

> *Max, Sarah, Marianne, Martin, Monica, and Matthias have known each other for ages. Lately, they don't spend time together as often as before. But one event is always fixed: each year they visit their favorite city as a group – Paris. As usual, they go there in two cars. This year, however, something is different. Max invites all to the trip via Clique Trip, a new app he wants to try out. This app promises to make its users feeling close to each other, even when being in two different cars. All friends are excited to test Clique Trip because they hate the feeling of being separated during the trip. It is time to depart. Max is driving one car, Sarah the other. Sarah is a very sporty driver (some say reckless) and Max drives very relaxed (some say painstakingly slow). Consequently, they tend to lose each other on the motorway, with Max getting more and more behind. But Clique Trip helps out. It changes the navigation system so that it guides Max (in the rear car) to Sarah (in the leading car). Ah, Sarah takes the scenic route. "Good choice", Max thinks. He announces "I guess the others plan to visit the nice little café in the city centre of Reims. Let me try to catch up". He does, and when the cars are close to each other, Clique Trip opens a communication channel. They can now talk to each other, as if sitting in one car. "Hey," Max yells, "I hope you are not planning to have a first glass of Champagne already? I am driving!"* [53]

Storyboards

A storyboard visualizes the important moments of an interaction between one or more characters and the system [103] as described by the experience story. It focuses on the sequence of interaction steps over time and shows the context in which the plot of the story takes place [53]. A storyboard consist of a number of single sketches in a certain order [88]. Small descriptions of the content can accompany each frame. Compared to the written story, Storyboards provide a more detailed view of the interaction and already include ideas *how* an interactive system could look like, without showing implementation details such as user interface elements or technical solutions.

The storyboard of Clique Trip (see figure 2.4) shows how Sarah and Max interact with the application. Both characters are represented only by their silhouettes, details such as hair color and faces have been avoided on purpose. The visible contours of a dashboard and a steering wheel show the inside of a car as setting for the intended experience. The user interface is reduced to a rectangle divided into several sections. A short text in each frame describes what the characters do or say.

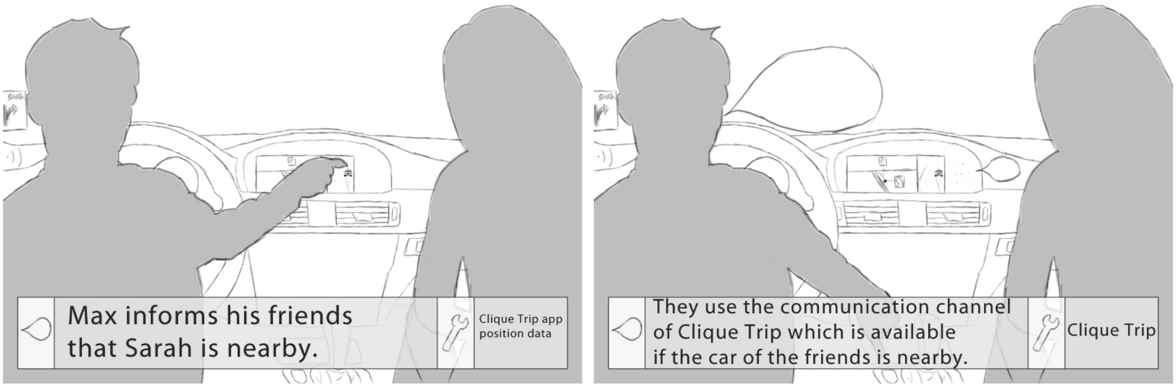

Figure 2.4: A key frame from the storyboard visualizing the Clique Trip application. [53]

2.4.3 Implementing Experiences

The storyboard is a visual representation of a concept providing a first look and feel. However, it "is still immaterial" [53], static and not interactive and thus provides rather limited capability to experience a concept. Therefore, Knobel suggests to transform the storyboard into a working prototype [52, p. 34].

Mock-Ups

However, the concept needs further exploration and testing before making the effort of implementing a system according to the iterative character of user-centered design [88, p. 64].

Errors and changes should be realized and implemented in early design stages in order to save time and effort. Knobel's solution is a interactive mock-up allowing to explore and try a concept without the need to pay attention to limitations due to the technical implementation. Mock-ups serve as a means to translate "the insights of the experience story as well as of the storyboard [...] into technology" [52, p. 33] and help to re-think and form the concept "before creating the fully functional prototype" [52, p. 34].

For Clique Trip, a mock-up based on a Adobe Flash web application was the first interactive representation [52]. In contrast to the storyboard, the mock-up provides details of the user interface design. The screenshot in figure 2.5 (top) shows an abstract map and the route lying in front of the group, giving an idea how far the other car is ahead. Additionally, a representation of the other car and its driver is visualized. Knobel et al. used this mock-up not only for the exploration of the concept, but also for informal evaluations to identify design issues and to find out whether the interface elements support the experience described by story and storyboard.

Functional Prototypes

After adapting the concept as well as the interaction design based on the results from exploring and evaluating the mock-up, the implementation of a fully functional prototype is the next step in Knobel's process. To be able to evaluate the holistic user experience of the system and because prototypes are "intended for a more active audience", "the prototype has to offer all the functionality and the features needed to operate throughout the experience" [52, p. 34]. As Experience Prototyping with its role in the design process and implementation aspects is the main topic of this thesis, related literature on this topic and relevant definitions will be provided in chapter 3.

Figure 2.5 (bottom) shows a screenshot of the final Clique Trip prototype [53]. The user interface of the application is visible in the central information display and shows on a map the environment around the car. Data is retrieved from an online map provider and constantly updated due to the positions of both cars. If the car ahead is close enough, a phone connection is established and the whole group can communicate from car to car. The visual representation of the car ahead changes its size depending on the distance between both vehicles. The application offers all intended interactivity and paves the way for extensive evaluations of the experience.

2.4.4 Evaluating Experiences

When evaluating experiences, the focus is not primarily on the usability of the systems, but rather on the ability of participants to relive the experience during interaction as described by story and storyboard. One strategy is the gathering of qualitative data by interviewing participants after they have used the prototype, e.g., asking how they would describe the

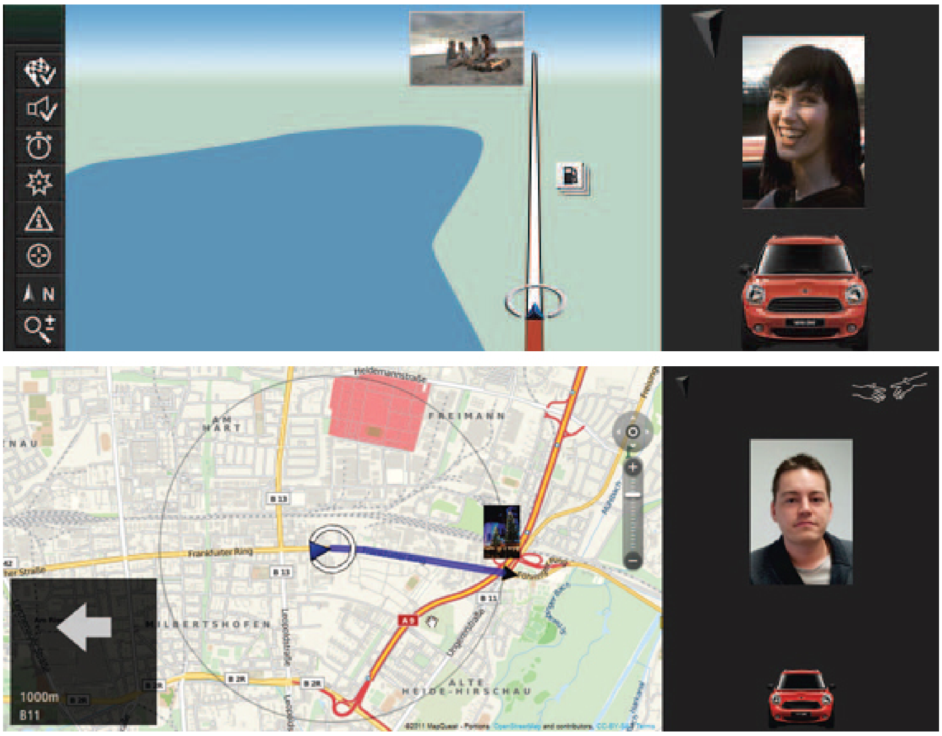

Figure 2.5: Top: A screenshot from the mock-up visualizing the Clique Trip application. [53] Bottom: A screenshot from the prototype implementing the Clique Trip application. [53]

situation, what thoughts they had or how they felt during the interaction [53]. Answers can then be analyzed, structured and mapped to certain emotions or psychological needs and subsequently compared to the intended emotions and needs defined by the experience story.

Nevertheless, this should be complemented by quantitative data. As the experienced situation should be evaluated against the experiences described in the story with its underlying pattern (see section 2.4.1), Knobel [52, p. 34] suggests to apply the same methods that were used during the analysis of past experiences (see section 2.4.1). Hence, participants complete questionnaires measuring the fulfillment of psychological needs, e.g., using need items by Sheldon [95], as well as the arousal of positive and negative emotions, e.g., using the PANAS [109] questionnaire.

When evaluating the Clique Trip experience, Knobel and colleagues reported that the need for relatedness was salient during interactions, which shows that the intended relatedness experience (feeling close to other and as part of a group, see section 2.4.1) was reenacted by participants. Furthermore, by looking for significant correlations between both scales, they conclude that the fulfillment of the need for relatedness triggered positive emotions, showing the successful design of a positive experience.

Chapter 3

Experience Prototyping

Tell me and I forget,
teach me and I may remember,
involve me and I learn.

– Xun Kuang (Chinese Philosopher) –

In human-centered design, prototyping is a key factor of the development process. Without prototyping artifacts of a future interactive system, requirements resulting from design research cannot be translated into features and functionality of a desired product. Furthermore, early evaluations of a concept are impossible without prototypes, preventing the implementation of iterative design processes.

Reports on using prototypes go back to the 1970s, when Brooks reflected on the development process in software engineering and suggests that "one has to build a system to throw away, for even the best planning is not so omniscient as to get it right for the first time" [6, p. 116]. In other words, Brooks suggested the implementation of a prototypical software helping to identify problems that can be fixed before delivering a final and more mature version to the customer.

Today, prototypes exist in various forms. Interactive technology can be represented by a 3D model, a video, a simple piece of software and hardware, or even by non-functional artifact made out of paper or sketched on the back of a napkin. An extensive amount of literature on prototyping proposes diverse definitions, suggests various characteristics of prototypes and proposes frameworks supporting design teams in planning and developing prototypes in different stages of the design process.

The following sections provide definitions for the terms *prototyping* and *experience prototyping*, elaborate why prototyping is essential for the development of interactive technology, present frameworks describing characteristics and dimensions of prototyping and conclude with a critical view on the topic.

3.1 Defining Experience Prototyping

According to the proposal "to build a pilot system and throw it away" by Brooks [6, p. 116], Gordon states that "prototyping is the process of developing a trial version of a system (a prototype) or its components in order to clarify the requirements of the system or to reveal critical design considerations" [23]. Despite the fact that these definitions introduce a basic method allowing for an iterative development process, they are rather abstract and do not provide further details on tools for or the purpose of prototyping. Further review of literature reveals two definitions differing in their interpretations of the medium or tool used for the development of prototypes.

Houde and Hill interpret prototypes as "any representation of a design idea, regardless of medium" [37]. Their point of view is supported by Buchenau and Suri, stating that a prototype can be "any kind of representation, in any medium, that is designed to understand, explore or communicate what it might be like to engage with the product, space or system we are designing" [8]. These definitions imply that a simple drawing as well as a first fully implemented version can be prototypes of an interactive systems.

On the other hand, Buxton [10] differentiates between sketches and prototypes by adding a timeline to his interpretation and considering different phases of the design process: "Sketches dominate the early ideation stages, whereas prototypes are more concentrated at the alter stages where things are converging within the design funnel". He supports his claim by stating that "the investment in a prototype is larger, [...] there are fewer of them, they are less disposable, and they take longer to build" [10, p. 139].

Holmquist [36] categorizes early versions of a future system by their focus on form or function. He defines mock-ups to be "objects that have the appearance but not the function of a certain artifact" and prototypes as "having the functionality but not the appearance of a finished artifact" [36]. Furthermore, he states that the term representation refers to both mock-ups and prototypes, implementing aspects of both form and function.

While Lim et al. confirm the definition of a prototype as a representation of a future system, they emphasize "the purpose of creating a manifestation that, in its simplest form, filters the qualities in which designers are interested, without distorting the understanding of the whole" [61]. By this "Fundamental Prototyping Principle" they suggest an economic way of implementing prototypes that are simple and efficient but yet able to communicate and evaluate a design idea.

Considering the different aspects proposed by these interpretations, I propose the following definition of Prototyping as a basis for the following chapters of this thesis:

> **Prototyping** describes the iterative and economic implementation of different representations of a design idea during different stages of the design process by using any kind of medium with the purpose of understanding, exploring, communicating and evaluating form and function of a future interactive system or parts of this system.

Experience Prototyping includes all aspects described by the definition of Prototyping but focuses on a different purpose. Gaver and Martin give a first hint by stating that "a prototype 'works' when it successfully captures the experience of using a given device, even if implementation issues are not fully resolved" [18]. Buchenau and Suri add a more detailed definition and stress that experience prototypes "emphasize the experiential aspect of whatever representations are needed to successfully (re)live or convey an experience with a product, space or system" and that experience prototyping focuses on "methods and techniques which support active participation to provide a relevant subjective experience" [8]. In their UX White Paper, Roto et al. ask for representation of ideas and concepts in form of experience prototypes in order to "stimulate the participation of prospective users", "enable the capture of emotional responses" and to "sustain the [designed user experience] throughout the design process" [89].

Together with my definition of User Experience in section 2.1.3 and Experience Design in section 2.2 that focuses on a person's emotions, feelings, perceptions and psychological responses resulting from the interaction with a system, I define Experience Prototyping as follows:

> **Experience Prototyping** extends the definition of Prototyping by the focus on implementing a representation of a designed User Experience independent from the underlying technology with the purpose of understanding, exploring, communicating, evaluating and sustaining this Experience throughout the design process as well as engaging the audience to actively interact with the prototype.

3.2 The Purpose of Prototyping

In her pioneering elaborations on prototyping, Floyd [15] formulated three approaches and included reasons why it is essential for the successful implementation of, in her case, software systems. According to Floyd, the first approach is *exploration* which serves the identification of requirements and features of the future system. After completing the requirements list, early prototypes help to discuss alternative solutions to certain issues. The second approach is *experimentation*, according to Floyd the original meaning of prototyping. The goal is to determine whether a possible solution is appropriate for meeting defined requirements. After the implementation of the desired system, further prototyping serves the purpose of *evolution* [15]. The system needs to adapt to changing requirements constantly over time and can thus be defined as a prototype itself.

By reviewing further literature, Floyd's suggested approaches to prototyping can be extended. The definition of Experience Prototyping provided above briefly hints at further reasons for integrating it into the design process, which are understanding, exploration, communication, evaluation and psychological influences on the design team.

3.2.1 Understanding Context and Existing Experiences

In the user-centered design process, design research precedes the development of design ideas and first prototypes. In this early stage, it is essential to understand different user groups and the specific context of use. Nevertheless, simple and fast prototypes can be integrated into this task to help "designers make discoveries themselves" [8]. As an example, Buchenau and Suri report on the development of a portable defibrillator that can be attached to the body and automatically activates as soon as a critical heartbeat occurs. In order to explore possible experiences of people required to wear such a device, each member of the design team carried a pager for several days. Each signal of an incoming message represented a shock triggered by the defibrillator. By logging the context of the exact moment of each 'shock', the team was able to understand the experience triggered in such a situation [8] and to derive the requirements and features of possible design solutions. In this stage, they describe the goal of prototyping as a "simulation of an existing experience which can't be experienced directly because it is unsafe, unavailable, too expensive, etc" [8].

3.2.2 Exploring and Generating Design Ideas

By this time, preferably with the help of prototyping, the design team has managed to understand the problem space, the given context and experiences by potential users with existing products or props. The core task in this next stage of UCD is the generation and exploration of design ideas and concepts. Note that the transition between both phases is fluid, i.e. first design ideas develop during the context analysis and may evolve into concepts during the design phase.

In his book on Sketching User Experience, Buxton underlines the importance of sketching for generating and exploring design ideas stating that sketching helps to "get the design right and the right design" [10]. In his process, he distinguishes sketches and prototypes due to their "cost, timeliness, quantity, and disposability" [10, p. 139]. According to my definition of prototyping I consider sketches to be early prototypes as they are first representations of a designed experience (see section 3), but we agree upon sketching being an important tool especially in the process of ideation.

Concerning the generation of design ideas, Buxton suggests sketches to be quick and plentiful [10, p. 111] and Greenberg at al. support this by the example of quickly "generating at least 10 competing (very different) design concepts" of how to connect two smartphones in order to exchange data [24, 19]. With the help of these early prototypes the experience designer can explore first ideas and discuss them within the design team, following Buxton's principle of "getting the right design" [10]. This is in line with the definition of Experience Prototyping by Buchenau and Suri who use it to develop design ideas making it "easier to grasp the issue" [8].

Continuing the design process, the team can now select promising ones from the pool of possible solutions. As this implies the need to omit several ideas, Buxton assigns the properties of being inexpensive and disposable to early sketches [10, p. 111]. This is also true for paper prototypes[1] or quick hardware hacks[2] which can usually be built in half a day or less. It will be more difficult to omit a prototype requiring higher costs and effort. Buxton suggests to "fail early and fail often" [10, p. 141] and to build or sketch cheap prototypes in order to explore design ideas with a high potential. Buchenau and Suri call this "exploring by doing" and use these early Experience Prototypes to answer the question "What would it feel like if ... ?" [8]

3.2.3 Communicating Design Ideas

In each phase of the UCD process it is essential to communicate ideas, concepts or solutions to others. As soon as somebody thinks of a new idea, she might want to discuss its potential within the design team. Houde and Hill support this by stating that this early feedback is important to critique ideas and to find alternatives [37]. Buchenau and Suri consider communication as important especially for interdisciplinary design teams to "create a shared experience and a common vision" [8]. Early prototypes such as sketches should therefore provide "a sense of openness and freedom" [10, p. 111] leaving room for discussion and alternative suggestions.

While ideas or concepts evolve, it gets more important to communicate them outside of the team. Houde and Hill [37] as well as Buchenau and Suri [8] describe the importance of indicating the progress and status of a project to management and other departments in organizations. Prototypes can help to provide an understanding of current results and issues the team is working on and being tangible artifacts resulting from the work of the team, they convey a feeling of progress to management [22]. However, a sketch or a paper prototype might trigger a lack of understanding and be interpreted as unfinished work or bad design [23]. Thus, it is important to communicate the purpose of such methods [8] before presenting the prototypes.

During the UCD process, it is essential to gain feedback by later users of an interactive system. Especially in experience design, prototypes serve the purpose of protecting the experience story from constraints caused by technological or safety aspects (see section 2). Thus, the successful communication of the experience story through each new prototype is essential and should constantly be subject to evaluations.

3.2.4 Evaluating Designs, Concepts and Implementations

After each iteration a concept should be part of one or more user tests, evaluating whether users interacting with a new prototype are still able to relive the designed experience (see

[1] http://www.nngroup.com/articles/paper-prototyping/ (accessed 10/16/2014)

[2] http://sketchingwithhardware.wordpress.com/ (accessed 10/16/2014)

section 2). Depending on the advancement of the development process, visual representations such as sketches and paper prototypes help to collect early feedback [10].

Though, as Rudd noted, early prototypes may not be a suitable type of representation for user evaluation, "because they are often demonstrated to, rather than exercised by, the user [which is why] it is more difficult to identify design inconsistencies and shortcomings" [90]. On the other hand, hardware prototypes providing parts of the system's functionality "allow active involvement and experiencing of a concept and leads to understanding" and thus to more detailed user feedback [8]. In their work comparing paper and computer based website prototypes, Walker et al. found "that low- and high-fidelity prototypes are equally good at uncovering usability issues" [108]. In summary, the type of prototype will depend on the current phase of the design process as well as the type of feedback the team is looking for.

3.2.5 Psychological Aspects

At last, the development of prototypes does not only have an impact on the project by analyzing the context or generating, exploring and evaluating design concepts, it also influences the design team itself. When observing projects developing interactive technology, Buchenau and Suri noticed that team members involved in prototyping show "a level of personal significance" [8] towards the product. When actively involved in the context analysis, e.g., as in the design of the portable defibrillator in section 3.2.1, they report on the phenomenon of an "owned experience" [8] meaning that they are able to imagine themselves in a specific situation and thus know users' potential feelings, emotions and reactions while interacting with a device.

Gerber and Carroll analyzed the psychological experience of prototyping in a tech-company [22] and conclude that this design method influences how people feel about their work. Gerber and Carroll reported that "the production and rapid visualization of multiple ideas through low-fidelity prototypes allows practitioners to reframe failure as an opportunity for learning, supports a sense of forward progress, and strengthens beliefs about creative ability" [22]. Additionally, they note how prototyping increases satisfaction and motivation by delivering "immediate feedback about work effort to employees who are tackling challenges with great uncertainty" [22].

3.3 Characteristics of Prototypes

Considering the different purposes and goals for using prototyping in iterative design, it is not a trivial task to decide for the right type of prototype for a given step during the development process. Depending on the type of feedback the team is looking for during evaluations, the available time and budget or the skills of designers and developers, various prototyping methods with varying requirements in terms of resources exist. The following sections will provide an overview about characteristics of prototypes and how they influence the feedback by users during studies or presentations.

3.3.1 The Fidelity of Prototypes

Fidelity is the most well-known characteristic of prototypes and has thus received much attention in related literature. When Wong presented his lessons from using prototypes in graphic design, he states that "prototypes constructed early in the graphic design process rely on different [...] rendering styles from those produced in the final stages" [112] ranging from drawings representing the layout structure of a book to printed versions of the layout focusing on the paper choice. Later, Houde and Hill described this characteristic of prototypes "closeness to the eventual design" and called it *fidelity* [37].

Low- and High-Fidelity Prototypes

Table 3.1 shows advantages and disadvantages for low- and high-fidelity prototypes. The most important reasons for choosing a low fidelity are low development costs in terms of time and effort, the possibility to develop several in parallel enabling the evaluation of alternative designs as well as their ability for being a proof-of-concept. On the other hand, high-fidelity artifacts are interactive, offer complete functionality, are robust and thus offer a prototype that can be used for extensive user testing.

Wong encourages the use of low-fidelity prototypes because they leave room "to brainstorm on new ideas and not focus the critique on visual placeholders that were obviously weak" [112]. Buchenau and Suri state that it is "important to promote a low-fidelity mindset for Experience Prototyping" and see a "great value in low-tech methods and improvisation with basic materials" [8]. Rogers et al. suggest to integrate low-fidelity prototypes into early phases of the design process since they are "never intended to be kept and integrated into the final product [...] they are for exploration only" [88, p. 243]. She suggests methods such as storyboarding (see section 2.4.2) and sketching [10]. Since low-fidelity prototypes implement little or no functionality at all (see table 3.1), the Wizard-of-Oz technique can be utilized. This method, named after the corresponding story, describes how a human being "simulates the software's response to the user" [88, p. 245].

Mixed Fidelity Prototypes

Naturally, a prototype may implement some of the system's functionality, but not the full range. Likewise, an interface of a website may be built with a software such as Adobe Photoshop in a high-fidelity manner but still be printed out on paper in a low-fidelity way. This implies a fidelity between high and low and is sometimes called mid-fidelity prototype (e.g., [14]). Nevertheless, Hennipman et al. claim that characterizing prototypes between high and low fidelity is not sufficient to "ensure that prototyping resources are well spent" and

	Advantages	Disadvantages
Low-Fidelity Prototype	Lower development cost Evaluate multiple concepts Useful communication device Address screen layout issues Identify market requirements Proof-of-concept	Limited error checking Poor detailed specification Facilitator-driven Limited utility after requirements established Limited usefulness for usability tests Navigational and flow limitations
High-Fidelity Prototype	Complete functionality Fully interactive User-driven Defines navigational scheme Use for exploration and test Look and feel of final product Serves as living specification Marketing and sales tool	More expensive to develop Time-consuming to create Inefficient for proof-of-concept designs Not effective for requirements gathering

Table 3.1: Advantages and disadvantages of low- and high-fidelity prototypes. [90]

that it is "insufficient to cover the space of possible prototypes" [34]. Therefore, McCurdy et al. introduce a framework for mixed-fidelity prototypes [73].

McCurdy at al. define five dimensions to describe any prototype of an interactive system [73]. The level of visual refinement defines the look of the prototype and can range from sketches to detailed mock-ups. The breadth of functionality describes how many features are already implemented, whereas the depth of functionality informs about the level of detail of the implementation. The richness of interactivity provides information about input and output offered by the prototype. Last, the richness of data model describes if the prototype uses a set of sample data or an actual database for its functionality.

Each of these dimensions can be realized in a different closeness to the eventual final design. Therefore, with the help of this framework, McCurdy et al. define that prototypes are implemented in mixed-fidelity when they provide "high fidelity on some of these dimensions and low fidelity on others" [73]. Hennipman states that "for an experience prototype, it is important that the 'front-end', the part of the prototype visible by the end users, should be as real as possible [...]. The back-end of the prototype [...] is not seen by the end-users and can be developed with very simple techniques (including Wizard of Oz)" [34].

3.3.2 The Resolution of Prototypes

Resolution is a characteristic of prototypes closely related to fidelity. While fidelity describes the "closeness to an eventual design", resolution describes the "amount of detail" [37]. If each feature of a future system is present, independent from the fidelity of its implementation, the prototype provides a high resolution. Please note that resolution does not depend on fidelity. A web interface can be sketched with a pencil on paper (low fidelity), but at the same time all interface elements of the eventual web design can be included in the sketch (high resolution).

In his discussion of prototyping in graphic design, Wong notes that a high resolution is not always beneficial. Especially in early conceptual stages of the design process, "leaving out details can encourage the team to consider alternative designs" and that "low resolution representations can encourage discussion on high level issues" [112].

In their Anatomy of Prototypes, a framework for describing the goals of a specific prototype, Lim et al. "identify an initial set of design aspects that a prototype might exhibit" and call this set *filtering dimension* [61]. They claim that a designer should only focus on specific details of a prototype in order to gain exactly the intended feedback and therefore use a filter when planing the implementation. Similar to McCurdy's framework (see section 3.3.1), Lim et al. define five dimensions of filters, namely appearance (e.g., size, color or weight), data (e.g., data type, privacy or data size), functionality (e.g., system function and user requirements), interactivity (e.g., input, output or feedback) as well as spatial structure (e.g., arrangement of interface or information elements). They suggest the use of these filters because "it is the incompleteness that makes it possible to examine an idea's qualities without building a copy of the final design" [61].

3.3.3 Passive and (Inter)active Prototypes

In their definition of Experience Prototyping, Buchenau and Suri consider "any kind of representation, in any medium" [8]. However, they differentiate passive and active prototypes referring to the degree of participation of the audience. According to this definition, "techniques such as storyboards, scenarios, sketches, videos [...] add value by communicating elements that make up an experience" but Experience Prototyping focuses on "methods and techniques which support active participation" [8].

Passive Prototypes

Naturally, passive prototypes are common in early iterations of the design process because concepts are not yet well defined and need further exploration. Sketches [10] can be a first step in visualizing design ideas. Being representations of a potential future product, they can in fact be considered as prototypes. However, they can merely be used to visually present the idea. The audience can try to imagine a potential future product, but in a rather passive way without the possibility to interact. Similarly, storyboards [103] or stories [84] can provide information about characters interacting with a product and help the audience to imagine themselves in the depicted situation, but again do not allow for any kind of interaction.

When concepts are defined in more detail, videos can be "a useful design tool for prototyping user interfaces" [104]. An early but impressive example is the Starfire video prototype[3]

[3] http://www.asktog.com/starfire/ (accessed 10/15/2014)

produced by Bruce Tognazzini at Sun Microsystems in 1992. The video shows characters interacting with large interactive touch surfaces, performing freehand gestures to control user interfaces and controlling remote technology with the help of mobile devices, which were future visions in the early 1990s. Tognazzini concludes that "Video prototyping is a powerful medium for communicating not only the functionality, but the spirit and personality of a new application or computer" [100]. Similar to Storyboards, they "provide an entire range of visual expressions" [104], but can as well solely be consumed without offering interactivity with the prototype.

Please note that the interactivity of prototypes is related but not equal to their fidelity. Sketches and Stories, of course, have a low fidelity and are not interactive. On the other hand, storyboards and especially videos can simulate complex interactions without the need to actually implement the underlying software and hardware. Thus, they can be produced in a high fidelity showing the complete range of a future system, but still have a passive character and do not allow for any interactivity between prototype and audience.

Active Prototypes

Since the goal of Experience Prototyping is the active engagement of users into representations of a design concept [8], interactive prototypes will be essential in the further course of the design process. They should allow for user input and provide feedback about the system state and possible actions. Most importantly, experience prototypes "are needed to successfully (re)live or convey an experience with a product, space or system" [8], whereas this experience has been designed in the analysis phase of the process (see section 2.4.2).

Paper prototypes can facilitate the first interactive representations of a design idea. They can be built in a quick and cheap way using office materials such as pencils, markers, scissors and sticky notes but also workable materials such as foam core or wire [24, p. 105ff.]. Naturally, paper prototypes do not actually implement functionality, but with the help of the Wizard-of-Oz technique [88, p. 245], they are convenient to simulate features of an interactive system. Greenberg et al. provide an example of designing screens for a smart watch interface [24, p. 133ff.]. After sketching a series of screens on a long piece of paper, they push it through a smartwatch made out of foam core and can thus react on interactions by a user and switch to another screen (see figure 3.1). This kind of prototype helps to find usability issues early on[4] but also to engage the user in the experience of using a new technology or interface. Note that paper prototypes can also be high-fidelity representations of a user interface if a detailed graphical mock-up is printed on paper and used for user evaluations.

In a next step, design concepts can be implemented as software and hardware prototypes. For graphical user interfaces, a wide range of dynamic wireframing tools exist. A popular example is balsamiq[5] which lets designers create interface mock-ups and connect several screens to an interactive click-through prototype. Similarly, POP (Prototyping on Pa-

[4] http://www.nngroup.com/articles/paper-prototyping/ (accessed 10/15/2014)

[5] https://balsamiq.com/ (Last Accessed: October 15th 2014)

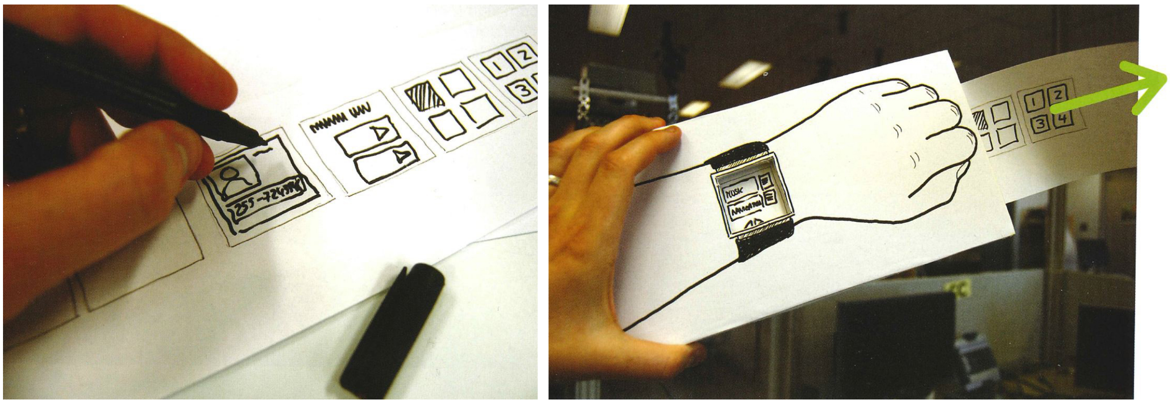

Figure 3.1: Left: Screen designs of an interactive smartwatch interface sketched on paper. Right: The screen can be pulled through a paper prototype of the smartwatch. [24, p. 133]

per)[6] supports the creation of early interactive prototypes for mobile devices by transferring sketched screens directly to the phone. By defining clickable areas, a user can navigate through the screen and get a first impression about the experience of using the eventual app. Additionally, high-level programming languages such as Processing[7] or HTML5[8] in conjunction with CSS[9] and JavaScript[10] allow for a relatively quick but high-fidelity implementation of interactive software prototypes.

For interactive technology, Arduino[11] offers a platform for a quick and inexpensive implementation of hardware prototypes. The electronics platform carries a microchip as well as connections for input and output technology. With the help of sensors, detecting light, temperature or movement, as well as actuators such as motors, LEDs or speakers, interactive representations of design concepts allow for physical user input, can adapt to changes in the environment and also provide different kinds of feedback to users. These methods can be supported by technologies for rapid prototyping (for an overview see [113]) such as 3D printing [92] or laser cutting, allowing for three dimensional processing of soft as well as hard materials and thus high-fidelity interactive prototypes not only focusing on functionality but also on the appearance (e.g., size, color and shape).

[6] https://popapp.in/ (accessed 10/15/2014)

[7] http://www.processing.org/ (accessed 10/15/2014)

[8] http://www.w3.org/TR/html5/ (accessed 10/15/2014)

[9] http://www.w3.org/Style/CSS/ (accessed 10/15/2014)

[10] https://developer.mozilla.org/en-US/docs/Web/JavaScript (accessed 10/15/2014)

[11] http://www.arduino.cc/ (accessed 10/15/2014)

3.4 Approaches to Prototyping

Depending on the purpose and the characteristics of the prototype, different approaches for the implementation exist. The following strategies help to plan all prototyping activities throughout the design process and should thus be considered before starting the design process.

3.4.1 Horizontal and Vertical Prototyping

First of all, the design team needs to decide whether they aim at the exploration of a certain functionality of the eventual interactive system or if a presentation of the entire spectrum of features and appearance is in the focus. Rogers at al. stated that "two common compromises that often must be traded against each other are breadth of functionality provided versus depth" [88, p. 247]. According to their definition, *horizontal* prototypes "provide a wide range of functions but with little detail", whereas *vertical* prototypes "provide a lot of detail for only a few functions" [88, p. 247]. The example of two software representations of a website show the difference: The first one, which is the horizontal prototype, shows an on screen high-fidelity mock-up of the user interface. Each feature of the design concept is visible, but when clicking on a certain link, the user simply receives a short message of what would have happened on the actual finished website. The second prototype, which is a vertical implementation, shows again a mock-up of the website, but only in form of a low-fidelity wireframe, which shows generic placeholders for the various planned features of the website. However, an input field and an icon showing a magnifying glass represent the search functionality of the website. When entering a phrase, the user receives the output of an search with several results in a certain order. Thus, the user is able to test the online search feature of the website and can provide feedback on the quality of the results, the reaction time or the appeal of the results page.

3.4.2 Throw-away and Evolutionary Prototyping

Second, the team needs to decide on the role of the prototype throughout the entire design process. Gordon and Bieman differentiate between two development philosophies [23]. The first is *throw-away* prototyping, which uses artifacts only as "stepping stones towards the final design" [88, p. 248]. Especially low-fidelity prototypes that require only little implementation effort in terms of time and cost. For instance, Buxton defines sketches as quick, inexpensive and disposable [10, p. 111]. The second philosophy is *evolutionary* prototyping and focuses on "evolving a prototype into the final product [88, p. 248]. An example is the horizontal prototype of a website mentioned above that can be constantly extended by implementing the functionality of each single feature over time. The advantage of throw-away prototypes is the possible focus on a specific design issue, but overall requires more time and effort to start new implementations from scratch. This could lead to the combination of several single prototypes into a final product under time pressure in final stages of a project, possibly leading to a loss of quality. On the other hand, evolutionary prototyping can lead to a robust product "but this must be clearly planned and designed for from the beginning" [88, p. 249] because adaptions to changing requirements will be more difficult when working on a mature high-fidelity prototype.

3.4.3 Prototyping Role, Look and Feel, and Implementation

Houde and Hill criticize the description of prototypes using characteristics such as the programming language it was developed with, "because the capabilities and possible uses of tools are often misunderstood [...] particularly to non-designers" [37]. They also point out that a description of prototypes solely by a high or low fidelity is misleading and unclear. Therefore, they introduced a three-dimensional model with each aspect leading to a different approach of prototyping. The first dimension describes the *Role* of the prototype, e.i. how "an artifact serves in a user's life - the way in which it is useful to them" [37]. As an example, they report on the development of a portable laptop computer. A storyboard visualizes the way somebody uses the laptop in his daily routine an thus prototypes the Role of the artifact for potential users. The second dimension is the *Look and Feel* of an artifact and "denotes questions about the concrete sensory experience of using an artifact" [37]. In their example project, they prototyped the size, form and weight of a portable computer by handing a weighted pizza box to a user and watching him carrying it around. This low-fidelity Look and Feel artifact helped to analyze the context in which such a device could be used. The last dimension of prototyping focuses on the *Implementation* of a system [37] and explores the feasibility and potential underlying technologies with their benefits and disadvantages. An Implementation prototype for the laptop example could provide first realizations of the operating system or tools so that developers and users can test reaction times, user interfaces or interaction sequences. Houde and Hill suggest to prototype for all three dimensions in parallel and to subsequently build *Integrational* prototypes "to represent the complete user experience of an artifact" [37]. Depending on the choice for a throw-away or evolutionary prototyping approach (see section 3.4.2), Integrational prototypes can be implemented from scratch or by extending the Implementation artifacts by including the concepts explored by the Role and Look and Feel prototypes.

3.5 Critical Points about Prototyping

With this chapter, I provided an overview of Experience Prototyping and showed why it is essential for each design process. However, if the approaches, methods and tools used for prototyping are not well planned, problems will arise causing misunderstandings between the design team and its audience. Therefore, the design team requires a greater expertise and solid prototyping skills [23].

Especially low-fidelity artifacts may cause irritations. For instance, paper prototyping is a well known method in HCI research but might be unknown among the addressed audience. To unaccustomed users, it can be difficult to make connections between an actual future system and a representation made out of paper or similar materials during user studies or presentations. Gordon and Bieman noted that the audience "may equate the incompleteness and imperfections in a prototype with shoddy design" [23] which can cause management to disbelieve in the progress of the project or users to express negative feedback on certain design aspects. Additionally, early prototypes implementing a first release of a functionality can have a negative effect on performance and robustness of the system [23]. Therefore, they suggest that "users should be clearly told that they are interacting with a mock-up for purposes of requirement clarification, and not with a working system" [23].

On the other hand, high-fidelity prototypes can cause wrong impressions and expectations among the audience. Holmquist states "when an artifact has a surface appearance that closely resembles that of a finished product, it is easy to start treating it as just that" [36]. Consequently, clients and management may believe that a working solution exists and is already deployable [8]. Again, it will be essential to communicate the purpose of each specific prototype (see section 3.2) and to choose appropriate characteristics for each artifact (see section 3.3). Furthermore, Houde and Hill noted that it is critical to choose the appropriate medium for presenting a prototype. For instance, showing a non-functional concept in the form of a video prototype can cause misunderstandings because "inexperienced audiences tend to believe [prototypes] to be more functional than they are just by virtue of being shown on a computer screen" [37]. This is also an issue inside companies if "sales staff may pass along inappropriate expectations to customers after seeing working prototypes" [23].

Chapter 4

CAR@TUM Project "User Experience"

CAR@TUM, the Center for Automotive Research in Munich, is a cooperation between Technische Universität München and BMW Group. Within CAR@TUM, PhD students with diverse backgrounds work on automotive projects with the goal to strengthen the exchange between research and industry.

I was involved in the CAR@TUM project "User Experience", initiated with the goal to develop an experience design process for automotive applications. BMW AG as an important car manufacturer in the premium segment succeeded in building cars based on reliable and innovative technology and creating, in the company's own words, "Sheer Driving Pleasure". Nevertheless, while producing technologically well-engineered cars, BMW realized that experiences while driving became more important for their customers. Furthermore, experiences of other passengers in the car, such as the co-driver and the children in the back, moved into the focus of marketing and development teams. But what is an experience? And how can experiences be designed? Which methods and tools are suitable to create experiences? The goals of the project included a theoretical background for user experience, a design process focusing on experiences in the car and a proof of concept in the form of experience prototypes translating the theoretical work into practice.

The interdisciplinary project team consisted of PhD students from Industrial Design, Ergonomics, Product Development and Human-Computer-Interaction. With my background in HCI and Media Informatics, I was responsible for the interaction design and the implementation of experience prototypes. Throughout the project, we designed and implemented several interactive in-vehicle information systems in order to develop and evaluate our experience design process. *Heartbeat*, the *Periscope* and *GestShare* are three of these case studies and will be elaborated in chapter 5, chapter 6 and chapter 7 of this thesis.

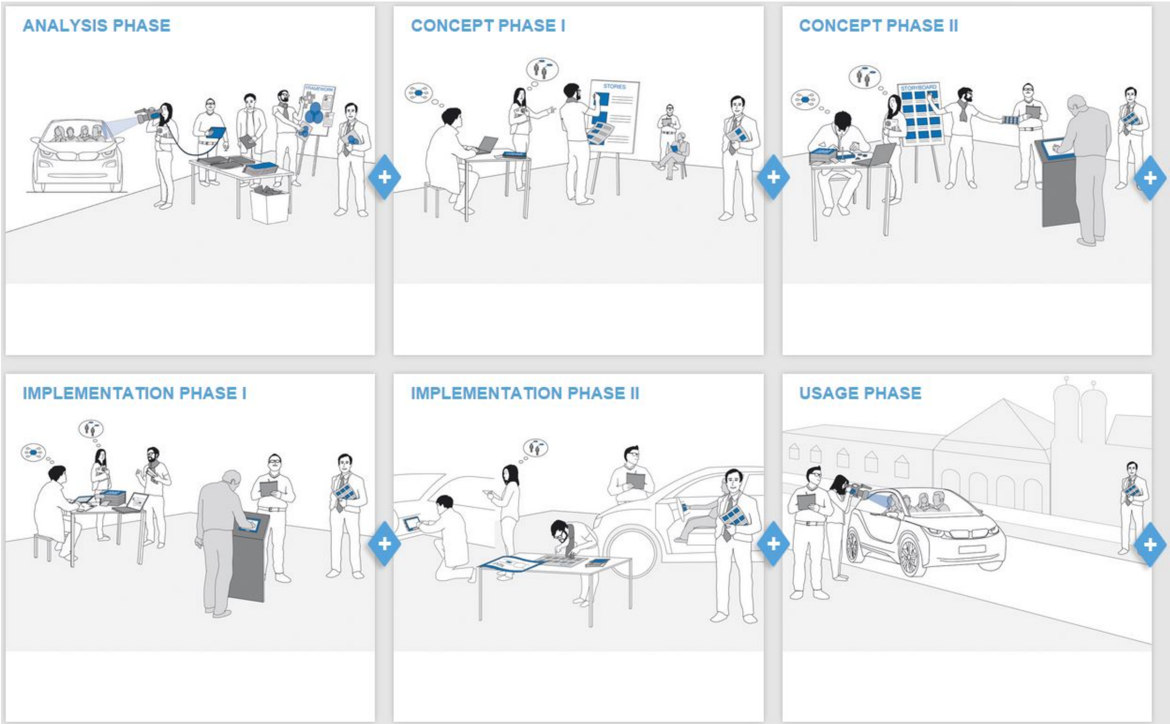

Figure 4.1: The CAR@TUM Experience Design Process Visualized in an Interactive Web Application available at http://designingexperiences.org/

4.1 The CAR@TUM Experience Design Process

Before dealing with the concepts of *Heartbeat*, *Periscope* and *GestShare* it is important to understand the underlying design process. It is divided into six *phases* (see Figure 4.1), each resulting in a *milestone*. Each phase consists of several process *steps*, each consisting of methods and tools we used during the project. Several team members with defined *roles* are involved in the process. Depending on different use cases automotive development teams might have, the process can be used for different *goals*.

To ensure an uncomplicated familiarization with the process, we visualized it as an interactive website. Users can zoom into the phase of interest and explore the underlying steps describing methods and tools. The website is available via http://designingexperiences.org/. It is optimized for Google Chrome, Apple Safari and Mozilla Firefox.

4.1.1 Roles in the Interdisciplinary UX Team

Summarizing the experiences we made in the course of the interdisciplinary work, we introduced five roles (see figure 4.2) that are crucial to an experience design project. While we suggest that the know-how of each role should be represented in the team, it is not necessary

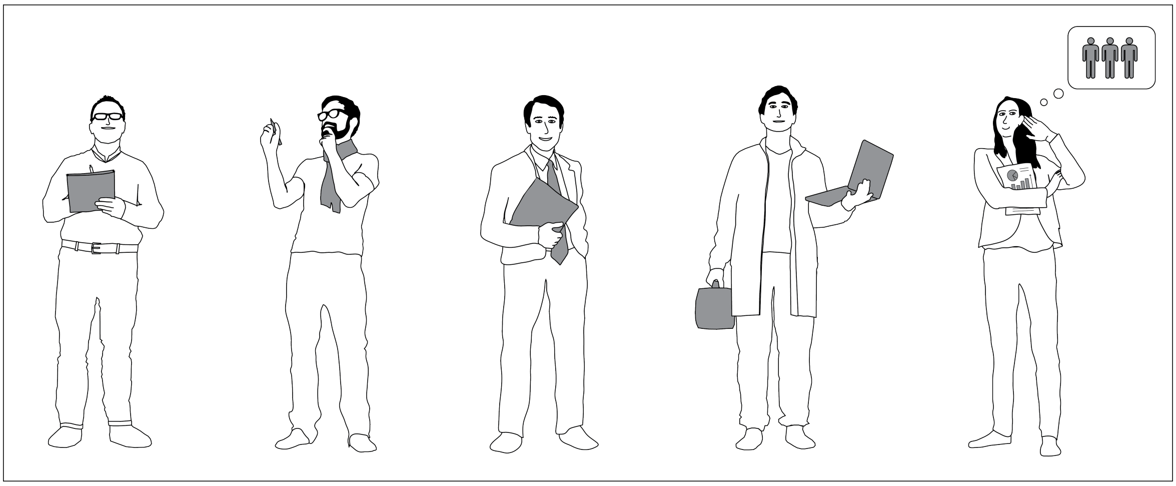

Figure 4.2: The roles of the CAR@TUm Experience Design Process. From left to right: Human Factors Expert, Experience Designer, Storykeeper, Developer and Customer Expert. Drawn by Marc Landau.

to fill in each role with a dedicated person. For instance, in the CAR@TUM User Experience Team I implemented hardware and software prototypes and thus cast the role of the *Developer*. At the same time, with my background in Human-Computer-Interaction, I took part in field research to identify user needs and in user studies to evaluate our designs, concepts and prototypes. Thus, I partly filled the roles of the *Customer Expert* and the *Evaluator* as well. Independent from the number of involved team members, know-how of the following five roles should be combined in an experience design team.

Human Factors Expert

The Human Factors Expert identifies user groups and knows their needs and motives. He combines this knowledge with technological potentials identified by the Developer. One of his important tasks is the development of methods and tools that help the team to evaluate usability and experiences. He designs, conducts and statistically evaluates user studies throughout the design process.

Experience Designer

The Experience Designer is a creative person contributing ideas to the design team. With his independent way of thinking, he is able to develop these ideas into concepts. He visualizes his thoughts in written stories, sketches and storyboards and thus communicates the concepts to the other members of the team, to the management and to potential later users. Especially in early design stages, the Experience Designer steadily exchanges ideas and concepts with the Developer, who gives input about the technical feasibility.

Storykeeper

While the other roles are important for project teams in general, the Storykeeper is a new role we defined especially for the Experience Design Process. The Storykeeper manages the design project and ensures the consistent design and development of experiences according to the underlying story and storyboard. With his responsibilities, he is not directly involved in the process steps, but can always act as a consultant and verifies each milestone according to the adherence to the experience story. His most important task is to protect the experience from the influence of other requirements, e.g., derived from safety regulations or technical specifications.

Developer

The Developer has a technological background. He scouts the market for future technologies and uncovers potentials for future interactive systems. With his know-how, he develops concepts for automotive interactive systems, derives technical requirements and thus translates stories and storyboards into prototypes, which are important to explore and evaluate potential experiences. The Developer generates functional requirements and communicates them to the executing engineers.

Customer Expert

The customer expert knows development and trends of the market. During user research, he observes and interviews representatives of the user group. Based on the results, he quantifies the user in terms of needs, motives and demographic data such as age, geographic information and social environment. The Customer Expert communicates the designed experience based on story, storyboards and prototypes to the user.

4.1.2 Six Phases of the Experience Design Process

In order to structure our approach and to allow for a reproducibility of our process, we divided it into six consecutive phases. In general, we followed the process model for user-centered design [88, p. 168] including user research and data analysis, concepts, prototypes and evaluation. Due to the importance of iterating concepts and prototypes with different degrees of fidelity and resolution, we implemented two concept and two implementation phases. Each phase consists of several process steps, which I will explain in the following sections.

Analysis Phase

The first step of the first phase is the definition of a user group, including demographic data, market analyses and strategic decisions. During step two, the user research including observation methods (e.g., 'A day in the live' or 'Shadowing'), semi-structured interviews and

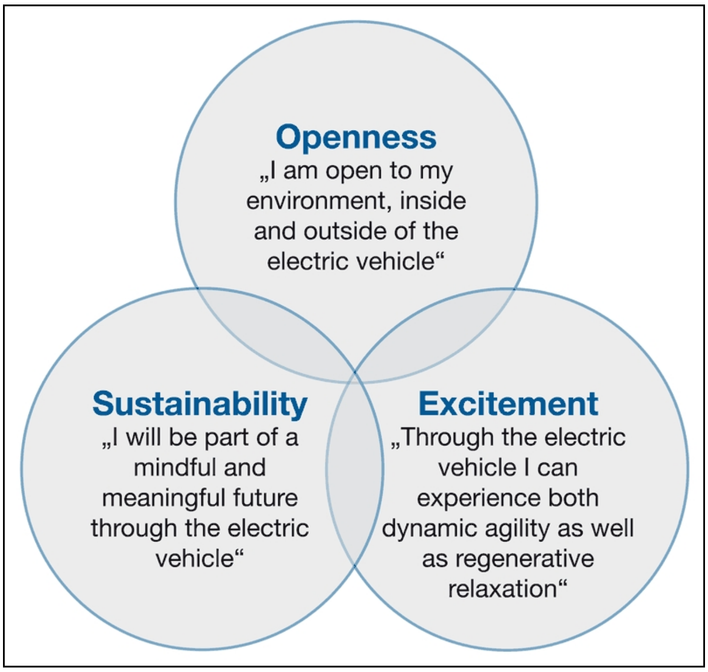

Figure 4.3: The Experience Framework is the result of the analysis phase of the CAR@TUM Experience Design Process. It defines Excitement, Sustainability and Openness and central themes for the design of experiences in the electric vehicle.

online surveys, we collect insights and experiences as a basis for later concepts. In step three, we structure the data collected during user research with the goal to identify user needs and motives. As experience designers, we focus on the positive aspects of interactive systems. Thus, the goal of step four is the identification of chances, i.e. potential experiences, instead of problems that need to be solved. Subsequently, as a milestone for the analysis phase, we define a framework, representing the essential findings from user research, in one single visual representation (see figure 4.3). The framework summarizes the most promising potentials for designing experiences, including first ideas and scribbles to support the validity and value of each potential.

Concept Phase I

The creation of experience stories is in the focus of the second process phase. Each story, derived from the framework, describes a potential experience in form of a written text. The story describes emotions, feelings and important interactions, but does not provide implementation details in order to avoid influences by technical constraints. Our first evaluation cycle starts in this early phase with online studies investigating the fulfillment of psychological needs and arousal of positive emotions while participants read the story and put themselves in the role of the main character. The milestone of this phase is a collection of stories, each representing a positive experience. With the completion of Concept Phase I stories are fixed, meaning that they are not allowed to be changed at any step of the design process in order to ensure a consistent experience. Therewith, the stories need to be translated into qualitative requirements that will complement the requirement specification defined during the following phases.

Concept Phase II

The experience stories resulting from the first concept phase need to be translated into storyboards during the second concept phase. These storyboards contain six to eight frames, visualizing the key elements of the story. According to [8], such a visualization is already a representation of an experience and therefore a prototype. Thus, similar to stories, storyboards need to be evaluated according to their need fulfillment and arousal of positive emotions. While drawing the frames, which is usually a competence of the Experience Designer, he is in a close exchange with the Developer. While refining and updating the storyboard they develop more detailed ideas about the interactive system that will realize the designed experience. The Developer implements first hardware or software prototypes in order to provide the look and feel of the future system, deriving technical requirements in addition to qualitative requirements from Concept Phase I. In an iterative process, the storyboard influences the next version of the prototype, which again affects the next storyboard. Storyboards together with early experience prototypes constitute the milestone of this phase.

Implementation Phase I

The milestone of the first implementation phase are prototypes implementing a higher fidelity and resolution compared to the early prototypes from the Concept Phase. The prototypes need to be interactive and robust enough for first extensive user tests. To ensure that the designed experiences are triggered while interacting with the prototypes, evaluations of every adapted implementation are crucial. We suggest to realize several alternatives of one prototype when certain design decisions need to be made. Results of an experience evaluation comparing both prototypes can support such a decision.

Implementation Phase II

When building a rather complex product, several development teams implement interactive systems with possibly different experience designs in parallel. These experiences potentially influence each other, affecting our goal of creating a holistic user experience. Therefore, a virtual concept for the integration of all components, including constraints such as safety and space, must be part of the design process. We suggest the development of this concept in Concept Phase I and a hand-over to all other phases. During Implementation Phase II we integrate high-fidelity and high-resolution prototypes into their working environment (e.g., in our case, a car’s dashboard) based on the integration concept. Positive results in terms of need fulfillment and triggering positive emotions demonstrate the successful design of a holistic experience.

Usage Phase

Experience evaluations should continue upon completion of the final prototypes. User studies in the field provide valuable insights about the successful design of experiences under real world conditions. Results in terms of quantitative and qualitative data as well as user stories told while interacting with the prototypes are an important resource for the Analyses Phase of the next design cycle respectively a follow-up project or successor product.

4.2 Outcomes

In the course of the project, we applied and adapted numerous methods from design, human-computer-interaction, psychology and engineering within an interdisciplinary team with the goal to propose an process for designing, developing and evaluation experiences in the automotive context. Several case studies, Heartbeat (see chapter 5), Periscope (see chapter 6), and GestShare (see chapter 7) served as experimental playground and proof of concept for our approach, leading us to the following results. In this thesis, I will provide details on the Experience Design process with a focus on Experience Prototyping.

The Experience Design Process implements all four activities known from user-centered design, namely analysis, design, implementation and evaluation. We translated these activities into six phases, dividing design and implementation into two phases each. Each phase is iterative, meaning that, independent from the medium, several representations of an idea, concept or prototype should be generated, refined and evaluated. The team delivers a milestone at the end of each phase, which is a fixed representation of the designed experience.

Five Different Roles illustrate the know-how crucial to the Experience Design Team. The Experience Designer is a creative person, creating and illustrating ideas and concepts. The Developer knows future technologies, has technical skills and implements concepts with interactive prototypes. The Human Factors Expert with his psychological background provides basic theories concerning user experience and evaluates experience prototypes in terms of the arousal of positive emotions. The customer expert quantifies the user group, knows their needs and motives and communicates experiences. We introduce a new role, the Storykeeper. He is a project manager and responsible for a consistent holistic experience at the result of the process.

The Designed Experience moves from one phase to another and materializes in different representations as a milestone at the end of every phase. Starting as an idea and a first sketch, it evolves to a written experience story describing feelings and emotions of one or more characters, while implementation details are left out. A storyboard visualizes the experience story and implements together with low fidelity prototypes a concept for an interactive system. Mid and high fidelity prototypes implement the functionality of the future system and allow for extensive experience evaluations. The integration of several prototypes implementing different experiences into one product and its evaluation based on a virtual integration concept is the last step towards a holistic experience.

II

Case Studies for Experience Prototyping

Chapter 5

Heartbeat: An Electric Vehicle Information System

A runner must run with dreams in his heart.

– Emil Zátopek (Olympic Track and Field Champion) –

In this chapter, I will introduce Heartbeat[1], a concept for communication energy-related information to drivers of electric vehicles. The design follows the metaphor of a runner placing a hand on her chest to feel the rhythm of her beating heart. According to this analogy, EV drivers can interact with Heartbeat to experience the state of the electric drive, the charging level of the batteries as well as the current energy consumption, helping them to explore this new technology and to create a feeling for the range of the car. Heartbeat is the first of three case studies I will present. The following sections focus on two aspects. (1) The description of the various steps of designing Heartbeat introduces the Experience Design process of the CAR@TUM project in more detail. It provides insights into the analysis of the context of e-mobility, the definition of the experience with the help of a story and a storyboard, the implementation of experience prototypes and the user studies we conducted to evaluate the Heartbeat concept. (2) A detailed elaboration on the implementation of two experience prototypes show that they are essential to communicate and explore the designed experience and how Experience Prototyping ensures the preservation of the story throughout the design process.

[1] This chapter is based on [64]. For more details please see the disclaimer on page ix.

5.1 Background and Motivation

"The Future of Cars is Electric"[2] claimed Martin Eberhard, Co-founder of Tesla Motors. There are good reasons why his prediction could prove to be true: Electric Vehicles (EVs) are clean, quiet and efficient. Because of the electric drive they offer a fast acceleration[3] and paired with the low center of gravity caused by heavy battery packs in the floor allow for a new kind of driving experience[4]. The new technology enables car manufacturers to leave out the center console[5] and thus to provide new design opportunities for the interior. The efficient use of electricity, if produced using renewable energy sources, leads to a sustainable way of driving. Governments of China [98], Germany [9] and the USA[6] are aware of these advantages and defined ambitious goals to each bring one million EVs onto their streets by the end of this decade.

However, potential customers are still skeptical and point out shortcomings preventing them from buying EVs. Range anxiety is a well known concern defined as "fear of becoming stranded with a discharged battery in a limited range vehicle" [99]. Additionally, drivers worry about an insufficient charging infrastructure, i.e. a low number of charging stations in disadvantageous locations, and a long charging time [25] compared to a fast and uncomplicated refueling of cars with a combustion engine. Combined with high prices and a limited range of offered models, EVs still lack attractiveness. It remains a challenge for researchers and car manufacturers to develop convincing e-mobility concepts and EVs in order to achieve a wide acceptance among customers.

5.1.1 Electric Vehicle Information Systems

In a series of workshops on Electric Vehicle Information Systems (EVIS)[7] at the International Conference on Automotive User Interfaces and Interactive Vehicular Applications[8], we brought together representatives from academia, industry and the U.S. Department of Transportation to discuss the future of e-mobility. As a result, we created a catalog of ten EV characteristics [80] that lead to chances and challenges which have an important influence on the development of EVs and their interactive technology. Examples are a different driving behavior, a novel sound experience or the need to communicate energy consumption and range prediction to EV drivers.

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[2] http://www.teslamotors.com/blog/future-cars-electric (accessed 10/22/2014)

[3] http://www.teslamotors.com/models/design (accessed 10/22/2014)

[4] http://www.bmw.com/com/en/insights/corporation/bmwi/concept.html (accessed 10/22/2014)

[5] http://www.bmw.com/com/en/newvehicles/i/i3/2013/showroom/design.html (accessed 10/22/2014)

[6] http://www.whitehouse.gov/briefing-room/Speeches-and-Remarks/2011/01 (accessed 10/22/2014)

[7] http://evis.medien.ifi.lmu.de/ (accessed 10/23/2014)

[8] http://www.auto-ui.org/ (accessed 01/05/2015)

When looking at EV models that are currently on the market, car companies have two approaches. The Volkswagen e-Golf is predominantly a copy of the Golf driven by a combustion engine and advertised by "The e-Golf looks confusingly like the Golf from the outside. The technological revolution happens under the bonnet."[9] This approach, which is called conversion design, is continued in the interior, where common interfaces are supplemented by a Powermeter that "shows the current level of energy available to the driver". On the other hand, as an example for purpose design, BMW started the brand BMW i to represent the development of a novel concept for e-mobility[10]. Considering exterior and interior design, their EV models i3 and i8 differ significantly from the serial cars with combustion engines. Additionally, specifically developed in-vehicle information systems and a smartphone app visualize EV specific information such as a map representing the possible range for different driving modes depending on state of charge and traffic situation.

Both approaches have advantages. On the one hand, customers might feel more comfortable in an environment they are used to, independent from the underlying technology. On the other hand, car companies have the opportunity to redesign the car itself, which has been unchanged for decades, and to adapt its design and functionality to the needs of EV drivers. Independent from the approach, manufacturers have realized a need for specific interfaces due to special characteristics of electric cars. The Discussion during the workshops lead to our recommendation to design and develop EVIS that "communicate EV specific information to all passengers in a positive and understandable way" [66].

5.1.2 Communicating the State of the EV

Communicating EV specific information to the driver is a novel field of human-computer interaction. Strömberg et al. [97] evaluated alternative EV instrument clusters, one designed in a traditional and the other in an innovative way. Their results confirm the advantages and disadvantages of the two approaches mentioned in the last section: Participants appreciated the prototype that matched the instrument cluster of a conventional car but it caused them to assume that "the vehicle functioned in the same way" and thus "they had trouble understanding the aspects specific to the electric car and the behavior of the instruments" [97]. The interface adapted to EV specific characteristics "made participants aware that this was a new type of vehicle" but at the same time "made them feel more insecure and more hesitant towards the vehicle and the interface" [97].

Lundström et al. [68] claim that information such as the Distance to Empty (DTE) is an abstract way of communicating energy related information to the driver. Instead they suggest that "a reachable area [according to the batteries' State of Charge] mapped onto a representation of physical space (maps) might provide a more graspable and understandable picture" [68]. Possible solutions take environmental factors such as wind, temperature and elevation,

[9] http://emobility.volkswagen.de/int/en/private/cars/eGolf.html (accessed 10/23/2014)

[10] http://www.bmw.com/com/en/insights/corporation/bmwi/concept.html (accessed 10/22/2014)

driving related factors such as energy consumption of in-vehicle information and comfort systems as well as speed and acceleration behavior into account [67].

One aspect critical for drivers is the communication of the state of the EV's electric drive. From cars powered by a combustion engine we are used to feel vibrations and to hear a typical sound of the starting engine whenever we turn the key or push the start-stop-button. This tactile and audible feedback is not present when starting the electric motor of an EV. Instead, in-vehicle interfaces display a 'ready' indication or move a gauge pointer to a position labeled with 'ready' [110]. Studies show that especially for inexperienced EV drivers it is difficult to tell if the car is ready to go or not. Strömberg et al. found that "improved information is needed to indicate to the driver whether the vehicle is ready to drive or not" because "the propulsion ready symbol was too difficult to notice as the participants were too used to auditory feedback" [97]. Wellings at al. report how "feedback from users suggests that when the subtle 'Ready' message is only textual, this is often missed" [110].

This is in line with observations we made during the analysis phase of our design process (see section 4.1.2). We interviewed EV drivers and analyzed articles from magazines, web sites and scientific EV studies. Furthermore, we visited BMW USA to test the ActiveE, Tesla to drive the Model S and the Automotive Research Center in Stanford to discuss the development of electric cars. One issue we became aware of at several occasions was a confusion about the state of the electric drive: is the car ready to drive or not? Another issue is the communication of the range or DTE of the EV: energy consumption is expressed in kilowatt hours, which is difficult to interpret without background knowledge [110]. The State of Charge (SoC) of the Battery is indicated in percent or by a gauge similar to a classic fuel indicator [110]. But compared to combustion engines, the SoC is strongly influenced by the environmental factors: low outside temperatures cause the batteries to discharge faster than usual; traffic jams or the usage of the entertainment systems decrease the SoC and with it the range of the EV.

Following our experience design process it was our goal to create an interface that communicates crucial information such as State of Charge and the state of the electric drive in a natural, understandable and experienceable way.

5.2 From the Idea to the Heartbeat Concept

When doing research on electric mobility, we visited DriveNow USA[11] in San Francisco. This car sharing company offers electric vehicles only and thus was an interesting resource for collecting user feedback. We used the opportunity and rented a BMW ActiveE[12], an all electric version of the BMW 1 Series Coupe. As DriveNow names all of his cars, our ActiveE was called Pete. When it was his turn to drive, one of our team members pushed

[11] https://us.drive-now.com/ (accessed 10/23/2014)

[12] https://us.drive-now.com/#!/bmw-active-e (accessed 10/23/2014)

the start-stop-button, looked around and finally said, obviously confused: "I have no clue if Pete is awake or not!"

Amused by him mentioning a human attribute when talking about a car, we picked up this analogy in a later discussion about our Experience Framework (see section 4.1.2) on electric mobility. During our analysis phase, we had already observed that especially inexperienced EV drivers have trouble recognizing whether the car is ready to go or not. One of our concepts for communicating the state of the EV to the driver was inspired by the anecdote happening at out test drive. We called it the Human Car and described it by "my e-car communicates with me in a human way". One of the first ideas emerging from brainstorming about this concept was the ability of the driver to perceive the heartbeat of his car when it is started. A second idea described how the driver can feel and hear the energy flow in his EV. The images of *The Heartbeat* and *Energy Flow* constitute the basis for the following experience story.

5.2.1 The Heartbeat Experience Story

The creation of an Experience Story is the milestone of Concept Phase I of our Experience Design process. This Story is essential for designing the experience *before* implementing prototypes and is important to explore the idea, the concept and the potential to create experiences (see section 2.4.2). Experience Stories express feelings and emotions of the characters that are based on the fulfillment of psychological needs (see section 2.2.3). In the Heartbeat Story, we addressed the following psychological needs:

Pleasure Stimulation: The driver explores the state and the energy flow of his electric vehicle in a natural and exciting way and experiences new sensations.

Control: The driver feels confident about his electric vehicle, can be sure that today's destinations are in reach and knows in time when to stop for a recharge.

The storyboard in figure 5.1 represents the first visualization of the Heartbeat Story. We used the split-screen method to show the analogies between the energy consumption of a human runner and an electric vehicle as described in the story.

The following story together with the storyboard can be considered as the first prototype of Heartbeat. Even though it does not describe a future interactive systems or any implementation details, it allowed us to communicate the idea to the other team members as well as project managers and consultants. Independent from their background, they were able to understand the content and thus to provide early feedback. Please note that this is not an Experience Prototype according to definition 3.1 because it does not involve the audience in active participation or interaction with the story.

The Heartbeat

Today, Lisa is going for a run. After taking a little ride out of town, she steps out of her car and increases her awareness of the outside environment. Lisa feels good, kind of alive and active. She slowly starts moving and picks up the pace.

Lisa increases her speed. She feels her heartbeat and how it becomes faster and more intensive. Soon, she finds her perfect pace.

After a while, Lisa is out of breath and starts to slow down. She needs a little break to take a drink and regenerate. Lisa evenly breathes in and out and fills up her body with new energy. She puts her hand on her chest and feels how her heartbeat slows down again. After a couple of moments, she feels ready to start her way back.

Lisa easily makes it back to the car. She gets inside and increases her awareness of the inside. She starts the car and senses its Heartbeat. Everything feels good, kind of alive and active. As Lisa puts her foot on the acceleration pedal, the car starts to move. As it picks up the pace, she can feel how the Heartbeat becomes faster and more intensive.

Half way home, Lisa sees that her car needs a break. She reduces the speed and feels how the Heartbeat slows down. "This way, I will easily make it home." After parking her car in the garage, she connects it to the wall outlet. "Good night" Lisa says, "see you tomorrow!"

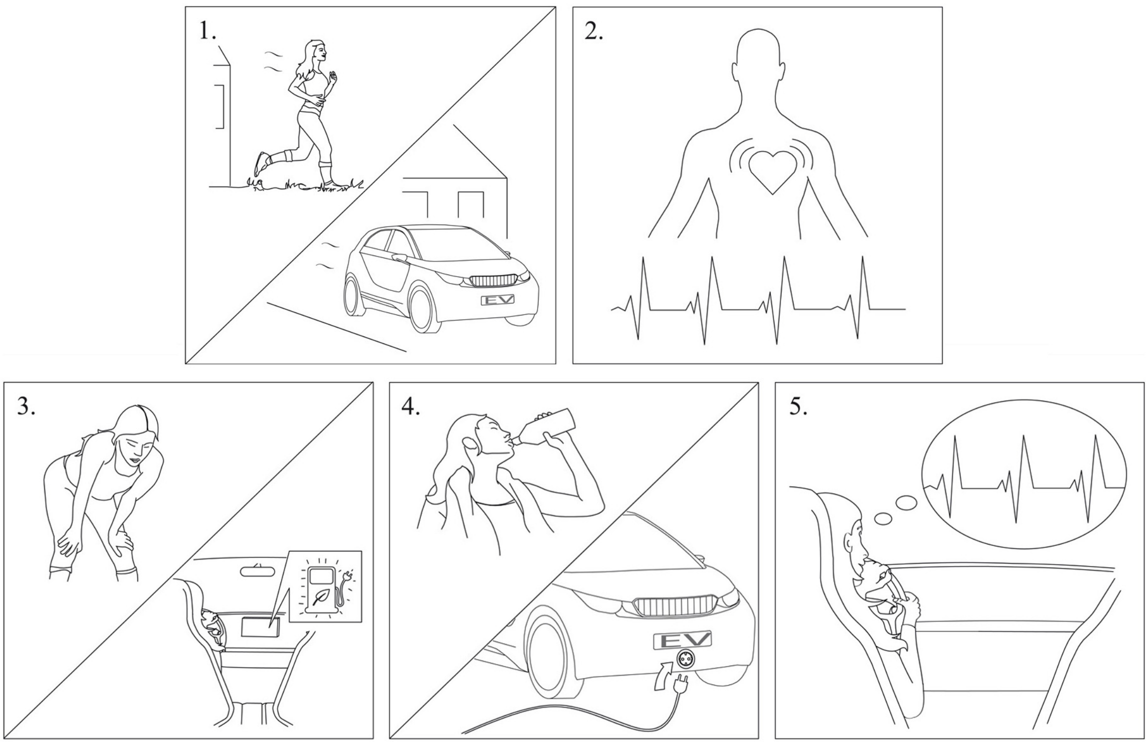

Figure 5.1: Storyboard visualizing the 'Heartbeat' concept. A runner feels her pulse (frame 2) and maps this feedback to the energy consumption of an EV (5). Drawn by Marc Landau and Verena Voppichler.

5.2.2 Translating the Experience into an Interaction Concept

Both story and storyboard represent the Heartbeat Experience. They set the context of e-mobility and focus on the emotions of EV drivers but do not contain a potential implementation of an EV information system. Before building first prototypes, it is important to derive requirements in order to formulate and preserve the essential parts of the experience throughout the design process. Therefore, we defined a list of working principles, each one representing an important detail of the Experience Story.

P1: Heartbeat is activated when the *car's* electric drive is *started*, indicating that it is ready to go (*alive and active*)

P2: *feel* implies a haptic feedback, which is perceivable on demand (*puts her hand on*)

P3: when going faster, the feedback becomes *faster and more intensive*, indicating that more energy is consumed

P4: *see* implies a permanent visual feedback, while *sense* implies an ambient character

P5: Heartbeat shows when the charge of the battery is low, relative to the current destination (*home*); a recharge (*break*) or a lower energy consumption (*reduce speed*) is needed

P6: when *reducing the speed*, the visual feedback adapts depending on the updated energy consumption

The story, storyboard and derived working principles led to a first scribble of the system, which inspired an early interactive experience prototype (see figure 5.2). Note that we did not change the Heartbeat story throughout the remaining process stages, e.g., due to technological constraints during prototyping or requirements caused by other functions and devices. This preservation of the story is essential to achieve a consistent experience. Each implementation described in the following sections will follow story, storyboard and working principles. Therefore, they function as requirements for all design decisions.

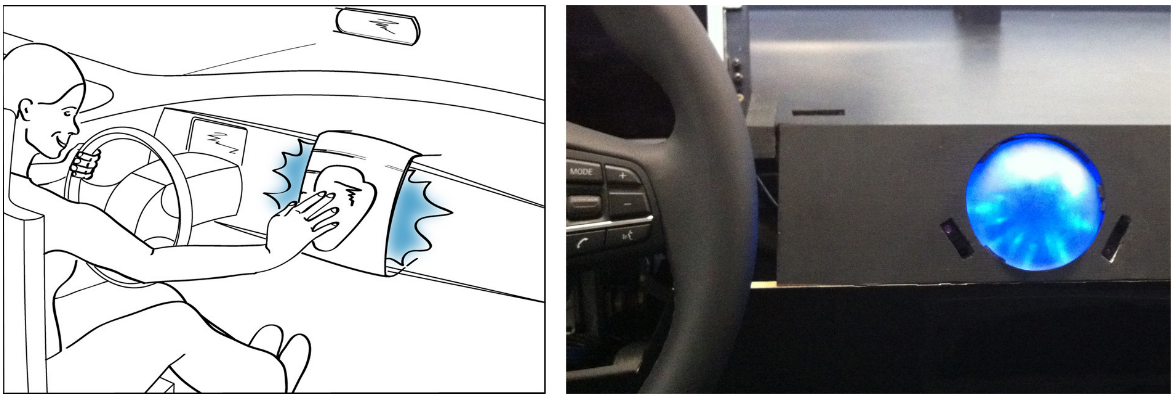

Figure 5.2: Left: First scribble of Heartbeat showing an interface in the dashboard of a car. Drawn by Marc Landau. Right: The first Heartbeat Experience Prototype is a sphere providing tactile and visual feedback.

5.3 The First Heartbeat Experience Prototype

Following the principle of "experience *before* product" [30, p. 63], prototyping was not a part of the actual design of the experience. Possible implementations were not included in the story in order to avoid constraints arising from underlying technologies. In the next step of our process (see section 4.1.2), interactive representations support the exploration, communication and evaluation of the Heartbeat concept. In several iterations I implemented two Experience Prototypes. The first primarily served the exploration and improvement of the interaction concept. To gain insights of how Heartbeat functions in its automotive context, we placed it in a car mock-up but without taking constraints of other in-car information systems into account. Subsequently, I implemented the second prototype with respect to results of earlier explorations and evaluations and to requirements derived from safety, ergonomic aspects and other devices and functions placed in the dashboard. Because they explored different aspects of the experience, both prototypes implement different levels of fidelity, resolution and interactivity (see chapter 3.3). We evaluated both to ensure a consistent experience in accordance to story and storyboard.

5.3.1 Implementing a Preliminary Experience Prototype

The prototype in figure 5.2 is the first interactive representation of Heartbeat. As its purpose was the exploration of the experience and the concept, the resolution is low. Interactivity is limited to a constant visual and tactile feedback that does not adapt to a driving situation. The feedback communicates the state of the electric drive, but not the State of Charge and whether or not it is sufficient to reach today's destinations. Due to the attempt to already convey a look-and-feel prototype I paid attention to the kind of feedback and material and therefore chose a mid-fidelity implementation. This prototype supported the designer in drawing a short storyboard showing the interaction sequence of using the Heartbeat interface (see figure 5.3).

Figure 5.3: Storyboard inspired by the first Heartbeat prototype showing how a driver checks the state of the electric drive by placing his hand on the prototype to feel tactile feedback. Drawn by Marc Landau.

Hardware and Software

An acrylic glass sphere is located in the middle of the dashboard of a car mock-up, prominently visible and easily reachable for both driver and co-driver. The sphere has a diameter of 10 cm, which in combination with its round shape offers an affordance to place the hand on the prototype. The membrane of a small speaker located behind the sphere touches the acrylic glass. Whenever a sound is played by the speaker, the membrane transfers the vibrations. A person touching the prototype can perceive these vibrations as tactile feedback. An amplifier powers the speaker and receives any arbitrary sound played by a connected computer. Eight RGB LEDs inside the sphere can emit light in different colors and intensities. Sanding the acrylic glass caused its surface to be nontransparent but at the same time translucent, diffusing the light emitted by the LEDs. Two infrared distance sensors next to the sphere detect hands reaching for the prototype. An Arduino board controls the LEDs and the distance sensors.

Interaction

When reaching for and placing the hand on the sphere, a driver or co-driver can perceive the tactile feedback. According to the metaphor described in the story, this actually feels like a human heartbeat and represents that the electric drive is active and the EV is ready to go. Additionally, the driver can judge the state of the EV visually. Similar to the LED in Apple MacBooks before 2013 [38], the prototype is slowly "breathing" when the car is in sleep mode, i.e. the brightness of the LEDs increases and decreases constantly. The moment the EV is started, the sphere lights up and thus represents the active state of the electric drive. The prototype emits a blue color representing power, energy and vitality [3], matching both the metaphor of Heartbeat and the color several car companies assign to their electric models (e.g., BMW i3 or Volkswagen e-Golf). The visual feedback (state of the electric drive) is perceivable in an ambient way whereas the tactile feedback (energy consumption) provides more detail on demand.

Qualitative Evaluation

The preliminary low-resolution and mid-fidelity prototype helped to gather early insights into the Heartbeat experience. We conducted a qualitative user study with nine participants. To set the context, we asked participants to imagine that the mock-up is a new electric vehicle and that it is time for a first test drive. We instructed them to sit on the driver's seat and to find out whether the EV is ready to go or not. To explain the functionality of the prototype, we presented the storyboard illustrated in figure 5.3 before starting the experiment. We told participants to take as much time as needed to explore the interface. After entering the car, the prototype slowly illuminated with increasing brightness. Placing a hand on the sphere activated the tactile feedback. We did not inform about the kind of tactile feedback and did not mention the name of the concept. After the experiment we conducted a semi-structured interview asking participants to share their impressions on the experience they just made. By gathering and clustering statements, we gained the following results:

Heartbeat communicating the state of the EV
Reactions articulated even *while* interacting with the prototype such as "The car's heart is beating, it's alive"[13] or "The heartbeat shows that the car is ready to drive" show that Heartbeat successfully communicates the state of the (imaginary) EV. The blue color triggered associations to "energy" and "vitality". Thus, Heartbeat allows for the exploration of the EV state.

Heartbeat as an emotional and human interface
One participant saw Heartbeat "almost like a virtual co-driver for long distance drives". He continued that the vibrations "provide the car with a human character" and how it could help him to "drive more carefully". Another participant was surprised to "experience a human characteristic in a dead thing [a car]" and concluded that "it was really emotional, there was a lot going on in my head". This hints at the potential of Heartbeat offering a stimulating experience.

More interaction wanted
We observed several participants trying to push and turn the sphere (under my rather worried supervision). One participants stated how "it is weird that the light changes without me doing anything". We gained the impression that users asked for more interactivity and how they would interact with this kind of prototype.

An imbalance between visual and tactile feedback
Several participants reported that the tactile feedback was not strong enough. Some of them took their hand away from the prototype quickly and said they "can't feel anything". On the other hand, the visual feedback was "too bright" and thus dominant. One participant reported that "at first I had no intention to touch the sphere because I was almost hypnotized by the blue light". Thus, the interdependence of tactile and visual feedback plays an important role for the experience.

Drawbacks of a low-resolution prototype
Because of the constant tactile feedback, one participant stated that "a mapping of the beating heart to a certain function would be important." This shows that the prototype with its low resolution and limited interactivity tested in a static situation is helpful for evaluating certain design aspects only. A later prototype used in a driving situation and allowing for the adaption of the driving mode would rather show the influence of the energy consumption on the Heartbeat frequency.

5.3.2 Implementing the First Experience Prototype

Following the evolutionary prototyping approach the working principles (see section 5.2.2) and the qualitative feedback resulting from the first evaluation led to an improved interactive representation of Heartbeat (see figure 5.5). Before the start of the next implementation phase, we extended the Heartbeat concept resulting in a revised storyboard (see figure 5.4).

[13] All statements have been translated from German to English by the author.

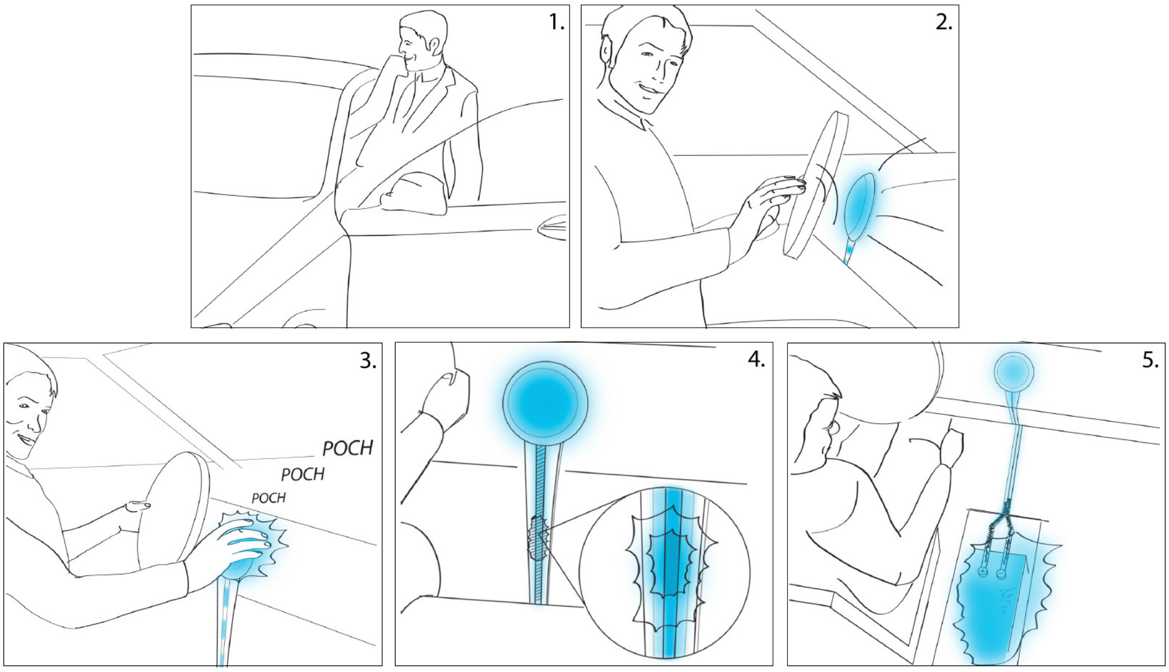

Figure 5.4: Storyboard visualizing the Heartbeat concept (frame 3) including the energy scale (4) representing the State of Charge of the batteries (5). Drawn by Marc Landau.

Interaction

We extended the sphere representing the actual Heartbeat of the EV by an energy scale. While Heartbeat communicates the state of the electric drive, this part of the prototype visualizes the State of Charge of the batteries. As illustrated 5.4, the energy scale is an illuminated stripe between the floor of the EV and Heartbeat. In our concept the width of the stripe is mapped to the charging level of the batteries dependent on today's destinations: the wider (and therefore brighter) the stripe, the more likely the reachability of today's destinations. A narrow and therefore rather dark scale indicates a low energy level and the need for a recharge.

Hardware

In EVs the batteries are usually located in the floor. In the prototype they are represented by a small illuminated battery mock-up integrated between the front seats (see figure 5.5). The energy scale consist out of three LED stripes that run vertically from the battery mock-up to the Heartbeat and emit blue light. The entire LED array is covered by frosted acrylic glass diffusing the light, which therefore appears as an illuminated surface. By dimming the outer two LED stripes, the width of the energy scale can be varied. All diodes are connected to the Arduino controlling the Heartbeat as well.

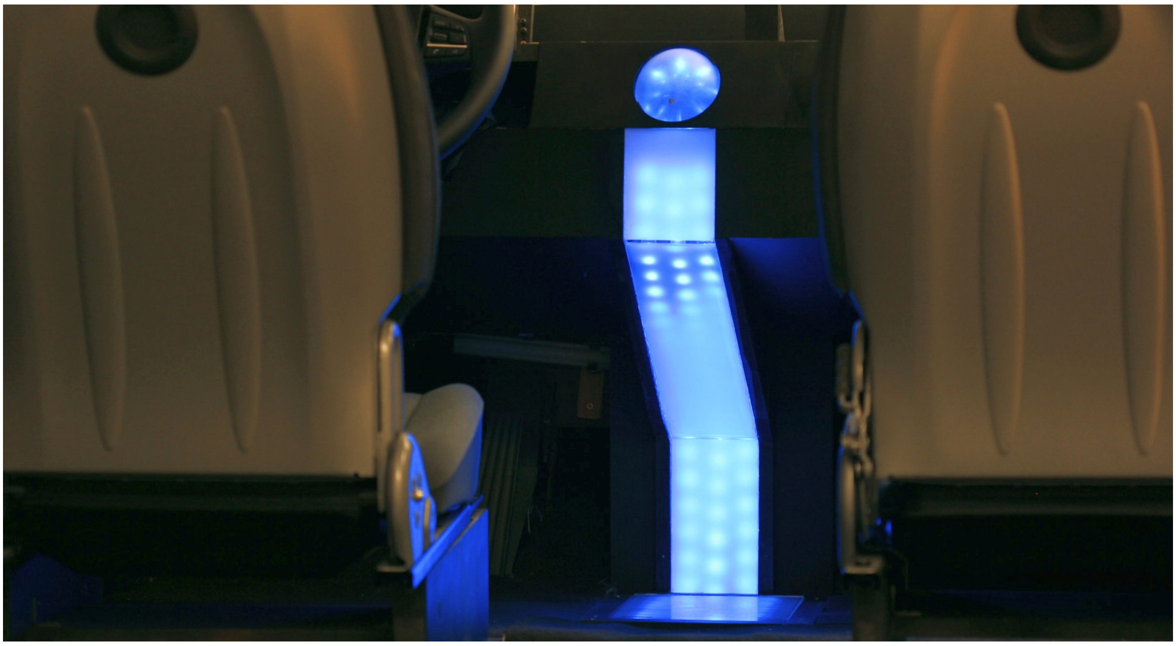

Figure 5.5: First experience prototype implementing the Heartbeat concept including the energy scale and the battery mock-up.

5.3.3 Evaluating the First Experience Prototype

One purpose of prototyping is to evaluate the designed experience based on the fulfillment of psychological needs and the arousal of positive emotion (see section 2.4.4). When implementing a concept, technological constraints may compete with this experience and derived working principles. Therefore, we conducted a first user study to investigate whether the Heartbeat prototype still allows for reliving the story before continuing to the next implementation phase of our process.

Setup and Procedure

All participants interacted with the experience prototype of Heartbeat while sitting on the driver's seat in our car mock-up as shown in figure 5.5. After a short introduction into the context of e-mobility, we asked them to imagine that they had recently purchased a new EV. To explain the task, we presented the storyboard illustrated in figure 5.4 and accordingly instructed participants to enter the car, wait until the EV starts, check the state of the electric drive as well as the State of Charge of the batteries. We did not set a time limited for using the interface. After leaving the mock-up, participants completed the User Experience Need Questionnaire (UXNQ, see appendix on page 153) measuring if the needs for Stimulation, Competence and Security[14] were addressed during interaction [56]. For quantifying

[14] In this early version of the UXNQ the need for Control (see section 5.2.1) was subdevided into the needs for Security and Competence.

the arousal of emotion we utilized a short version of the Positive and Negative Affect Schedule (PANAS) [48]. We completed the study with a semi-structured interview questioning participants about their experience of interacting with Heartbeat. Each trial lasted about 30 minutes and we handed out a gift certificate with a value of five Euros as an incentive.

Results

29 test persons with a mean age of 25.2 years participated in this study. Four of them were female. Results of the UXNQ (see table 5.1) show that the mean scores for Stimulation (M = 3.33, SD = 0.99) and Competence (M = 3.36, SD = 1.16) were significantly higher than the scale mean of 3. This means that both needs were fulfilled during interaction with the Heartbeat prototype because a rating above 3 represents the first answer category that is in agreement with a need item ("I somewhat agree"). The need for Security (M = 2.91, SD = 0.93) was thus not fulfilled. Cronbach's α showed excellent reliability of the Competence scale and good reliability for Security and Stimulation. The Positive Affect was rated slightly above the scale mean (M = 3.09, SD = 0.81) with a good reliability, while Negative Affect was rated low (M = 1.41, SD = 0.36).

To analyze whether the fulfillment of the psychological needs correlates to the arousal of positive emotion, we calculated the correlation coefficient Person's r. The need for Stimulation ($r = .55, p < .01$) and Competence ($r = .56, p < .01$) significantly and positively correlate with Positive Affect. This is not the case for Security. None of the need scales correlate with Negative Affect.

	M	SD	α
Stimulation	3.33	0.99	0.84
Competence	3.36	1.16	0.91
Security	2.91	0.93	0.70
Positive Affect	3.09	0.81	0.76
Negative Affect	1.41	0.36	0.34

Table 5.1: Descriptive values of UXNQ and PANAS resulting from the evaluation of the first Heartbeat experience prototype

Discussion

Heartbeat triggered a stimulating experience
While using the Heartbeat prototype, participants experienced Stimulation. According to Sheldon's definitions (see table 2.1), interacting with Heartbeat thus allows for the exploration of "new sensations and activities" and triggers "physical pleasure and enjoyment" [95]. Statements made during interviews such as "I experienced the car by touching it" and "I liked how I could explore the energy level with several senses" support this result. The human characteristic of Heartbeat mentioned during the qualitative pre-study was again recognized by expressions such as "the car is alive" or "It felt like I would sit in something that is

a living thing". One participant called Heartbeat "a very interesting and futuristic concept". Consequently, the fulfillment of the need for Stimulation triggered positive emotion.

Heartbeat made participants feel competent
Additionally, the interaction with Heartbeat addressed the need for Competence, i.e. participants felt "capable in what they did" and "successfully completed difficult tasks" [95], leading to positive emotion. One participant stated that "the visual feedback told me that I was doing the right thing", another said "I was able to know what's going on without looking at a display".

Stimulation counteracts Security
The need for Security was whether fulfilled nor related to positive emotion. This need implies the want for routines, structure and predictability [95], which was not satisfied during the interaction with Heartbeat. The reason for this result may be the same that caused the fulfillment of the need for Stimulation: participants explored a novel and unfamiliar automotive interface. This triggered a meaningful experience in the terms of new sensations but at the same time opposed the need for predictable and habituated use of a system. For instance, participants were not able to predict the kind of tactile feedback they would feel when touching the sphere. Consequently, evaluations investigating the experience triggered by an interactive system need to involve experienced users as well in order to be able to study long term effects on the User Experience of the interaction. On the other hand, a mid-fidelity prototype such as this first Heartbeat implementation might lack robustness and detail for extensive user testing.

Interdependency between storyboarding and prototyping An interesting observation of our development process is how storyboards influence prototypes and vice versa. Figure 5.2 illustrates how a first scribble inspired the implementation of the first prototype. In turn, this first prototype inspired the further development of the storyboard (see figures 5.3 and 5.4), which again served as a draft for the second experience prototype (see figure 5.5). This interdependency caused a effective collaboration between the Industrial Designer and the HCI Expert of our interdisciplinary team. Different prototyping techniques, in this case storyboarding and hardware prototyping, helped both of us to communicate our individual interpretations of the experience. Thus, Experience Prototyping supports the communication between team members with different backgrounds and disciplines and thus significantly contributed to the success of the project.

Limitations
Results have to be treated with respect regarding some limitations. Due to its limited interactivity and functionality, the study was conducted in a static situation without a driving simulation. Therefore, participants were forced to imagine parts of the interaction, e.g., they were not able to actively start the car ("How does this work, does the EV start on its own?"). This limits the ability to reenact the actual experience and thus may have caused comparably low ratings for the need scales and Positive Affect. According to agile iterative development, the purpose of the study was to quickly evaluate the success of translating the story into a first interactive representation without losing the essential aspects of the User Experience.

This early implementation of Heartbeat resulted in a mid-fidelity prototype with the goal to explore and communicate the design concept and therefore does not resemble the eventual future interactive system. However, the UXNQ and PANAS questionnaires serve the purpose of evaluating the potential for experiences triggered when interacting detailed prototypes in a realistic context of use. Nevertheless, with the help of the storyboard participants managed to imagine themselves in the situation of entering and starting an electric vehicle. They interacted with the prototype and reported a meaningful Heartbeat experience.

Results show that we successfully translated the story into an experience prototype and allowed us to continue to the next implementation phase of our process, which focuses on the integration of Heartbeat into the dashboard of the EV.

5.3.4 Improving the Heartbeat Concept

From user feedback and observations during the evaluation, we adapted the design concept for Heartbeat and derived the following improvements:

Stronger tactile feedback
Several participants made comments such as "I had a hard time feeling the vibrations" or "the vibrations were not strong enough". The reason was a trade-off caused by the underlying technology: the sound of the heartbeat caused the membrane of the speaker and therefore the attached sphere to vibrate. When increasing the volume of the sound in order to intensify the tactile feedback, the heartbeat sound itself became audible. Therefore, the next implementation would implement tactile feedback using vibration motors. This is a practical example how a chosen technology can influence the experience triggered when interacting with experience prototypes. Note how participants successfully relived the story independent from technological challenges.

More subtle visual feedback
Statements such as "the scale should take up a much smaller area" or "the light is kind of distracting" showed another trade-off of early experience prototypes. To explore the Heartbeat concept, we placed the prototype with its dominant visual feedback in the middle of the dashboard not taking other devices and functions into account. On the one hand, this approach helped to communicate an experience without other distracting factors. On the other hand, it seemed to cause unintentional feedback: because they were sitting in a car mock-up, participants thought about effects the prototype would have on driving, e.g., distraction, and on the design of the dashboard containing other devices typically found in cars. The next Heartbeat prototype will implement a smaller energy scale and less dominant visual feedback.

A vertical and more detailed energy scale
Several participants commented on the energy scale saying that "it is hard to read a horizontal scale" and suggested to "use a vertical scale such as a thermometer known from everyday use". Additionally, participants had problems mapping the visual feedback of the energy

scale to the State of Charge of the batteries. Some also stated that "my arm occluded a big part of the scale while I was touching the sphere". The next version of the prototype will implement a vertical scale placed above the Heartbeat with a more detailed visualization.

A redundant battery mock-up
The battery mock-up integrated into the floor representing the source of energy did not receive any attention at all. We received only one comment stating that "I'm not sure what this is supposed to do". This experimental feature seemed to have no influence on the experience and will therefore not be part of the next version of Heartbeat.

More interactivity
Confirming results of the preliminary prototype, participants repeatedly asked for a higher degree of interaction. We observed that the sphere with its visual feedback and convenient form factor invited users to touch and interact with it. One stated that "I wanted to push the button to trigger the vibrations, but nothing happened". The next version of Heartbeat will integrate energy-related functionality and therefore allow for more input.

5.4 The Second Heartbeat Experience Prototype

The evaluation of the first experience prototype implementing the Heartbeat concept showed how I successfully translated Experience Story and Storyboard into an interactive implementation. Participants were able to relive the story and quantitative as well as qualitative evaluations resulted in fulfilled needs for Stimulation and Competence triggering positive emotions and therefore a meaningful experience.

I implemented the first Heartbeat prototype in mid-fidelity and medium resolution and placed it prominently in the middle of the dashboard in order to communicate, explore and improve the concept. The core issue during the second implementation phase of our design process is the integration of the experience into its context of use.

5.4.1 The Revised Heartbeat Concept

Before implementing the second Heartbeat prototype, we updated the concept and visualized it in an updated storyboard. This was necessary due to the goal of integrating the Heartbeat experience into the dashboard of an electric vehicle while respecting given constraints. The following paragraphs summarize aspects that influenced the updated concept. All listed requirements together with the working principles (see section 5.2.2) derived from the experience story lead to an updated storyboard (see figure 5.6).

Feedback from evaluating the first prototype
Section 5.3.4 summarized improvements derived from user feedback and observations resulting from the evaluation of the first experience prototype. To meet these requirements,

the second prototype includes a more prominent tactile feedback, a less prominent visual feedback, a vertically aligned and more detailed energy scale as well as a higher level of interactivity. A representation of the battery will not be part of the updated prototype.

Integration with other energy-related functions
The integration of a new functionality into the car such as the communication of the energy state into the dashboard of an EV by providing tactile and visual feedback is a challenging problem. Not only the broad number of applications already existing in today's cars play a major role, but also the novel requirement of maintaining the experience as proposed by our design process is a crucial factor. Therefore, the experts on product development of our project team applied the Design Structure Matrix (DSM) and the Domain Mapping Matrix (DMM) with the goal of clustering the energy-related functions of an EV based on motives such as "getting a feeling for energy consumption", psychological needs such as Stimulation and use cases such as "driving ecologically" [75]. The application of the matrices resulted in the combination of five control elements and indicators within one Heartbeat interface: (1) a start-stop-button activating and deactivating the electric drive of the EV, (2) an indicator showing if the EV is ready to drive, (3) a control element to change the driving mode, (4) an indicator visualizing the current driving mode and (5) an indicator visualizing the State of Charge of the batteries.

Integration with respect to other devices in the car
Despite of the function and indicators integrated into Heartbeat, other devices located in the dashboard cause constraints influencing the updated and integrated concepts. Obviously the prototype cannot be placed in the area of the center stack since this area in the middle of the dashboard is reserved for infotainment systems. EVs such as the BMW i3 oder Tesla Model S do not have a center console. Other devices such as cup holders, storage compartments, displays and ventilation slots cover a large proportion of the dashboard. Compared to the first prototype, Heartbeat needs to be relocated and its size significantly decreased.

Constraints related to ergonomics and safety
Concerning safety, Heartbeat cannot be placed in an area utilized by airbags, which is true for parts of the dashboard and the center of the steering wheel. One option was the integration of Heartbeat into the steering wheel itself which would have been a promising location for providing tactile feedback. However, this would interfere with other integrated feedback such as a vibrating steering wheel as part of advanced assistant systems such as lane departure warning or driver drowsiness detection. Because of its functionality as a control element for the electric drive and the requirement of providing tactile feedback, Heartbeat needs to be placed in the driver's ergonomic space within reach.

5.4.2 Implementing the Second Experience Prototype

Based on the requirements listed in the last section, Heartbeat underwent an evolution from a mid-fidelity, medium resolution to a high-fidelity, high resolution prototype. The number of necessary changes had two implications: First, the evolutionary prototyping approach

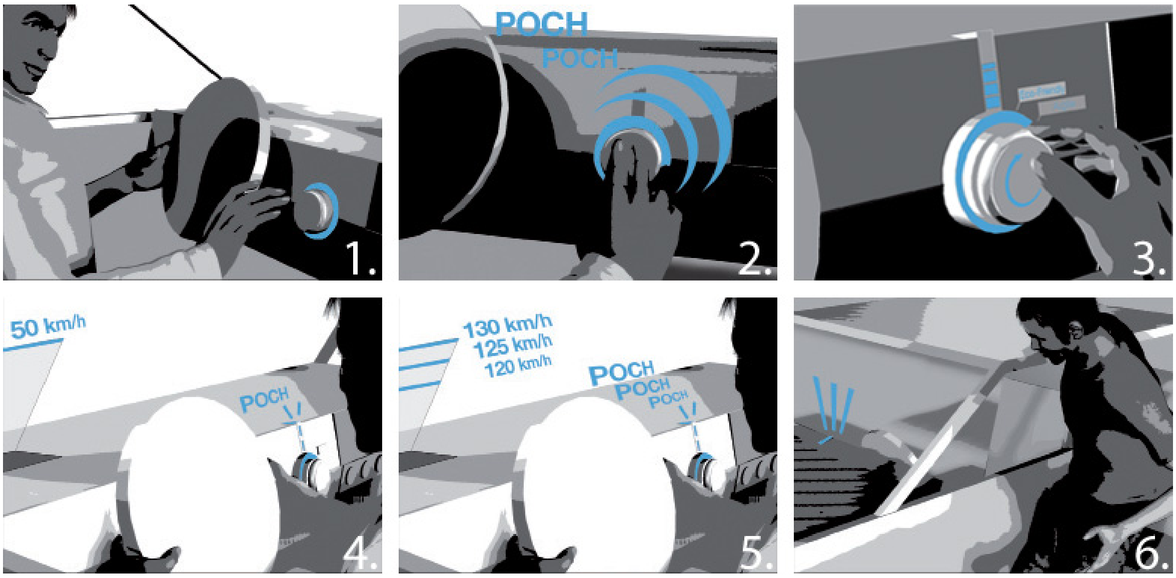

Figure 5.6: Storyboard visualizing the concept for the second Heartbeat experience prototype. The driver can start and stop the EV (frame 2) and change the driving mode (3). The tactile feedback representing the heart frequency changes depending on the driving mode (4 & 5). Drawn by Marc Landau.

used while implementing the first representation was not applicable for the new version. Changes in the underlying technology, i.e. the use of a vibration motor instead of a speaker, the additional input options for controlling the electric drive and the smaller size forced us to abandon former implementations. Second, the evaluation of the new experience prototype was of utmost importance. All changed requirements and subsequent changes of the implementation concept increased the danger of interfering with the important aspects of the experience defined in the story, making extensive evaluations an important step of the process.

Interaction

As illustrated by the storyboard in figure 5.6 Heartbeat now offers additional input modalities. When pressing the start-stop-button, an encircling ambient light appears (see figure 5.7) indicating that the electric drive is started and the EV is ready to go. The realization of Heartbeat as a start-stop-button has the advantage that the driver *has* to touch it when starting the car and thus immediately becomes aware of the tactile feedback. This feedback again feels like the actual beating of a human heart. After starting the EV and any time while driving or standing, the driver can change the driving mode. The concept includes two modes, Eco-Friendly and Agile. In Eco mode, the frequency is 60 beats per minute, approximately the human heart rate when resting. In Agile mode the frequency increases to 100 beats per minute, representing a higher energy consumption due to a rising performance. Tactile feedback can be sensed on demand, any time the driver is touching Heartbeat.

Figure 5.7: The second experience prototype Implementing Heartbeat as a start-stop-button and control element to change the driving mode between Eco-Friendly and Agile. The energy scale is located above.

The energy scale is located vertically above the start-stop-button. It consists of seven bars illuminating from bottom to top. More illuminated bars represent a higher State of Charge. A horizontal bar moves up and down and represents the cumulated distance to today's destinations. Whenever the scale drops below the level indicated by the bar, a recharge or a lower energy consumption is needed. The energy scale conceptually adapts to driving behavior, a changing driving mode and energy consumption by devices such as infotainment or air conditioning.

Hardware and Software

The start-stop-button itself is an aluminum housing with a diameter of 4 cm (see figure 5.7). It contains a vibration motor which converts any sound into tactile feedback. The actuator is connected to an amplifier which receives the sounds played by a computer. The button is placed on an incremental encoder that provides force feedback when being pressed and stepwise force feedback when being turned. The encoder is connected to an Arduino micro controller interpreting the input. When the button is turned to the left or right, the driving mode adjusts to Eco-Friendly respectively Agile. Two small indicators are labeled with both driving modes and illuminated by an LED according to the selected mode. When the button is pressed, eight LEDs illuminate a frosted acrylic glass ring encircling Heartbeat. The energy scale consist of seven chambers made out of acrylic glass. Each one can be illuminated by an LED. The vertical bar is a peace of aluminum and can be adjusted manually. When the button is pressed while being active, i.e. the electric drive is turned on, all LEDs turn off indicating that the EV is turned off. All LEDs are controlled by the Arduino.

5.4.3 Evaluating the Second Experience Prototype

The Heartbeat experience prototype described above is significantly different from the first prototype (see section 5.3.2 in terms of appearance and functionality. It is smaller, utilizes different materials, is placed in a different location and combines a start-stop-button and a controller for changing the driving mode. Although it still implements the working principles derived from the experience story, an evaluation is essential to ensure the creation of a consistent experience.

Setup

In contrast to the first evaluation, we included a driving simulator in the setup (see figure 5.8). A projector located on the roof of the car mock-up projected the SILAB[15] simulation on the wall in front which was two meters away. Next to the driving scene, the image also contained the speed limit, the current speed and an indicator informing the driver about the correct direction at crossroads. For controlling the simulation, we installed a Logitech Driving Force GT steering wheel and acceleration as well as braking pedals. The driving route consisted of a country road as well as a section through a small town.

Pushing the start-stop-button conceptually started the electric drive and thus caused Heartbeat and the energy scale to illuminate. On start, the Eco-Friendly driving mode was selected and drivers were able to feel the corresponding tactile feedback. Changing the driving mode triggered an adaption of the frequency of Heartbeat as well as an adaption of the energy scale: one bar disappeared as soon as the Agile mode was selected and one bar was added for the Eco-Friendly mode. The software of Heartbeat was not connected to the driving simulation, i.e. the tactile and visual feedback did not adapt to changing speed or the duration of the drive.

Procedure

The procedure was similar to the first evaluation. We introduced participants to the EV context and asked them to envision that they own a new EV. Each of them completed a training drive without using the prototype until feeling comfortable of using the simulator. Next, we presented an adapted version of the storyboard illustrated in figure 5.6 and verbally provided the following instructions:

Imagine you want to drive to the bakery in the morning with your new electric vehicle. After starting the vehicle with the start-stop button, you will be able to feel the state of the electric

[15] http://www.wivw.de/de/silab (accessed 11/4/2014)

drive. You can also change the driving mode by turning the start-stop button. With the help of the scale you can find out whether the batteries are sufficiently charged to reach your current destination. When reaching the bakery, please park the car and turn it off.

After the experimental drive, which was about five minutes long, participants completed the UXNQ as well as the PANAS questionnairs. We also gathered qualitative feedback by performing semi-structured interviews. Using the Laddering technique [85], we continued to ask participants to explain statements in more detail, until we were able to assign each statement to a psychological need. Each participant received a gift certificate with a value of ten Euros as an incentive. One complete trial took approximately 30 minutes.

Results

The study was completed by 34 participants, 17 of them were female. The mean age was 23.9 ranging from 20 to 40 years. Table 5.2 shows the scale ratings and reliability scores for the psychological needs Stimulation and Control as well as Positive Affect and Negative Affect. Stimulation (M = 3.86, SD = 0.66) was rated significantly above the scale mean of 3 ($t(33) = 7.68$, $p < .001$) which represents the first answer category stating need satisfaction. This is also true for Control (M = 3.87, SD = 0.72; $t(33) = 7.01$, $p < .001$) and Positive Affect (M = 3.39, SD = 0.43; $t(23) = 4.49$, $p < .001$). Negative Affect was rated low (M = 1.49, SD = 0.41). Cronbach's α shows good reliability for both need scales and acceptable reliability for Negative Affect. The reliability for the Positive Affect is low.

Figure 5.8: Evaluation of the second Heartbeat experience prototype. A driving simulation is projected onto the wall. The participant touches Heartbeat to feel the tactile feedback.

The correlation coefficient Person's r helps to analyze whether Positive Affect is positively correlated to the satisfaction of psychological needs. Stimulation correlated positively with perceived Positive Affect with a medium effect size (r = .29, p = n.s.), Control (r = .22, p = n.s.) did not. Both results were not significant. Control significantly correlated with Negative Affect (r = -.38, $p < .05$).

	M	SD	α
Stimulation	3.86	0.66	0.81
Control	3.87	0.72	0.79
Positive Affect	3.39	0.43	0.38
Negative Affect	1.49	0.41	0.62

Table 5.2: Descriptive values of UXNQ and PANAS resulting from the evaluation of the second Heartbeat experience prototype.

Discussion

A stimulating experience
The interaction with Heartbeat addressed and satisfied the psychological needs for Stimulation. During the interviews participants supported the aspect of exploring new sensations with statements such as "it is exciting to feel the tactile feedback which matches EVs" and "this metaphor is something new and thrilling". Using laddering, we attributed those and similar statements of seven participants to Stimulation. We observed that 18 participants continued to explore the prototype even after the experimental drive was over and we told them that they can leave the car now, underlining the stimulating character of the concept.

Being in control
Participants experienced a satisfaction of the need for Control while interacting with Heartbeat. This was supported by 18 participants with statements such as "you can clearly see that the engine is running" or "this feedback means less distraction and therefore more control over the car". Some underlined the calming aspect of the interface by saying "the pulse calmed me down" and "the feedback was comforting for me".

Moderate Positive Affect
Although we found a Positive Affect during interaction with Heartbeat, results show a low reliability score. This affected the correlation between the scales. Thus, we did not find evidence that Positive Affect was triggered by the fulfilled needs. Two reasons may have caused this result. First, items used by the PANAS questionnaire might not match the given situation. When excluding the item "alert" from the scale, reliability rises to α = .50 representing a good effect size. The feeling of being alert might have contradicted the calming character of the feedback reported by several participants. Even though the PANAS provided a reliable tool in several studies (e.g., [109]), further research concerning its application for Experience Design will be necessary. Second, the needs for Stimulation and Control addressed by the experience story might have conflicting effects. While Stimulation aims at

exciting exploration of new sensations, Control describes the desire to anticipate and solve potential challenges. Thus, the correlation between different psychological needs remains an interesting research question.

5.5 Implications for Experience Prototyping

Heartbeat is a novel concept for communicating the state of the electric drive and the batteries to electric vehicle drivers. One central aspect of the designed experience is ambient visual feedback representing relevant information in an abstract way. The other aspect is tactile feedback inspired by the beating of a human heart representing information on the energy consumption of the EV. A first experience prototype enabled the exploration of the Heartbeat concept and an evaluation showed that users can relive the experience during interaction. A second experience prototype integrated Heartbeat into the dashboard of a car mock-up with respect to constraints and requirements of this context. A further evaluation showed the successful integration of Heartbeat and the preservation of the experience throughout the development process.

Defining the experience with story and storyboard

Following the postulation 'experience *before* product' we created a story and a storyboard before implementing interactive prototypes. They help to communicate a concept and to gather early feedback. By staying on a conceptual level not including implementation details we avoided the influence of technological constraints. The story is a fix milestone and must not be changed in the course of the process in order to ensure a consistent experience.

Translating the experience to a first experience prototype

We derived working principles from the story in order to translate the experience to an interactive prototype. By using these principles as reference points when making important design and implementation decisions, all aspects of the prototype were motivated by the story ensuring the creation of a consistent experience. A first prototype with its mid-resolution allowed for the exploration of those design aspects that were important for the creation of the designed experience. The mid-fidelity implementation allowed for a successful first evaluation of the communicated experience but at the same time triggered feedback on a conceptual rather than detailed design level.

Alternating storyboards and prototypes

First scribbles and a storyboard inspired the design and implementation of the first experience prototype. A first quantitative evaluation and qualitative feedback resulted in an extended interaction concept for implementing the designed experience visualized by another storyboard. Thus, each storyboard led to a new version of the experience prototype and vice versa. This does not only illustrate the interdependency of different prototyping techniques but also of the team members applying these methods, namely Experience Designer and Developer respectively HCI Expert.

Integrating the experience into the context of use

The implementation of the second prototype considered contextual constraints due to space, safety, ergonomics, and the functionality of other systems. A representation with a high resolution enabled the realization of these requirements and integrated several energy-related control elements and indicators. The high fidelity of the prototype allowed for an evaluation of the experience in a simulation of the driving context and triggered feedback on a detailed level.

Preserving the experience through experience prototypes

Two interactive prototypes mediated the experience described by story and storyboard. Evaluations of each new implementation analyzed whether users can relive the designed experience despite of changes in appearance, interaction design or underlying technology. Thus, experience prototypes are essential to ensure the preservation of the important aspects of the story throughout the development process.

Evaluating the experience early in the process

In contrast to the evaluation of the first mid-resolution, mid-fidelity representation, we tested the second high-resolution, high-fidelity prototype during simulated driving situations. Both interactive prototypes are results of early design stages and serve as a proof-of-concept for the design experience. Because of a lack of robustness, a missing link to in-car networks and the need for quick and early results, there is a need for preliminary user studies in the lab. We successfully evaluated the Heartbeat concept and thus provided first evidence that it triggers a meaningful experience as an electric vehicle information system.

Chapter 6

The Periscope: A Mobile Navigation Device

The real voyage of discovery consists not in seeking new landscapes, but in having new eyes.

– Marcel Proust (French Writer) –

In this chapter, I will introduce Periscope[1], a concept supporting passengers in the car to explore the environment together. The metaphor is based on periscopes used in submarines to observe activities above the surface of the water that would otherwise not be visible. The designed Periscope experience focuses on Stimulation, allowing for a playful exploration of points of interest on the way to the destination. As discoveries trigger conversations among the group and can be shared with others by physically handing over the Periscope, interactions also focus on Relatedness experiences.

Periscope is the second of three case studies I will present. The following sections focus on two aspects. (1) In contrast to the Heartbeat concept, several people are part of the Periscope experience. This case study shows how experience prototypes can spark collaboration and communication leading to social interactions. (2) I implemented and evaluated two experience prototype both featuring a high resolution and interactivity but different degrees of fidelity and usability. Results show that both prototypes supported our team to preserve the Periscope experience throughout the development process. I will provide details on the design and implementation of the Periscope concept.

[1] This chapter is based on [65]. For more details please see the disclaimer on page ix.

6.1 Background and Motivation

In the previous chapter, I introduced Heartbeat and described how prototyping supported the integration of a designed experience into its context of use. Heartbeat is an electric vehicle information system communicating the state of the electric drive and the batteries. This supports the driver in exploring the 'energy flow', i.e. the special characteristics of his electric vehicle, triggering a stimulating experience. Additionally, interacting with Heartbeat allows for an experience based on control because visual and tactile feedback enable the driver to predict the status and the range of the car.

In this chapter, I will report on the development of Periscope, a concept supporting the passengers of a car to explore the environment together as a group. In contrast to the Heartbeat concept, Periscope involves several users in a *social interaction*. Kurvinen et al. describe this term as "people engaging in interaction with other human participants" [58]. In their work, experience prototypes play a central role because social interactions are "mediated by the technology or affected by its presence" [58]. This is in line with Hassenzahl's definition of User Experience, which is an experience mediated by an interactive technology [31, p. 8] but with a focus on the involvement of several people. Kurvinen et al. continue that "the central claim is that a prototype is not only a representation of a product or technology [...] but that it consists of both the representation and the social interaction the participants create together" [58]. Thus, when developing the Periscope prototypes we focused on both, the interactive representation of the experience *and* how these prototypes where used to experience Relatedness among the group in a car.

6.1.1 The Psychological Need for Relatedness

Ryan and Deci [91] as well as Sheldon et al. [95] identified Relatedness as one of the three psychological needs that are most relevant drivers for well-being and positive affect. Sheldon et al. describe Relatedness with the feelings of being "close and connected with other people who are important to me" and "who care for me, and whom I care for" as well as having "a strong sense of intimacy with the people I spent time with" [95].

Hassenzahl et al. analyzed and identified "strategies of mediating intimate relationships through technology" and suggest these strategies as "starting points for the experience-oriented design of technology" [32]. Next to the strategies of designing for Awareness, Expressivity, Physicalness, Gift Giving and Memories, allowing for a Joint Action is the key strategy for the Periscope: Our goal is to provide an artifact supporting passengers to explore the environment and select a destination together. Hassenzahl et al. define key requirements for this strategy as "activating communication, behavioral interdependence, selection of activities and serendipity" [32], which are thus part of interacting with the Periscope prototypes.

6.1.2 Experiencing Relatedness in the Car

Several research projects explored how interactive technology can support social interactions in the car especially focusing on Relatedness. Eckoldt et al. identified the car as a design space for creating Relatedness experiences and state that a car "physically connects people" and that it "provides an ideal space for good and even intimate conversations" [11]. Thus, they call for exploring the car's potential as a space for social experiences. They provide an example by converting reachable surfaces in the car into drums producing different sounds and thus creating a positive experience as people started "drumming together" [12].

Wilfinger et al. identified Togetherness [111] as a need for passengers in the car, in particular for children in the back seat. One of their findings was that children "see them selves as part of a joined travel activity" and "want to contribute to and support their parents' tasks" [111]. The Periscope enables this in terms of navigational tasks. Inbar and Tractinsky suggest that driver distraction can be reduced by "allowing passengers to actively control selected in-car systems" [39]. Forlizzi et al. explored "navigation as a social activity among drivers and navigators" [16].

Maurer et al. explored "the car as a collaborative tangible game controller" [71] by installing several sensors in the interior of a mock-up, e.g., to notice when a passenger grabs the handle above his window, puts his feet down on the floor mat or uses his seat belt. Thus, they transformed the car's tangible elements to input controllers for an in-car game involving all passengers. In contrast to the view that a car locks all passengers into a tight space [47] their gaming approach seemed to create "a feeling of working together and actually being a team due to the confined space of the car simulator" [71].

Knobel et al. [55] designed an in-vehicle navigation device supporting experiences based on Stimulation and Relatedness. Rather than driving to a predefined destination, ExplorationRide helps passengers to explore an area and to find activities along the road,. The displayed map is vague in the beginning and uncovers more details as the car comes closer to points of interest. This "made the exploration a social [...] experience" [55] triggering conversation and making passengers feel as part of a team.

6.2 From the Idea to the Periscope Concept

The idea for the Periscope concept evolved from a section of our Experience Framework (see section 4.1.2) we called Openness, representing the motive of being open-minded about the environment, inside and outside of the electric vehicle. These two interpretations of Openness match with the two psychological needs we address in this experience:

Pleasure Stimulation: Passengers in the car explore the environment outside of the car by discovering points of interest in a playful and exciting way.

Relatedness: Passengers can communicate their discoveries to others in the car and physically share their experience in the group.

The metaphor goes back to periscopes that are used in submarines when the ship is underwater. Navigators can see the environment above the surface and can thus explore what is actually not visible. Figure 6.1 shows the first scribble of the idea. A user looks through the periscope and explores the environment to discover interesting objects. The sketch visualized the original idea and thus helped to capture fundamental aspects.

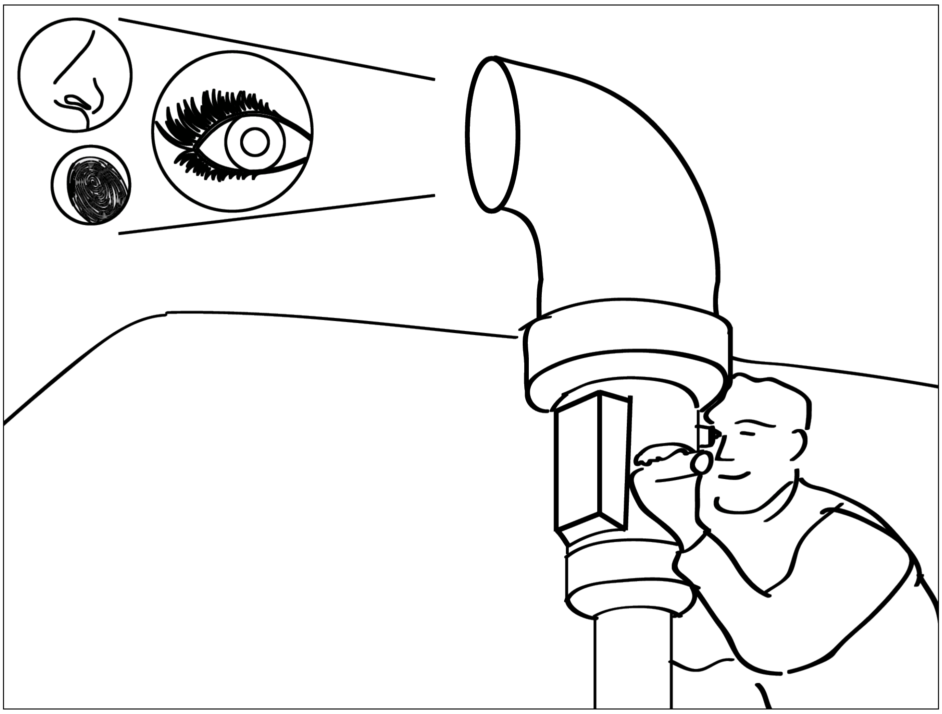

Figure 6.1: First scribble visualizing the 'Periscope' concept. The user can explore the outside environment and discover things that are usually not visible. Drawn by Marc Landau.

6.2.1 The Periscope Experience Story

Following this idea and the motivation of creating an experience based on the need for Relatedness we wrote the experience story. With reference to our design process, the story describes feelings and emotions of the characters as well as key elements of the interaction but does not yet suggest details on a potential implementation of a future system.

The Periscope

One evening, Richard is sitting at the living room table with his wife Anna and his son Lucas, planning their vacation. Last year the long ride to their holiday destination was awfully boring for Lucas. This year, everything is supposed to be better. "We will really go on holidays together", Anna says. "Lucas, while we are driving, you can help me to find places we would like to visit."

During the trip Lucas is curious, what there is to see along the way. Using the periscope he is able to take a look at the sights ahead. He discovers a castle close to them, which he absolutely wants to see. Lucas is a big fan of the middle age and brave knights.

Eager to share his discovery, he tells his parents about the castle. "Let me have a look at it, too", Anna says. While taking turns looking through the periscope, they talk about the castle and who might have lived there hundreds of years ago.

"Wow, it is huge!" Lucas exclaims. He really likes to visit the castle. Anna browses through more information and spots that they offer tours. They can already hear two knights fighting with their swords. This trip is a real adventure for Lucas, who is happy to spend some fun time with his parents.

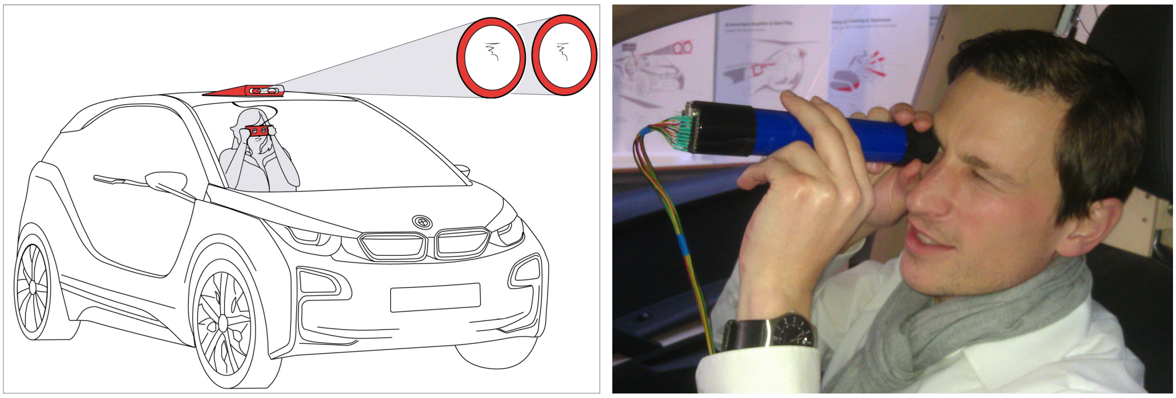

Figure 6.2: Left: Second scribble visualizing the 'Periscope' concept. Drawn by Marc Landau. Right: The preliminary Experience Prototype is a telescope with a small display.

The story inspired the Experience Designer to sketch how the Periscope could be integrated into the car (see figure 6.2 on the left). A device such as a camera is attached to the roof of the car and transmits pictures to a mobile device located inside. A passenger can use the mobile device to explore the environment by looking at the recorded images that can be augmented with additional information. Inspired by story and this sketch, I implemented a preliminary experience prototype (see figure 6.2 on the right) which I will present in more detail in section 6.3.1. In short, it is a telescope[2] showing a representation of the outside environment.

[2] Please note that we kept the name 'Periscope' even though the experience prototypes are based on a device shaped like a telescope because this name was already well adapted in the team and the project management when prototyping started.

6.2.2 Translating the Experience into an Interaction Concept

In parallel to the implementation of the preliminary prototype, the experience designer of our team drew a storyboard (see figure 6.3) visualizing the interaction with Periscope as described in the story inspired by this first interactive representation (see figure 6.2). The key frames of the storyboard visualize important aspects of the interaction and can be translated into the following working principles:

P1: Periscope is a mobile device that can be used by the passengers of a car to explore the outside environment (story: *able to take a look at the sights ahead*; storyboard: frame 2).

P2: Only one person can use Periscope at a time, triggering conversation about discoveries (*He discovers a castle* and *tells his parents*, frame 3).

P3: Discoveries can be shared by actively handing over the Periscope, enabling the exploration of points of interest as a group (*let me have a look at it* and *taking turns looking through the periscope*, frame 4).

P4: The co-driver can access detailed information once a discovery is made (*Anna browses through more information*, frame 5).

P5: Once the group has discovered a point of interest, audio feedback enriches the experience (*they can already hear two knights fighting*, frame 6).

P6: A discovered point of interest can be chosen as a next destination (*he really likes to visit the castle*, frame 7).

6.3 The First Periscope Experience Prototype

With the Periscope experience story and the working principles as requirements for realizing interactive representations in mind, I implemented a first experience prototype in the next step of the design process. A preliminary low-fidelity prototype with limited functionality helped to explore the concept and to determine details for further implementations. The following sections will provide details about the implementation and evaluation.

6.3.1 Implementing a Preliminary Experience Prototype

Inspired by the experience story and first sketches I built an interactive representation of the Periscope experience (see figure 6.2 on the right). We used this prototype in the design team to explore the concept and to generate ideas how to integrate it into the car, leading to the storyboard illustrated in figure 6.3. Additionally, the prototype helped to communicate the concept to other people related to the project, such as university professors, management and our scientific consultant.

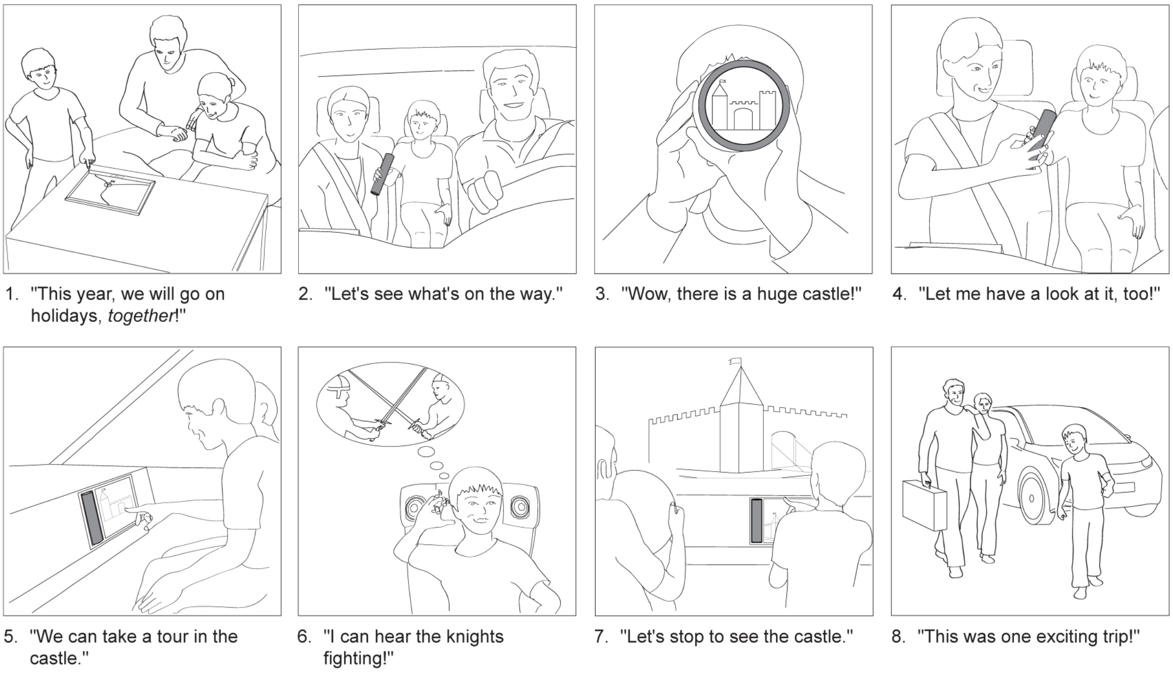

Figure 6.3: First storyboard visualizing the 'Periscope' concept. Passengers can explore the environment (frames 2 and 3), share discoveries with others (4), retrieve additional information (5 and 6) and navigate to the new destination. Drawn by Marc Landau.

Software and Hardware

The implementation was done in roughly one day and therefore features low fidelity and resolution. The body of the prototype is an actual toy telescope with a length of 30 cm. First, I removed the lenses and all other components from the inside of the housing. Second, I attached a small 1 inch TFT display to the front opening of the telescope. The display is powered and controlled by an Arduino, meaning that a cable runs from the board to the Periscope. The display features an SD card reader where I stored some images of restaurants nearby. I attached the prototype to the roof of the car mock-up between the front seats so that it was easy to reach for co-driver as well as passengers in the back seat.

Interaction

One possible action is taking the Periscope and looking through the opening. The images of the restaurants are now visible and presented as a slide show automatically switching to the next picture after five seconds. Now, the person exploring the images can pass the prototype to another passenger and they can start a conversation about choosing one of the shown restaurants. The prototype features a low interactivity and is rather far from the actual use case of a driving situation. But when presented with the story before using the Periscope people were able to imagine the given scenario and treat the low-fidelity prototype as the illustrated device.

Qualitative Evaluation

To discuss the concept and explore the Periscope experience, we conducted a workshop with ten participants including the members of the design team as well as other project related persons. We collected qualitative feedback by observing the usage of the prototype and evolving situations. We also took pictures documenting the interaction as well as notes gathering statements and comments. By analyzing and structuring the feedback we extracted further details enhancing the interaction design for the Periscope. This lead to an updated and more detailed storyboard illustrated in figure 6.4.

An interactive map representing the outside environment
When looking 'through' the Periscope, a part of a map showing the outside environment is visible. This part of the map will adapt to the user's movements. E.g., when turning to the side while holding the periscope, the view will dynamically pan in the specific direction. Thus, a map covering 360 degrees will be available.

The exploration of interesting sights
The user can zoom in and out of the map and thus increase the level of detail. When spotting a new point of interest, it is possible to zoom towards the location. This will unveil additional information such as the distance or a picture.

An option to lock the current view
With the visible part of the map adapting to the user's movements, a discovered point of interest would get lost when handing over the Periscope to another passenger. Therefore, it provides a function for locking the current view (see frame 3 in the storyboard shown in figure 6.4). When the next person is done looking at the shared discovery, the view can be unlocked and the exploration continues.

Story and storyboard provide the context for early prototypes
Donald Norman, who was the scientific consultant during our project, likes to try prototypes and play with them. Without knowing the story or the concept, he took the Periscope and looked at the pictures for a minute. Then he said "Well, this is pretty cute but worthless." But after listening to the story and taking a look at the first storyboard depicted in figure 6.3 he interacted with the prototype again, now knowing the context of use, and stated more positive and constructive feedback about the concept. This was a general observation we made when presenting and using early implementations in user studies. The low-fidelity and low-resolution prototype with its limited interactivity only unfolded its full potential in combination with the context illustrated by story and storyboard.

A dedicated device
One issue discussed during the workshop was the kind of device realizing the Periscope experience. One suggestion was the implementation of an app running on the central display in the dashboard of the car. We decided against this solution because the story clearly defines a moment where the visualization is only visible to one person at a time triggering conversation about points of interest. For the same reason, we did not choose to implement an app for the smartphone or a tablet. Another aspect arguing against the use of a mobile device is

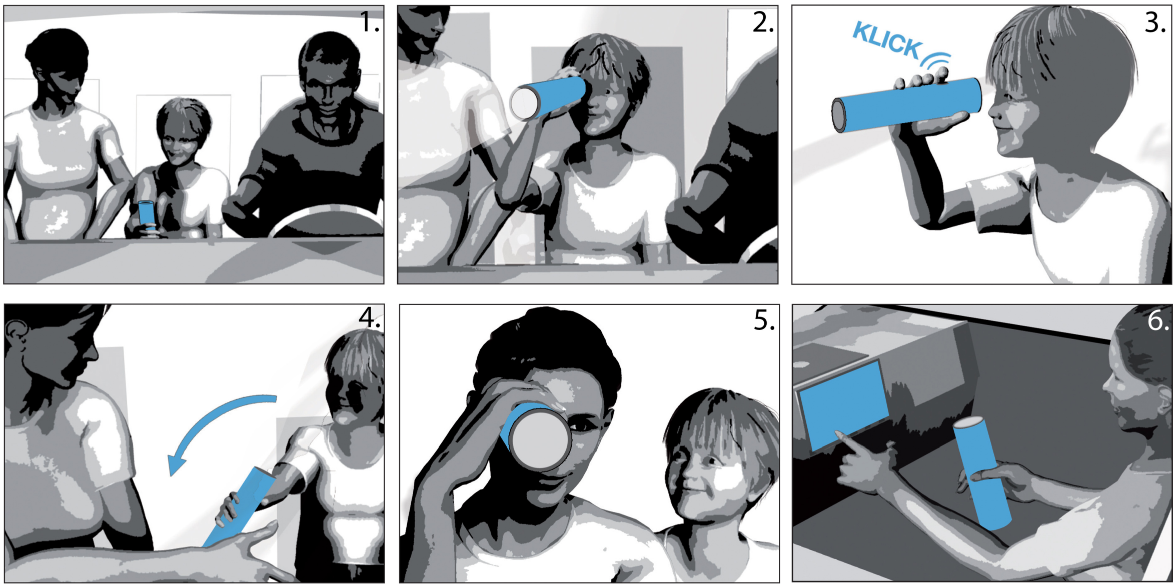

Figure 6.4: Second storyboard visualizing the enhanced 'Periscope' concept. A discovery can be 'locked' before passing the Prototype on (frame 3) and the user can zoom in and out of the visualized map (5). Drawn by Marc Landau.

its private character as it belongs to one of the passengers, which contradicts the moment of sharing the experience with others when passing on the Periscope. The design decision of realizing a dedicated device is an example of how the implementation of a concept must pay attention to all aspects of the story in order to achieve a consistent experience.

6.3.2 Implementing the First Experience Prototype

The exploration of the Periscope concept by building and testing a preliminary low-resolution and low-fidelity prototype with limited interactivity resulted in an updated interaction design illustrated in figure 6.4. The next step was the implementation of the Periscope experience in a high-resolution prototype (see figure 6.5) with the goal to evaluate whether the sketched interaction can lead to the desired experience described in the story[3] However, I kept the fidelity low in order to allow for a fast iteration and thus enable quick evaluation results.

Interaction

When looking through the Periscope, a passenger can see a part of a map representing the area around the car (see figure 6.6). The perspective is not the bird's eye view, but the

[3] The first Periscope experience prototype was implemented by Maximilian Hackenschmied in his Bachelor thesis under my supervision. For more details on the implementation see [26].

Figure 6.5: The first Periscope experience prototype and a display providing additional information about discovered points of interested are placed in the dashboard in front of the co-driver.

driver's point of view. Points of interest (POI) such as sights or lakes are marked on the map. When the user turns to the left or right while holding the prototype, the visible part of the map changes accordingly. It is possible to zoom in and out of the map by rotating a part of the housing similar to camera zoom lenses. When zooming towards a POI, the color of the marker changes to indicate that this sight is selected. Now, the user can click a button to 'freeze' the image he is currently seeing. Thus, when handing over the Periscope to share a discovery it will not get lost due to the movement of the prototype. When the button is pressed again, the visible part of the map adjusts to the direction the Periscope is currently pointing at.

Whenever a POI is selected, the co-driver can press a button on his display and further information such as opening hours or historic details appear on the screen. Additionally a sound representing the POI is played. When the group decides to visit a POI, the co-driver can press a button to send the new destination to the navigation system.

Hardware

Figure 6.7 illustrates the setup of the prototype. A piece of drainpipe forms the housing of the Periscope, defining its telescope-like structure. The pipe is divided into two parts by

[5] https://www.google.com/earth/ (accessed 01/02/2015)

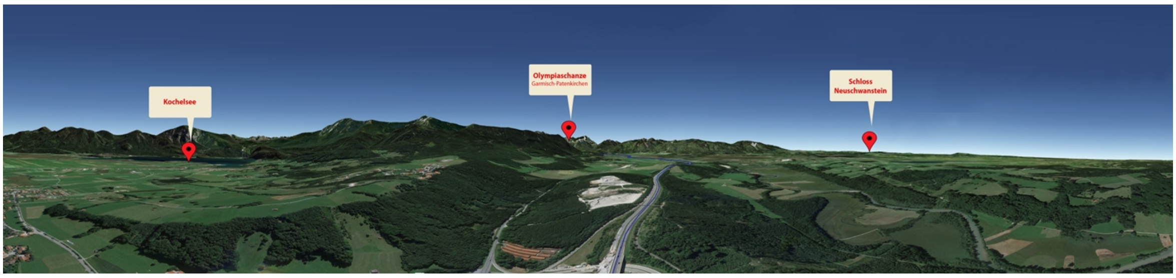

Figure 6.6: The representation of the environment visible when looking through the Periscope prototype. Markers represent points of interest. The graphic was made by Maximilian Hackenschmied based on material obtained from Google Earth[5].

a chassis made out of acrylic glass holding a smartphone, the Samsung Galaxy S running Android. We decided to use a smartphone because it provides an accelerometer to track the movements of the prototype, a display to show the map, storage to save the map image as well as a processor to determine and update the screen contents. The front part of the Periscope carries a button that can be clicked to freeze the part of the map that is currently visible. Besides this button, this part of the prototype does not hold any other electronic parts that would otherwise block the view onto the screen of the smartphone.

The back part of the Periscope is a rotatable wheel implementing the zoom functionality. The wheel is attached to a rotary potentiometer measuring if and how far it is turned. An Arduino Micro, a smaller version of the Arduino microcontroller platform, reads inputs of the button and the potentiometer. The Arduino is powered via USB cable connected to a computer.

A tablet PC displays additional information about POIs and plays audio via its internal speakers. The tablet as well as the Periscope prototype are located in the dashboard in front of the co-driver (see figure 6.5).

Software

The software architecture of the first Periscope prototype consists of four parts, namely the Arduino, the smartphone, a tablet PC and a desktop computer. The computer runs a Java server and thus constitutes the central element of the client-server architecture. The Arduino, the first client, reads the input values generated by the button and the rotary potentiometer. These are transferred via a USB connection to the computer. The server calculates the current zoom level and determines the freeze-state of the map based on the sensor values.

A WLAN connection to the computer embeds the smartphone as the second client into the network. The smartphone stores a high-resolution image of a map (see figure 6.6). An Android application constantly calculates the visible part of the map based on sensor values of the integrated accelerometer and displays the resulting image on the screen. Additionally, the app receives zoom level as well as freeze-state from the computer via TCP and updates the screen accordingly.

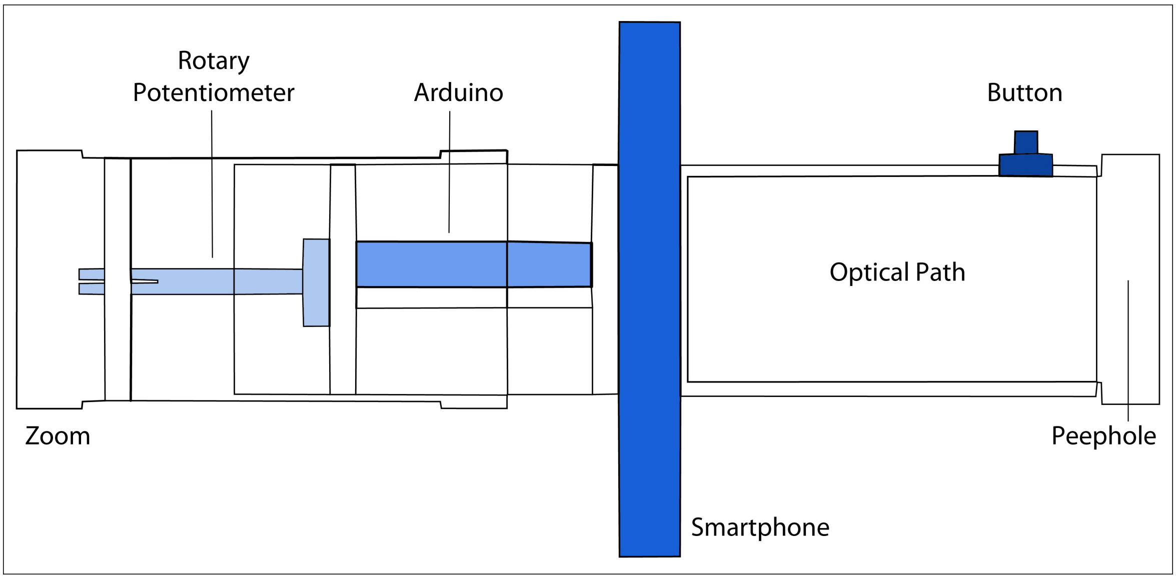

Figure 6.7: Blueprint of the first Periscope experience prototype. A smartphone tracks movements and displays the map of the environment. An Arduino determines whether the button is clicked to freeze the image or the wheel is rotated to zoom in and out of the map. Based on [26].

The third client is the tablet PC that is embedded using a WLAN connection. The tablet runs an Android application displaying additional information on the POI that is currently selected and plays corresponding audio feedback. By clicking a button on the screen, the address of the POI can conceptually forwarded to the navigation system as a new destination.

The map of the environment is represented by a static panorama image (see figure 6.6). It does not show the actual environment of the lab where evaluations will take place. It does not change and adapt due to the virtual driving situation described in the experience story, but depending on the movements of the person holding it.

6.3.3 Evaluating the First Experience Prototype

As this prototype constitutes the first interactive representation of the Periscope implementing the full resolution and interactivity of the concept, it was essential to evaluate whether it triggers the designed experience. In contrast to the Heartbeat concept, Periscope allows for a social interaction engaging more than one user [58] and thus invited teams of two passengers. We tested this first prototype in a static situation without a driving simulation and thus decided to conduct the study without the role of the driver.

Setup and Procedure

In each trial of this study, two participants took the roles of the co-driver sitting in the right front seat and a passenger sitting in the back seat (see figure 6.8) of our car-mock up (see fig-

Figure 6.8: First Periscope experience prototype used during the user study. The co-driver finds a point of interest and talks to the passenger in the back about her discovery.

ure 6.11) according to the roles described in the experience story. First of all, we welcomed participants and introduced the context of the study by showing the car mock-up and saying that we evaluate a device for exploring interesting sights during leisure rides or on vacation trips. Next, we explained the functionality of the periscope by presenting the storyboard illustrated in figure 6.4. We provided time to look at the scenario and asked participants to imagine themselves in the illustrated situation. Then, we instructed them to enter the mock-up, explore the prototype and use it to decide together which point of interest they would like to visit. We did not set a time limit for solving this task. All groups interacted with the prototype a time between 10 and 15 minutes. After the experiment, participants completed the UXNQ (see appendix on page 153) measuring the fulfillment of the psychological needs for Stimulation and Relatedness as well as the PANAS measuring Positive and Negative Affect. The study concluded with a semi-structured interview asking participants about how they experienced interacting with the prototype. As an incentive each participant received a gift certificate with a value of ten Euros.

Results

Altogether 28 participants grouped in 14 teams of two attended the study. Nine were female. The mean age was 25. Table 6.1 summarizes the quantitative results. Stimulation (M = 4.07, SD = 0.56) was rated above the scale mean of 3. The same was true for Relatedness (M = 3.55, SD = 0.81). Cronbach's α showed an acceptable internal consistency for both scales (Stimulation: α = .63; Relatedness: α = .69). We found Positive Affect (*M* = 3.37, *SD* = 0.72) whereas Negative Affect was not present (*M* = 1.72, *SD* = 0.27).

Pearson's *r* showed that both needs Stimulation (*r* = .44, *p* = .02) and Relatedness (*r* = .41, *p* = .03) positively correlated with Positive Affect. Both needs did not correlate with Negative Affect (Stimulation: *r* = -.21, *p* = .29; Relatedness: *r* = -.15, *p* = .46).

For each trial we asked participants whether they knew each other before attending the study of whether they just met. We found that familiar teams (*M* = 3.77) rated Relatedness higher than unfamiliar teams (*M* = 3.04), which was a significant difference (*t*(26) = -2.30, *p* = .03).

We performed multiple independent t-test to analyze differences in the experiences of the roles co-driver and rear-seat passenger but did not find significant results for Stimulation (*t*(25) = -0.20, *p* = .84), Relatedness (*t*(26) = -0.38, *p* = .71), Positive Affect (*t*(26) = -0.84, *p* = .41) and Negative Affect (*t*(26) = -1.14, *p* = .27).

	M	SD	α
Stimulation	4.07	0.56	0.63
Relatedness	3.55	0.81	0.69
Positive Affect	3.37	0.72	0.77
Negative Affect	1.72	0.27	0.48

Table 6.1: Descriptive values of UXNQ and PANAS resulting from the evaluation of the first Periscope experience prototype

Discussion

The Periscope triggered a stimulating experience
The psychological need for Stimulation was fulfilled through the interaction with the Periscope prototype. This resulted in positive emotion and thus a positive experience. One participant told us "I had a pleasurable experience that made me curious" and another said that "this is a good way to overcome boredom on long drives". In the interviews participants pointed out the moment of looking through the prototype and the moment of seeing further information on the display to be most exciting.

Interacting with the Periscope fostered Relatedness
The teams experienced Relatedness when using the Periscope together and reported positive emotion. One team underlined "the social event: we explore the environment *together* in a playful way" and highlighted "the moment when you pass on the picture and share something". We observed how conversations started as soon as the first person using the prototype saw the map and discovered a POI: "Hey, I see the mountains. This looks nice, I wanna go there. Do you want to take a look too?" All teams passed the prototype back and forth several times and continued their exchange about the POIs until they decided for a new destination.

Familiar team members were more likely to experience Relatedness
Team members who signed up for the study together scored Relatedness items higher than

those who met for the first time. This is in line with the focus of the UXNQ items related to this need on people "who are close to me" and "who are important to me". Therefore, when prototyping for experiences based on Relatedness, the social relation between users has to be taken into account.

A positive combination of Stimulation and Relatedness
Both Stimulation and Relatedness were addressed and lead to Positive Affect. Additionally, qualitative feedback shows that comments related to one need were often followed by comments based on the other: "You can actually do something while driving and then share it with somebody" or "It is something that I have never done before and I could even store and share new destinations". These results suggest that a design based on this combination of needs offers a high potential for creating positive experiences.

A low usability did not prevent experiences
Because of its mid-fidelity and the focus on the experience rather than the implementation the prototype offered a low usability. We observed that at first contact with the prototype, some participants held it upside down or tried to look into the wrong end of the housing. One person said how he "got tangled up in the cable". Some noted that the prototype is "heavy and clumsy". A jitter of the image and delayed updates of the screen after moving the prototype were other reported usability problems. We gathered comments on usability issues from all groups but at the same time this fact did not seem to interfere with the positive experience participants reported.

In this study, we evaluated the first functional prototype implementing the Periscope experience. Results show that we successfully translated the story into an interactive representation in an early stage of the development process. The second experience prototype described in the following sections will implement the Periscope with the same resolution and functionality but in a high fidelity while also paying attention to appearance and usability. A second evaluation will show whether the higher fidelity will lead to a more meaningful experience.

6.4 The Second Periscope Experience Prototype

The next step in the process of designing the Periscope experience was the implementation of a second prototype. Compared to the advancement of the Heartbeat described in section 5.4, there is a difference in the resolution of both representations. The first Heartbeat prototype implemented only some functionality and was then upgraded to a high resolution. On the other hand, the first Periscope prototype already realized the entire functionality and thus had a high resolution. Therefore, we set the focus for the second prototype on its design and usability in order to improve the Periscope experience. Based on the qualitative feedback and our observations gathered during the first user study, we decided to realize the following improvements:

Stand-alone device: Instead of a cable connecting the prototype to the computer, we implemented a wireless connection. This improved the handling of the Periscope especially when handing it to a passenger in the back.

Improved design: The material of the first prototype and the use of a smartphone underlined the low fidelity and caused it to be unhandy. Thus, the new version followed the shape of a telescope and we adapted the appearance to fit the interior of the car mock-up. We chose more professional parts to realize the interactive elements such as the button and the zoom wheel.

Improved visual feedback: Compared to the jitter and delays of the first prototype, we tracked movements more precisely and chose a screen with a higher resolution and frame rate.

Improved optics: Two participants of the first study who were 50+ years old stated that they had problems to focus the screen contents. In fact, the distance between eye and screen is short, causing people who are farsighted do to their advanced age to have difficulties when focusing on the displayed image. We solved this problem by integrating a close-up lens into the opening of the prototype.

6.4.1 Implementing the Second Experience Prototype

Figure 6.10 shows the second experience prototype[6] implementing the Periscope story. The interaction design did not change, as functionality and resolution are identical to the first prototype. However, the implementation differs in terms of soft- and hardware.

Hardware

The housing is a custom-made part produced with a 3D printer. On the outside it realizes the shape of a telescope (see figure 6.10) and on the inside it is designed to hold all electronic parts (see figure 6.9). The zoom wheel is 3D printed as well and its surface contains notches offering an affordance indicating that it can be grabbed and rotated. The opening of the Periscope carries a 10-diopter lens magnifying the display contents to counteract farsightedness. The lens can be screwed in and out of the thread in order to adjust the focal length individually.

An Arduino Pro Mini powers and reads values from three sensors. A button offers the functionality of freezing the image visible before passing on the Periscope. An incremental encoder is attached to the zoom wheel and measures its rotation. An accelerometer integrated into an inertial measurement unit (IMU) tracks the movements of the Periscope.

[6] The second Periscope experience prototype was implemented by Patrick Proppe in his Bachelor thesis under my supervision. For more details on the implementation see [83].

The display showing the map is provided by a MotoACTV smartwatch. The smartwatch is connected to the Arduino via USB and to the computer via WLAN. To realize the USB connection, we extended the Arduino with a USB shield.

Because we abstained from a cable connecting the Periscope to the computer, we needed to add a power supply to the prototype. Two cell phone batteries power smartwatch, Arduino and USB shield. Two chargers enable us to recharge the batteries via a USB connection. A converter adjusted the voltage difference between power supply and Arduino, USB shield as well as IMU.

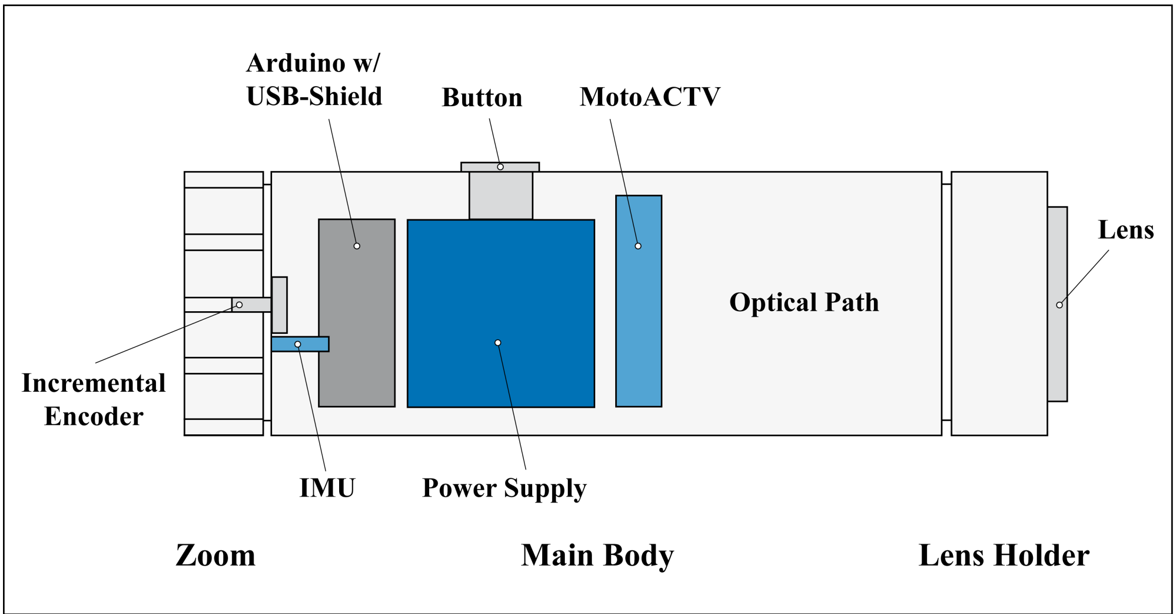

Figure 6.9: Blueprint of the second Periscope experience prototype. A sensor unit tracks movements and a smartwatch displays the map of the environment. An Arduino determines whether the button is clicked to freeze the image or the wheel is rotated to zoom in and out of the map. Two cell phone batteries deliver the power.

Software

As in the setup for the first prototype, communication between devices is based on a client-server architecture. The two clients in this case are the smartwatch integrated in the Periscope and the tablet located in the dashboard. Both are connected to the computer via WLAN. The Arduino reads all sensor values and calculates the zoom level, the state of the button as well as the part of the map that should currently be visible based on the movement of the prototype. It constantly transfers the data via a USB connection and the Android Debug Bridge protocol (ADB) to the smartwatch.

The smartwatch runs an Android application serving two purposes. First, it updates the visible part of the map based on the location calculated by the Arduino and displays it on the screen. Second, it informs the server whenever the user selects a new point of interest. The

Figure 6.10: The second Periscope experience prototype. The co-driver clicks a button to freeze the image showing a point of interest she just discovered before passing on the prototype to a passenger in the back.

JAVA server passes this information on to the tablet in the dashboard in front of the co-driver, which shows additional information about the POI on demand, i.e. whenever the co-driver touches a specific software button.

6.4.2 Evaluating the Second Experience Prototype

The second Periscope experience prototype implements the same resolution as the first one but now in a high fidelity. It features an improved design, upgraded hard- and software as well as a better usability. We conducted a second user study to evaluate whether the new prototype still supports passengers to relive the Periscope experience that is illustrated in the storyboard. To adjust the setting to the higher fidelity of the prototype, we extended the setup of the first study and introduced the role of the driver and a driving simulation.

Figure 6.11: Second Periscope experience prototype used during the second user study. The passenger in the back explores points of interest and communicates his discoveries to the other passengers.

Setup and Procedure

The study took place in the same car-mock up we used for the first evaluation. However, we simulated a driving situation to integrate the role of the driver into the setting. The SILAB software[7] simulated a route through a small town and a country road. We projected the image, additionally showing speedlimit and current speed, onto the wall in front of the car mock-up. We provided a Logitech Driving Force GT steering wheel and acceleration as well as braking pedals to control the simulation.

Compared to the previous user study, we invited groups of three who represented the roles of a driver, a co-driver and a back seat passenger (see figure 6.11). We welcomed participants and introduced the context of exploring the environment while driving. Next, we presented the prototype and its features by showing the storyboard illustrated in figure 6.4. We let each group decide on the allocation of the three roles with the requirement of the driver having a valid driver's license. After explaining the setup and handling of the simulation to the driver, we provided sufficient time for a test drive to get used to the steering wheel and pedals and reminded the driver to obey the traffic rules during the experiment. We instructed the group

[7] http://www.wivw.de/en/silab (accessed 01/02/2015)

to use the prototype to explore the environment and to choose one point of interest as the next destination. We did not set a time limit for the experiment. Similar to the first study, the groups interacted with the prototype for about 10 to 15 minutes.

After the experiment we provided a questionnaire to each participant containing items from the UXNQ to measure the fulfillment of the psychological needs for Stimulation and Relatedness. To quantify the arousal of positive emotion, we included the joviality scale of the PANAS-X[8]. We concluded the study by conducting a semi-structured interview asking about the Periscope experience. We also used Laddering [85] to identify the underlying psychological need of certain statements.

Results

Altogether 39 participants organized in 13 groups took part in this study. Twelve of them were female. Participants were between 19 and 32 years old with an average of 24.2. None of them had participated in the evaluation of the first Periscope prototype.

Both psychological needs for Stimulation (M = 3.97, SD = 0.68) and Relatedness (M = 3.48, SD = 0.83) were fulfilled during the interaction with the Periscope (see table 6.2). We found proof for the arousal of Positive Affect (M = 3.34, SD = 0.58). Chronbach's α determined a good reliability for all scales (Stimulation: $\alpha = .84$; Relatedness: $\alpha = .78$; Positive Affect: $\alpha = .83$). Both needs Stimulation ($r = .46$, $p < .01$) and Relatedness ($r = .49$, $p < .01$) positively correlated with Positive Affect according to Pearson's r.

	M	SD	α
Stimulation	3.97	0.68	0.84
Relatedness	3.48	0.83	0.78
Positive Affect	3.34	0.58	0.83

Table 6.2: Descriptive values of UXNQ and PANAS resulting from the evaluation of the second Periscope experience prototype

To analyze whether the experience differentiated between the three roles of driver, co-driver and back-seat passenger, we performed a one-way ANOVA. We did not find significant differences for Stimulation ($F(2.36) = 2.47$, $p = .10$), Relatedness ($F(2.33) = 0.26$, $p = .77$) or Positive Affect ($F(2.36) = 1.04$, $p = .36$).

Discussion

The Periscope triggered a stimulating experience
Results show that the fulfillment of the need for Stimulation caused positive emotion and

[8] http://www2.psychology.uiowa.edu/faculty/watson/PANAS-X.pdf (accessed 11/20/2014)

therefore created a meaningful experience. When applying the laddering technique we collected statements of 20 different participants during the interviews that were based on Stimulation. Examples are "it was great how the Periscope helped to discover places in an unfamiliar town" or "we actually moved while being in the car which was new to me" or "it made me curios and my curiosity was satisfied".

Interacting with the Periscope fostered Relatedness
Qualitative and quantitative results show that participants experienced Relatedness, i.e. they felt close to people they like and as part of a team. Using laddering we identified statements made by 12 participants that were based on this need. One said that he "usually feels segregated when sitting in the back, but this was different with the Periscope". Another said that "this is something we can do during long drives and that involves everybody in the car". A third "liked that I can share with others what I see".

The driver was a part of the experience
Before conducting the experiment, we expected participants who took on the role of the driver to report a different experience than the passengers because they concentrate on driving and do not actually use the periscope. However, we did not find differences between the results of all three groups. Comments such as "I was able to concentrate on driving while the others helped me with the organizational stuff" and "I listened to the others and to the audio information about the sights" showed that drivers felt as part of the social experience without being distracted from the driving task.

An improved usability did not lead to a better experience
One goal of this study was to find out whether the improved quality of the Periscope prototype has an influence on the perceived experience. Comparing the results of both evaluations shown in tables 6.1 and 6.2, we found no notable difference in the fulfillment of the needs for Stimulation and Relatedness or the arousal of Positive Affect. Both studies resulted in a correlation between both needs and the Positive Affect. I conclude that both high-resolution prototypes allowed for an evaluation of the concept's experienceability independent from the implemented fidelity in different stages of the design process.

Limitations
When analyzing the results of the studies, the following limitations should be kept in mind. (1) Although I commented on the equality of the quantitative results of both Periscope evaluations, their comparability is limited. The second study involved a driver and a driving simulation. Additionally, the UX Need Questionnaire used in the second study contained five instead of three items per need in order to consider further aspects of the interaction, e.g., "I felt as part of the team". Compared to the first study where we applied the PANAS to measured Positive Affect, we used the subscale 'Joviality' of the PANAS-X in the second one[9]. (2) We conducted both evaluations in lab situations with a car mock-up. While this was done on purpose to realize fast evaluation results in early design stages, predictions

[9] Please note that one of the tasks of the CAR@TUM project was the development of methods to quantitatively measure User Experience. Therefore, the questionnaires evolved and changed in parallel to the implementation of the prototypes.

on the experienceability of the Periscope prototypes in actual driving situations cannot be made. Real-world environments are more complex and might have significant influences on the fulfillment of needs and the arousal of positive emotion.

6.5 Implications for Experience Prototyping

The Periscope supports passengers in a car to find interesting sights, even if these are not directly visible. Two key elements of the interaction are crucial to the experience. First, one person uses the Periscope to explore points of interest. This situation stimulates conversations about discoveries and points the attention to the outside environment. Second, by passing on the Periscope to another person, discoveries can be physically shared within the car, triggering a feeling for being part of a group and a common activity. A first experience prototype with a high fidelity and a low resolution allowed for the exploration of the idea and a first evaluation of the social experience. With a second experience prototype with a significantly improved fidelity we showed that participants relived the experience as illustrated in the storyboard in groups of three including a driver and driving simulation.

Prototyping social experiences

In this project, both experience prototypes did not directly cause positive emotion, but were developed to mediate social interaction leading to meaningful experiences. A careful interaction design as well as the compliance of the prototypes to the situations described in the story triggered conversations and social behavior within the groups. Qualitative and quantitative results of both studies show that the prototypes mediated social experiences based on the need for Relatedness.

Prototyping a dedicated device

In several stages of the process, crucial design decisions were necessary. A prominent example is the implementation of the Periscope as a dedicated device, where qualitative feedback contradicted requirements derived from the experience story: Users suggested an app for their smartphone or tablets in contrast to our realization of a telescope. This kind of device allowed for an isolated usage by one person only, leading to curiosity and conversation. Additionally, it supported the active sharing of discoveries with the physical act of passing on the prototype without any privacy concerns.

Involving the uninvolved

In the story as well as during the interaction with the Periscope, the driver takes on a rather passive role. It was somewhat surprising to see that participants with this role felt as part of the experience during evaluation. Even though they did not actively use the prototypes, they were happy to be able to leave the navigational task of finding the next destination to the co-drivers, followed conversations about interesting sights and felt as part of a group. However, some stated that passengers should not be able to activate new destinations without their approval, which hints at concerns triggered by the need for Competence. We conclude that passive roles should also be considered in the definition of the experience, the design and implementation of prototypes and their evaluation.

Embedding prototypes in their context

Prototypes with low resolution and low fidelity cannot be expected to be self-explanatory. Especially when playing a crucial role as mediators for experiences, they need explanation and embedding into their context. The combination with non-functional prototypes such as story and storyboard proved to be helpful to illustrate and communicate the meaning of the intended interaction.

Considering the usability of experience prototypes

The fidelity of a prototype also has an impact on its usability. A clumsy handling and an immature functionality characterized the first Periscope prototype. Nevertheless because it implemented all details of the interaction concept, it successfully supported participants in reliving the designed experience. We achieved the same results with the second prototype, realizing high resolution *and* fidelity and therefore an improved usability. However, we observed less comments on the usability of the prototype during the second study. Thus, the fidelity does have an influence on the kind of feedback during evaluations.

Chapter 7

GestShare: Experiencing Freehand Gestures in the Car

To improve the golden moment of opportunity,
and catch the good that is within our reach,
is the great art of life.

– Samuel Johnson (English Writer and Poet) –

In this chapter, I will introduce GestShare[1], a concept supporting drivers in communicating with other traffic participants. Driver-to-driver interactions can be performed using freehand gestures, which are suitable because they are a well-known and direct means of communication. GestShare enables drivers to virtually connect to others nearby by pointing in the direction of a car. Once a connection is established, it is possible to 'grab' and listen to the music currently playing in the other vehicle or to initiate a phone call.

GestShare is the third and last case study I present. After introducing the story, the storyboard and the prototype implementing the GestShare concept, I will focus on the evaluation of the experience. While we evaluated Heartbeat and Periscope solely in lab settings with and without applying driving simulations, we conducted two equivalent user studies with the GestShare prototype, one in the lab and one in the car in a regular traffic situation. The goal was to gather first evidence whether early experience prototypes require evaluations in their real world context or if a simulated environment is sufficient.

[1] This chapter is based on [82]. For more details please see the disclaimer on page ix.

7.1 Background and Motivation

After introducing Heartbeat, an in-car information system for electric vehicles, and Periscope, a mobile device supporting the exploration of the outside environment, in this chapter I will report on the experience of using freehand gestures as an interaction modality in the car. Gestures have been utilized as an input modality in HCI research since the 1980s. Nowadays, they found their way into the gaming industry and medical operating rooms, but are not yet ready to be applied in the car. In the following sections I provide a short introduction into the history of freehand gestures in HCI and the application areas they became relevant for.

7.1.1 From Gestural Language to Gestural Interfaces

In his 1996 book "What Gestures Reveal about Thought", McNeill defined gestures as "movements of hands and arms when people talk" and states that they "coexist with the words and sentences of speech but [...] are a separate symbolic vehicle with their own history, and finding their own outlet in space, movement, and form" [74, p. 105]. He concluded that gestures support and enlarge the expressiveness of our language and identified five different types. *Iconics* illustrate the content of spoken words and thus the combination of both generates "a complete picture of a person's thought process" [74, p. 13]. *Metaphorics* are iconic as well, but they refer to "an abstract idea rather than a concrete object or event" [74, p. 14]. *Beats* are hand and arm movements with a certain pattern representing the rhythm of spoken words to emphasize their relevance. *Cohesives* connect "thematically related but temporally separated parts" [74, p. 16] of a spoken discourse by performing the same gesture several times. *Deictics*, the last type, are pointing gestures identifying actual objects in the real world, but can also indicate something that was present at the time of the event the speaker is currently talking about.

The link between deictic gestures and language described by McNeill was already made by Bolt as early as 1980 when he implemented "Put-That-There" [5]. By speaking commands such as "create a blue square *there*" while pointing at a position on a wall, it was possible to create, move, change, name and delete objects which were projected onto a large screen. This multimodal system was the first prototype integrating gestural input into a human-machine interface. Gestures were tracked by a capacitive sensor measuring changes in an electrostatic field caused by movements of the hand. In 1993, Baudel presented Charade [4] which allowed a presenter to directly manipulate his presentation by performing gestures tracked by a data glove. The speaker can point at a projected screen and perform commands such as "go to the next slide" by "moving the hand from left to right" [4]. Baudel underlines the advantages of gestural input being a "direct" and "natural" type of interaction and recommends to iteratively design a specific and appropriate command set which is easy to learn, quick gestures to avoid fatigue as well feedback to indicate recognized gestures.

7.1.2 Application Areas for Gestural Interfaces

Next to capacitive sensing as well as tracking based on sensors that are attached to the hand and measure orientation and acceleration, vision-based gesture tracking became popular due to decreasing hardware costs for cameras and its unobtrusiveness. By using real-time image processing the hand and its movement can be identified by shape, color, depth, motion, or a combination of these features (for an overview see [106]). A steady improvement of technology and tracking algorithms led to the integration of gestural interaction into different application areas.

Human-Robot Interaction

The recognition of gestures is one of the important issues in human-robot interaction. Next to spoken language, robots are supposed to understand gestures to allow a natural communication between robots and their users. Triesch et al. implemented a real-time gesture tracking [102] based on motion and skin color for commanding a robot to grab an object and put it somewhere else. Nickel and Stiefelhagen [78] utilized pointing gestures to direct a household robot to go to the indicated object. Waldherr et al. [107] taught a service robot to follow a user and to understand instructions to pick up trash based on gestures such as waving for telling the robot to follow, an outstretched arm for telling the robot to stop and pointing for showing the robot where to clean up. Yang et al. [114] implemented an algorithm for detecting whole-body gestures such as jumping, lying down or walking.

Medical Applications

Jacob et al. developed Gestonurse [43], a robot passing surgical instruments that are indicated by the surgeon via static hand postures. In such medical environments the staff is often required to remain sterile. Contactless interactions utilizing freehand gestures enable the control of technical equipment without touching non-sterile parts. Graetzel et al. allowed the surgeon to use his finger to point and click on parts of a screen showing pictures taken by an endoscope instead of instructing a nurse using a mouse. Several systems implement gesture tracking for browsing through medical images and for rotating and zooming single pictures during surgery (e.g., [51, 42, 96, 105]).

Gaming Applications

In the entertainment sector, manufacturers of gaming consoles enhanced the experience of playing computer games by integrating freehand and body gestures into the interaction. Nintendo introduced the Wii[2]. Players are equipped with a Bluetooth remote control containing motion sensors as well as infrared LEDs to enable a wireless and motion-based control of games. The PlayStation Move controller by Sony[3] registers the player's movement with

[2] https://www.nintendo.com/wiimini/ (accessed 12/07/2014)

[3] http://www.playstation.com/en-us/explore/ps3/ (accessed 12/12/2014)

built-in inertial sensors and its position is determined by a webcam tracking the controller's illuminated tip. The Microsoft Kinect sensor for the Xbox console[4] as well as the Sony PlayStation Camera[5] track hand and body gestures of two players by emitting and sensing infrared light and thus generating and analyzing a depth image in combination with a video image.

7.1.3 Gestural Interfaces in the Car

As Riener stated, "while defining gestures for videogames is often straightforward [...] this is not the case for computer controls, including those in the car" [86]. Interacting with in-vehicle information systems is critical in terms of driver distraction and resulting safety issues. This leads to numerous constraints making it challenging to support gestural interfaces [1]. Thus, the contactless opening of the trunk with a movement of the foot is the only commercially available functionality implementing gestural interaction related to the car until today[6].

In research, several approaches exist. Akyol et al. [1] implemented a gesture recognition system by integrating an infrared camera into the roof of the car tracking hand movements in the area above the gear shift. They allow six static hand postures to browse through and play recorded traffic messages and conclude that the use of gestures was rated as "natural and intuitive" [1] by participants of a study but state that recognition accuracy is prone to varying lighting conditions due to the underlying technology. When comparing user inputs while driving using haptic controls and gestural input, Geiger et al. found "substantially reduced distractions when using gestural user input for controlling an automotive MMI" [20]. Zobl et al. [115] conducted a usability study applying wizard-of-oz prototyping and found that participants prefer dynamic gestures that can be used across a variety of applications. In a follow-up study [116] testing a system enabling the control of an in-car infotainment system using static and dynamic gestures, they suggest that such applications require a user-centered design process as well as an adaptive help system to support the learnability of a gesture set. Geiger [19] suggested an inventory of twelve hand gestures and eight head gestures and successfully implemented the hand tracking using an array of distance sensors based on infrared light.

In a more recent project, Endres et al. [13] introduced Geremin, a capacitive tracking system recognizing micro-gestures performed by the index finger while keeping the hand on the steering wheel. The finger draws symbols such as circles, lines, squares and triangles to execute commands potentially controlling an infotainment system. Riener [86] used a Geremin-like approach to track pointing gestures performed while having the right hand on

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4 http://www.xbox.com/en-US/xbox-one/accessories/kinect-for-xbox-one (accessed 12/07/2014)

5 http://www.playstation.com/en-us/explore/ps4/accessories/ (accessed 12/12/2014)

6 http://www.bmw.com/com/en/newvehicles/7series/sedan/2012/showroom/convenience/contactless-tailgate.html (accessed 01/02/2015)

the gear shift and mapped this input to the central information display, enabling the driver to point at and select objects. In a similar setup [86] he applied a Kinect camera to track static and dynamic gestures in the gear shift area to control the on-screen interface. Riener also made a step towards defining an interaction space for freehand gestures in the car. In an elicitation study, he asked drivers to perform a number of gestures and found that "most of the subjects perform gestures in the same region (bounded by a 'triangle' between steering wheel, rear mirror, and gearshift) and with similar spatial extent (on average below 2 sec)" [87].

In summary, research on gestural interfaces in the car has been focused on fundamental aspects such as tracking technologies and gesture sets. However, the adoption of this type of interaction is still delayed due to a lack of acceptance by both manufacturers and their customers. Acceptance has so far been determined in usability tests (e.g., [1]) and elicitation studies (e.g., [115]). In this chapter, I report on our approach of investigating the potential of using freehand gestures to create positive experiences for drivers. In earlier work, we suggested that gestural interaction addresses the psychological needs for Security, Competence and Pleasure-Stimulation [62]. In a second project, we analyzed the acceptance and hedonic qualities by implementing a small set of gestures that are culturally independent and can be used universally across different devices [63]. In a first user study applying the 'stop' gesture in real driving situations we found that attractiveness and hedonic quality was rated significantly higher compared to haptic controls, motivating us to investigate the potential of gestural communication in more detail by applying the CAR@TUM Experience Design process.

7.2 From the Idea to the GestShare Concept

From the day I started to do research in early 2011, I was always fascinated about freehand gestures as an input modality for interactive systems. In the HCI community, I mainly experienced skepticism and amusement towards the ambition of introducing gestures to the car. But everybody seemed to agree that there is some potential for exciting interactions, which became obvious in the gaming industry that introduced tracking systems such as Nintendo Wii or Microsoft Kinect. Researchers who did believe in the potential of in-car freehand gestures focused on their advantages for the driver with respect to a reduced distraction and mental load. In contrast, I intended to apply gestures with the goal to create meaningful experiences and positive emotion. The Experience Design process we created by implementing Heartbeat and Periscope paved the way for exploring gestural interaction in the car from that perspective.

7.2.1 Context Analysis

To analyze the potential of creating meaningful experiences by using freehand gestures in the car, we conducted an analysis according to the first phase of the design process[7]. To gather inspiration for the design of experiences, we conducted a focus group, two rounds of interviews, one of them while driving, as well as a social media analysis.

Focus Group

We conducted a focus group with five drivers discussing their attitude towards using this input modality in the car. Participants concentrated on devices and functions in the car that can be controlled by using gestures. As an example, the reading light could be activated or deactivated by moving a hand directly towards it with the advantage of quickly performing a vague gesture instead of finding and pressing a specific button outside of the field of vision. Participants also suggested to use swipe gesture to control the volume of the radio or the temperature of the air conditioning. To sum up, suggestions for possible gestural interactions in the car mirrored known concepts that have already been analyzed in research projects or design studies by car manufacturers. On the one hand, participants highlighted the potential of allowing easy and quick interactions reducing driver distraction, but on the other hand underlined known problems such as the need to learn a gesture set and the lack of feedback in contrast to other control elements such as buttons.

Interviews

Additionally, we performed three interviews in actual driving situations, asking participants about their general attitude towards using gestures as well as what they do while driving and how they could imagine to integrate gestures into those activities. One participant stated that he is happy with his car and that gestures would not offer and additional benefit. In contrast, the second driver suggested that gestures would be helpful to control devices that are out of reach, such as the glove compartment or the outside mirrors. The driver mentioned that gestures could be helpful and fun, but only if they worked properly. The third participant stated that it would be useful to control devices in the center console with the right hand that is available most of the time anyway. This driver raised concerns about the accidental input of gestures while driving which would cause confusion.

In a second round of interviews, this time not conducted while driving, we asked three participants about positive experiences while driving they remember. Our goal was to gain insights on factors that contribute to the creation of such situations. By clustering the collected statements, we identified three relevant aspects: One is based on entertainment and stimulation, e.g., driving "Highway 1 on the US West Coast" or "along a country road with little traffic, when there is a lot to see" or "in the city with the scenery passing by". The second is being close to others, which was mentioned in statements such as "driving alone

[7] I will only introduce selected steps and results in this section. For more details see [82].

is boring" or "playing guessing games with others in the car". The third factor was security which is provided by the car "when driving in bad weather" and is a concern "in bad traffic".

Input from Social Media

To collect further information about gestural interfaces, we analyzed different social media channels. One the one hand, we scouted relevant user forums as well as blogs of manufacturers producing gesture tracking systems for comments on experiences with this technology. This approach gave insights into positive as well as negative experiences, as comments were either expressing frustration about technical issues ("the Kinect nearly killed me, unresponsive, buggy and nausea causing") or statements about reasons why users like an application or not ("I love the Kinect, it makes you feel like you are part of the game and it makes gaming a more active activity"). On the other hand, we started a digital pinboard called Gesturaction on Pinterest[8], where we collected interaction concepts, tracking technologies, articles, research projects and patents related to this topic. This social media analysis is not a common tool in Human-Computer Interaction research, but it can offer starting points for the design of experiences Similar to moodboards used by designers as a source of inspiration [69, p. 100].

Results

To review and structure the data collection generated during the context analysis, we created an Affinity Diagram [69, p. 12]. First, we placed pictures and sticky notes representing quotes, devices, functions, gestures and technologies on a whiteboard. Second, we sorted all items into categories representing possible applications of freehand gestures in the car. Third, we assigned one or more psychological needs to each category. Fourth, we brainstormed ideas for potential experience designs for each category. In the fifth and last step, we classified and clustered all ideas along two axes: (1) Is only one or are several people involved in the interaction? (2) Is the interaction limited to the car or does it involve the outside environment? One of the clusters represented the classification "interaction with others outside of the car" and included the following ideas:

Poke: A gesture directed at a certain direction can catch the attention of another person.

Push/Pull: A gesture directed towards the own car can pull something from another car and a gesture directed at a certain direction can push something to another car.

Connect: A gesture directed towards another car can initiate a virtual connection between two or more vehicles.

Share/Donate: A gesture directed towards a car or a building outside of the car can be used to donate or share something with others.

Games: Passengers of a car can use gestures to play a game with passengers of other cars.

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[8] http://www.pinterest.com/DerLoehmi/gesturaction/ (accessed 12/08/2014)

7.2.2 The Experience Story

With these ideas in mind, this project is located between Excitement and Openness within the Experience Framework of the CAR@TUM project (see section 4.1.2). The former is true because of the enjoyment that people experience when using gestures, which is due to the directness of the input and thus the natural way of imitating real world interactions. The later is characterized by the social interactions that become possible through the use of gestures. Interacting with other drivers who are usually isolated in their own cars and sharing media between cars represents openness towards other traffic participants. Considering these characteristics, the experience is based on the following psychological needs:

Pleasure Stimulation: The driver uses and explores an input modality that is new to in-car interactions. Furthermore, he can use them to explore the environment and thus extend the borders of his own car towards the outside. The driver can be inspired by listening to music played in other vehicles.

Relatedness: The driver is able to contact other drivers nearby to share music or establish communication by making phone calls. This way, it is possible to be close to others despite the situation of being enclosed in the own vehicle.

Based on the results of the analysis and the underlying psychological needs, we formulated three experience stories, each realizing different ideas for potential experiences and sketched one storyboard for each experience. We evaluated these storyboards in an online study with 107 participants. First, we randomly presented one storyboard together with a short introductory text. Then, each participant completed the UXNQ (see appendix on page 153) and PANAS questionnaires together with the instruction to imagine to be the character in the presented scenario. We also provided the option to provide additional qualitative feedback. Quantitative and qualitative results [82] led to the decision to work with the following experience story. The interactions are inspired by *Sound Pryer* [81], an entertainment application allowing drivers to listen to music that is played in other cars nearby.

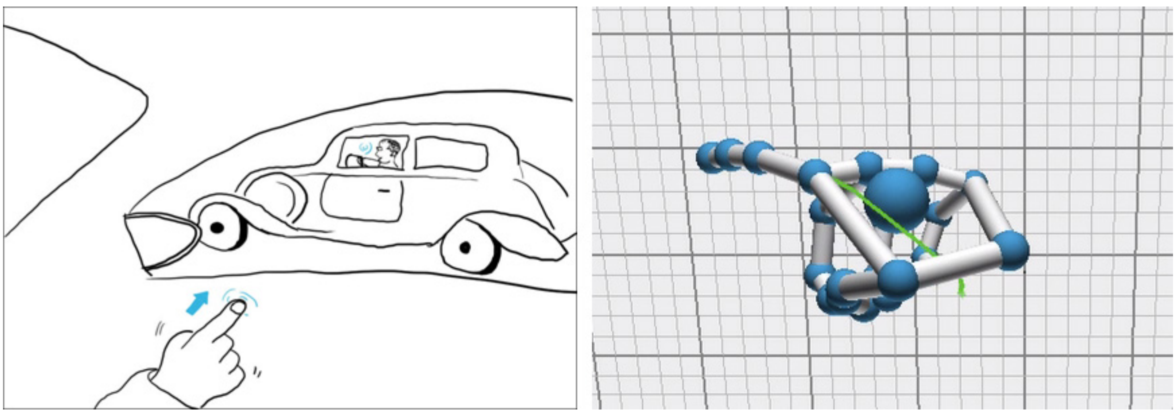

Figure 7.1: Left: First scribble illustrating the 'poke' gesture of the GestShare concept. Drawn by Johannes Preis. Right: The 'poke' gesture visualized by the LEAP FingerVisualizer.

GestShare: Other drivers within arm's reach

Like every Monday, Oliver leaves the house at 7 a.m. for his one hour commute. For six years he has been driving this route almost every day. The commute used to be a poor start of the day - the slow moving traffic was both tedious and exhausting. Despite hundreds of other drivers on the road Oliver felt isolated from the outside world in the shell of his car. As Oliver gets into his new car he is looking forward to the upcoming drive. "I wonder what's awaiting me today", he thinks curiously and starts the engine. A few minutes later he drives onto the busy main street. Stop-and-go. "Well, this might take a while", he sighs and uses the time to look at the cars around him.

He notices a classy vintage car on the right lane. The elderly gentleman driving the car is whistling. "I wonder what he is listening to!", Oliver asks himself. With a short poke directed at the vintage car, Oliver calls the attention of the driver. The elderly gentleman smiles friendly and waves. Oliver reaches out to grab in the direction of the other car and thereby "fetches" the music from the other driver. Shortly after Elvis Presley starts playing on Oliver's audio system. "Get outta here! Right up my alley!!", Oliver smirks and turns up the volume. The cars in front of Oliver start moving and he only sees the elderly man reaching out for his music as well. "If he likes Elvis he'll like my music too!" Oliver is happy about this short but interesting encounter. "Well, music unites."

Oliver is still listening to Elvis as he notices a gentle sound from the back of his car. Now he has been poked. It's Oliver's colleague Tom. "Right, Tom is back from vacation!" Oliver briefly waves with his right hand and thereby accepts Tom's poke. "Now, let's say hi to him", Oliver thinks and calls Tom with a grab in his direction. Tom tells Oliver about his holidays and they begin planning for the upcoming day at work.

Oliver and Tom arrive at the office. "Now other drivers really are within arm's reach!", Oliver thinks as the two colleagues walk towards the office building. Oliver brightly greets his colleagues. In secret he is already looking forward to the drive home in the evening: "Maybe I will see that Elvis fan again?"

7.2.3 Translating the Experience into an Interaction Concept

Based on the story, we illustrated the GestShare experience with the help of first scribbles (see figure 7.1 on the left) and finally a storyboard (see figure 7.2). In parallel, we started to work on a first software sketch (see figure 7.1 on the right) implementing a basic recognition for the gestures illustrated in the storyboard. The important interactions are part of all three representations and we translated them into the following working principles:

P1: The driver can perform a pointing gesture towards another car to request a virtual connection between the two vehicles (story: *With a short poke directed at the vintage car, Oliver calls the attention of the driver.*, storyboard: frame 2).

P2: Other drivers can use the pointing gesture to contact the own car (story: *He notices a gentle sound from the back of his car. Now he has been poked.*, storyboard: frame 4).

P3: A request for a virtual connection needs to be accepted by performing a wave gesture (story: *The elderly gentleman smiles friendly and waves.* and *Oliver briefly waves his right hand and thereby accepts Tom's poke*, storyboard: frame 5).

P4: A request for a virtual connection can be declined by performing a stop gesture (derived from P3).

P5: Depending on the mode of the infotainment system, a grab gesture can be performed to play the music another driver is currently listening to in the own car *or* to initiate a phone call (story: *Oliver reaches out to grab in the direction of the other car and thereby fetches the music from the other driver* and *Oliver [...] calls Tom with a grab in his direction*, storyboard: frames 3 and 6).

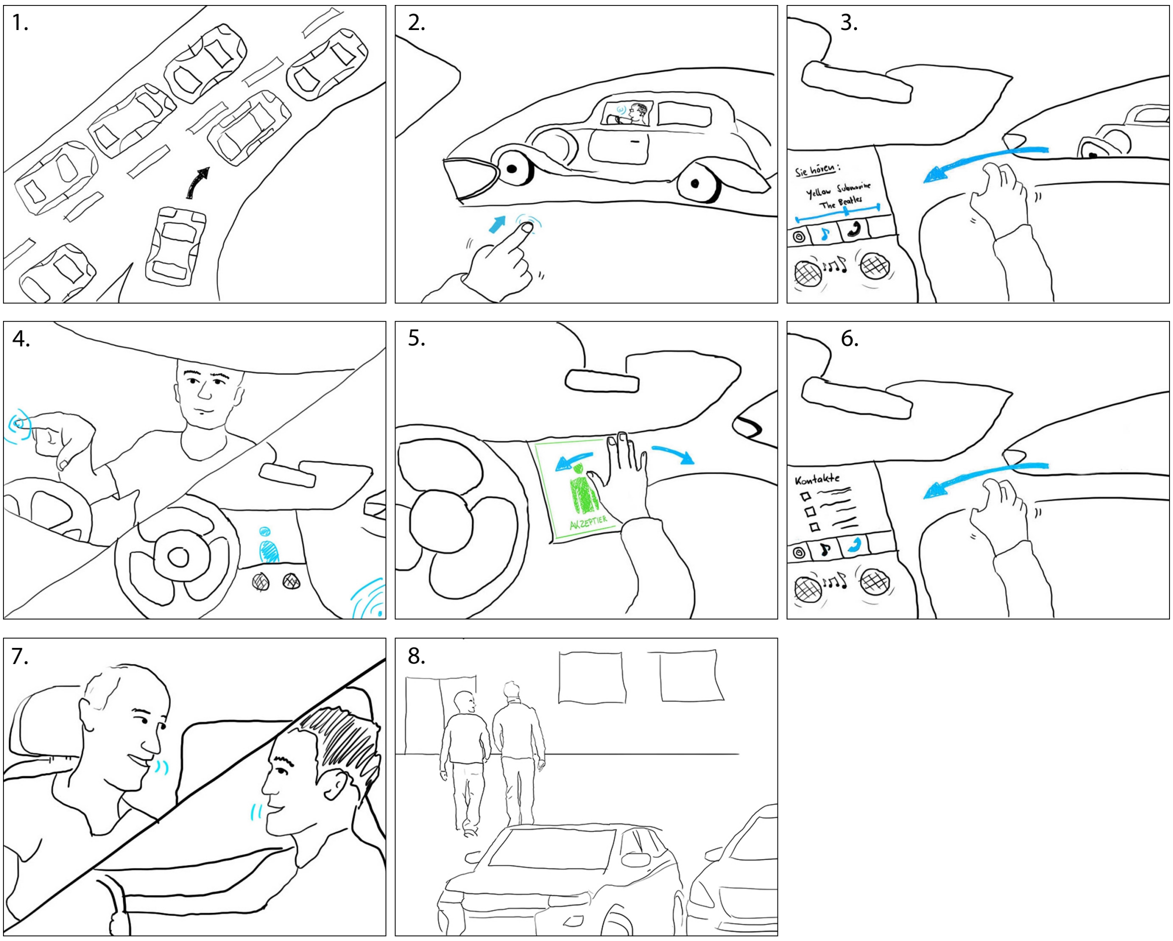

Figure 7.2: Storyboard visualizing the GestShare story. A driver can connect to other drivers by 'poking' them (frames 2 and 4) and exchange music (frame 3) or initiate calls (frame 6) by grabbing and dragging. Drawn by Johannes Preis.

7.3 The GestShare Experience Prototype

In contrast to the Periscope and Heartbeat projects, an early evaluation of the GestShare concept in its real world context was the priority for the realization of an experience prototype. To be able to conduct a study in the car in actual traffic, the prototype had to have a sufficient robustness and reliability. Therefore, we implemented a high-fidelity user interface but kept the resolution at a mid-level i.e., we realized only the features that are relevant for the experience story and thus limited the level of interactivity. We focused the prototyping on three crucial parts: First, tracking the driver's gestures was important to allow for the interactions illustrated in the storyboard. Second, a graphical user interface was necessary to provide feedback and guide the driver through the experience. Third, we needed to integrate the prototype into the car mock-up and an actual car with respect to given constraints.

7.3.1 Gesture Tracking

According to story, storyboard and interaction concept, four gestures are part of the GestShare experience (see figure 7.3). The *poke* gesture is directed at other drivers and is used to request a virtual connection between both cars. The driver being contacted can now choose to *wave* to accept the inquiry or perform a *stop* gesture to deny. Once a connection is established, both drivers can *grab* content such as music in the other vehicle and drag it into the own car.

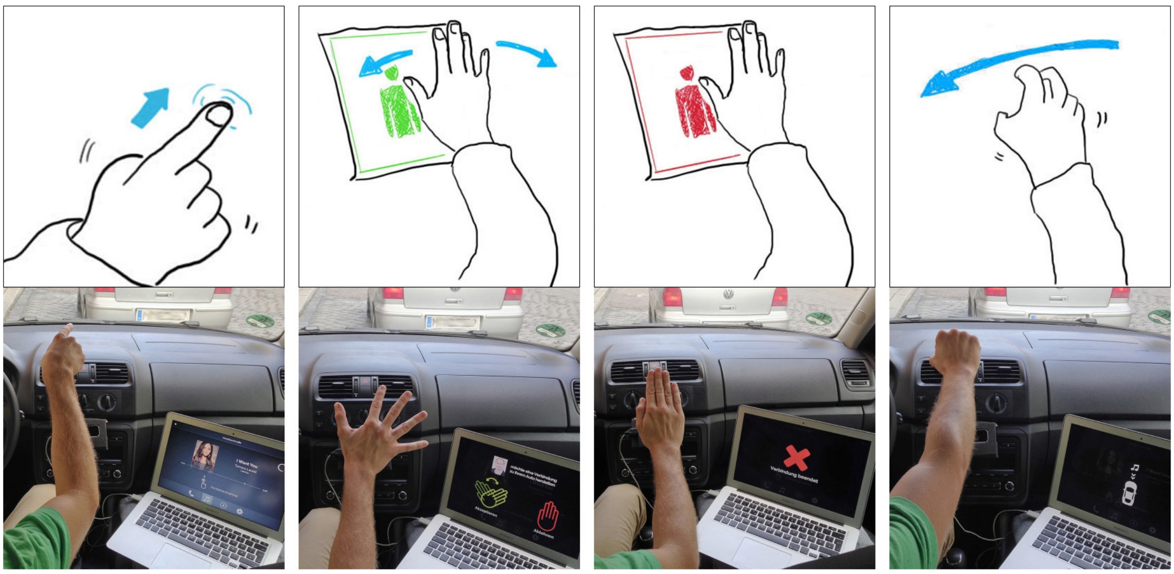

Figure 7.3: The four gestures illustrated in the GestShare story and implemented in the prototype. From left to right: poke, wave, stop and grab. Photos and drawings by Johannes Preis.

After analyzing different technologies for tracking freehand gestures such as distance sensors, camera based systems or the Kinect sensor, we decided to use the LEAP Motion controller[9]. LEAP is a small (13x13x76 mm) and lightweight (45 grams) USB device that tracks the distance to hands and fingers within a distance of approximately one meter. Spanning an interaction space, three LEDs emit infrared light which is reflect by objects and tracked by two infrared cameras. On the one hand, LEAP covers a relatively small interaction space compared to other sensors such as Kinect, but on the other hand it offers a robust and high-resolution tracking. As another advantage, the LEAP development kit natively offers the detection of basic gestures such as *grab* and thus served our purpose well. With its compact dimensions it allows for an easy integration into a given environment.

7.3.2 User Interface and Interaction

We implemented a user interface representing a reduced infotainment system providing a basic audio player and a basic phone controller (see figure 7.4). For prototyping the software we used Processing[10], a high level programming language suitable for quickly sketching interactive visual interfaces. The LEAP software development kit provides a Processing library enabling the handling of the gesture tracking data provided by the LEAP service.

The interactivity of the prototype is limited to the interactions illustrated by story and storyboard. For the planned user study, we focused on a fixed interaction sequence. After poking another car to establish a virtual connection, the driver receives a notification that the request has been accepted. Then, the driver performs a grab gesture and is now able to hear the music played in the other car. By performing a stop gesture, the music can be switched back to the own playlist. In the next step, the driver receives an incoming connection request by another driver which needs to be accepted by a waving the hand. With the interface being in phone mode, the driver can now perform another grab to call the person in the connected car. A stop gesture will end the call.

7.3.3 Limitations

Please note that due to the intended limited functionality of the prototype not all parts of the interaction described above are actually implemented. The connection to the other car exists solely on a conceptual level and interactions of the driver in the other car, e.g., accepting the request for a connection and the second request itself, are thus triggered by the prototype software itself. During the study, the phone call was established by the experimenter following the Wizard-of-Oz prototyping technique. Thus, participants used a mid-resolution prototype but perceived the functionality to be fully implemented.

[9] https://www.leapmotion.com/ (accessed 12/4/2014)

[10] https://www.processing.org/ (accessed 12/4/2014)

Furthermore, to track a pointing gesture for selecting a another car while driving needs a more complex implementation. It would be necessary to track GPS data of both cars and to determine the position of one vehicle in relation to each other. By combining this information with the direction of a one finger pointing gesture, it would then be possible to determine the car the driver is pointing at. However, because of the static situation of the traffic jam illustrated in the story as well as the scenario used in the user study, the implementation of this tracking was not necessary and we thus did not make the effort for this early prototype.

7.4 Evaluating the GestShare Experience

In contrast to the previous projects of Periscope and Heartbeat, we evaluated the GestShare experience prototype in two settings. While the implementation of and the interaction with the system was identical in both studies, the context and setup utilized two different levels of fidelity. We conducted the first evaluation in a lab setting with a car mock-up as described in the last two chapters. The second study however took place in a real-world environment involving two drivers in two cars on a busy street (see figure 7.5). By comparing the results of both studies, we aimed at gathering first insights on the suitability of lab and in situ studies when evaluating early experience prototypes concerning the fulfillment of psychological needs and the arousal of positive emotion.

Figure 7.4: The graphical user interface of the GestShare prototype. A connection to another car has been established. The driver can now perform a *grab* gesture to listen to the music that is currently played by the driver of the other car. Screenshot by Johannes Preis.

Figure 7.5: We conducted the in situ study evaluating the GestShare prototype on a busy side road in central Munich. Participants used the prototype in the car on the left and interacted with another driver represented by the second experimenter sitting in the car on the right. Photo by Johannes Preis.

7.4.1 Setup and Procedure

For the user study we installed the prototype in both the car mock-up in our lab as well as an actual car. To be able to achieve comparable results, we payed close attention to an equivalent placement of the sensor and the user interface in both settings. The software controlling the LEAP motion sensor and the Processing sketch ran on a laptop with the UI being displayed on the screen. We placed the laptop on the co-driver's seat in an elevated position (see figure 7.6) so that the UI was displayed in a height similar to a car's central information display. We installed the LEAP motion sensor in the center stack, tilted slightly upwards so that it tracked the area next to the steering wheel where participants performed their gestures.

Because of the static driving situation in situ according to the traffic jam in the story, we did not apply a driving simulation in the lab setup. The experimenter positioned himself in front of the car mock-up representing another traffic participant. Thus, according to the studies conducted with Heartbeat and the Periscope, a part of the story was open to the imagination of the participants. In the real world setting, on the other hand, a second experimenter drove a second car that the participants could interact with. This study took place on a side road in the center of Munich (see figure 7.5). The car hosting the prototype remained in the same location throughout the study, according to the situation of the traffic jam illustrated in the story. One experimenter sat on the back seat of the car and observed the operation of the prototype.

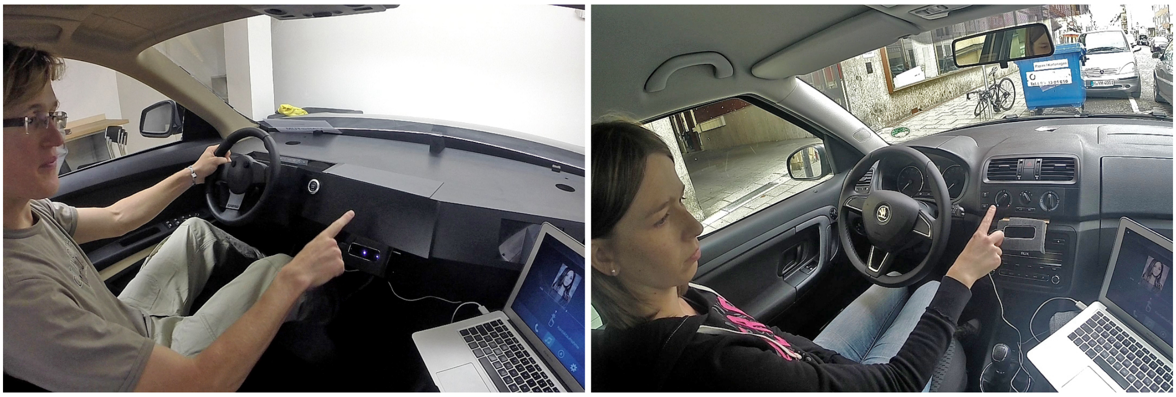

Figure 7.6: Two studies evaluating the GestShare experience prototype took place in the lab (left) and in an actual traffic situation (right). Photos by Johannes Preis.

Both studies followed an identical procedure. First, we welcomed the participant and introduced the purpose of using freehand gestures in the car. Then, we presented the GestShare concept with the help of the storyboard illustrated in figure 7.2. We asked participants to imagine themselves in the role of Oliver and shortly introduced each possible interaction by showing and explaining the correspondent frame. Then, we asked the participant to enter the car and sit on the driver's seat. The interaction sequence of the experiment was identical to the interaction described in section 7.3.2. After using the GestShare prototype, participants completed the UXNQ and PANAS questionnaires and took part in a semi-structured interview. As an incentive, we handed out a gift certificate with a value of ten Euros.

7.4.2 Results

In both evaluations, we applied the UXNQ and PANAS questionnaires to analyze whether the psychological needs for Stimulation and Relatedness as well as Positive Affect have been addressed while interacting with the GestShare prototype. Additionally, as mentioned multiple times during the focus group, the interviews as well as earlier work on this input modality [62], interactions using freehand gestures address a feeling of security. This is due to the fact that gestures can be performed without or with low visual attention and therefore potentially reduce driver distraction. Thus, we included the need for Control in the UXNQ. Because of the observation of Autonomy being one of the three most relevant needs causing human well-being [91, 95], we also included it in the questionnaire. Finally, we added Competition as kind of control element, a need that is not addressed by the designed GestShare experience and thus was not expected to be addressed during the study. Table 7.1 summarizes and compares the results of both studies.

Lab Study

16 participants (8 of them female) attended the study that took place in the lab environment. On average they were 28 years old ranging from 19 to 58. The needs for Stimulation ($M = 4.22$, $SD = 0.69$), Relatedness ($M = 3.55$, $SD = 0.66$), Autonomy ($M = 3.89$, $SD = 0.69$) and Control ($M = 4.17$, $SD = 0.54$) as well as Positive Affect ($M = 3.83$, $SD = 0.53$) were rated significantly above the scale mean of 3. The need for Competition ($M = 2.36$, $SD = 0.67$) and Negative Affect ($M = 1.52$, $SD = 0.42$) were rated significantly below the scale mean.

Cronbach's α shows good reliability for Positive Affect ($\alpha = .81$), acceptable reliability for Stimulation ($\alpha = .78$), Competition ($\alpha = .78$), Autonomy ($\alpha = .75$) and Negative Affect ($\alpha = .74$), questionable reliability for Control ($\alpha = .69$) and unacceptable reliability for Relatedness ($\alpha = .44$).

Pearson's r revealed a high positive and significant correlation to Positive Affect for the needs Stimulation ($r = .83$, $p < .01$), Relatedness ($r = .55$, $p < .05$), Competition ($r = .46$, $p < .05$) and Control ($r = .51$, $p < .05$).

In Situ Study

18 participants (10 of them female) attended the study that took place in the lab environment. On average, they were 24.2 years old ranging from 18 to 34. The needs for Stimulation ($M = 4.29$, $SD = 0.48$), Autonomy ($M = 4.18$, $SD = 0.58$) and Control ($M = 4.10$, $SD = 0.46$) were rated as fulfilled, the needs for Relatedness ($M = 3.01$, $SD = 0.77$) and Competition ($M = 2.63$, $SD = 0.86$) were not . Participants perceived Positive ($M = 3.85$, $SD = 0.55$) but no Negative Affect ($M = 1.37$, $SD = 0.41$).

The scale for Negative Affect ($\alpha = .82$) achieved a good reliability, the scales for Stimulation ($\alpha = .73$), Competition ($\alpha = .73$) and Positive Affect ($\alpha = .75$) an acceptable reliability and the scales for Relatedness ($\alpha = .36$), Autonomy ($\alpha = .42$) and Control ($\alpha = .14$) an unacceptable reliability.

	Lab Study			In Situ Study		
	M	SD	α	M	SD	α
Stimulation	4.22	0.69	.78	4.29	0.48	.73
Relatedness	3.55	0.66	.44	3.01	0.77	.36
Competition	2.36	0.67	.78	2.63	0.86	.73
Autonomy	3.89	0.69	.75	4.18	0.58	.42
Control	4.17	0.54	.69	4.10	0.46	.14
Positive Affect	3.83	0.53	.81	3.85	0.55	.75
Negative Affect	1.52	0.42	.74	1.37	0.41	.82

Table 7.1: Descriptive values of UXNQ and PANAS resulting from both evaluations of the GestShare prototype in the lab environment and in situ.

Stimulation was significantly positively correlated to Positive Affect (r = .57, p < .01). We did not find any other correlations between fulfilled psychological needs and Positive Affect. Competition was significantly positively correlated to Negative Affect (r = .43, p < .05)

7.4.3 Discussion

GestShare triggered a stimulating experience
According to the quantitative results of the study, the psychological need for Stimulation was addressed during the interaction with the GestShare prototype. This triggered positive emotion and thus lead to a meaningful and stimulating experience. This is true for both the setup in the lab as well as the study conducted in situ. Concerning quantitative results, we did not find differences in perceived Stimulation between the setups. However, results need to be treated with care. The need for Stimulation is defined by "experiencing new sensations and activities" and finding "new sources and types of stimulation" [95] (see section 2.2.3), which is represented by the corresponding items of the UXNQ. Statements from the interviews such as "only the technology itself was already very interesting" or "it was something new for a change and it was also exciting" match the observation that Stimulation was rated higher for the Gesturaction prototype compared to all Heartbeat and Periscope prototypes. Thus, I conclude that Stimulation was significantly triggered by the novelty effect of being able to use gestures in the car.

No evidence for an experience based on Relatedness
Even though the satisfaction of the psychological need for Relatedness has been reported during the lab study, this result is without validity due to the low reliability score of the respective UXNQ scale. Cronbach's α expresses the reliability of a scale that consists of several items by determining its internal consistency. The UXNQ contains five items measuring the satisfaction of the need for Relatedness. As these items relate to different aspects of this need, i.e. whether the participant felt close to people she cares for *and* whether she felt as part of a team or a group, it is possible that only one of these aspects is met, which evidently leads to a low reliability score. This is true for both setups, in the lab and in situ. Therefore, the expressiveness of the scale is not precise enough to make meaningful statements about a GestShare experience based on Relatedness. To identify items that caused a low reliability, we repeated the calculation of Cronbach's α by systematically omitting single Relatedness items. Without the item "I was close to others who are important to me" the reliability of the Relatedness scale in the lab study increased to an acceptable value of α = .72. For the study in situ, the value likewise increased to an acceptable α = .72 when leaving out the inverse item "I rather acted alone than together with others". This observation was supported by qualitative feedback which predominantly focused on the stimulating character of the gestural interaction. Only one statement was based on Relatedness and underlined how the use of gestures opened up the boundaries of the own car causing the sense of community.

Comparing the results of both setups
One purpose of this project was the comparison of two studies evaluating the same experience prototype in two different settings, one of them in a lab environment and one in situ. Quantitative results reported equal values for Stimulation and Positive Affect and in both studies Positive Affect was caused by a stimulating experience. We did not find Negative Affect in both cases. The reliability scores for the UXNQ scales for Relatedness were too low to make statements about this psychological need. As expected the need for Competition was not addressed in both studies.
We found a difference between the results of the scales for Autonomy and Control. Both needs were addressed in both evaluations. However, in contrast to the lab study, the reliability of both scales was unacceptable in the study in situ. Considering the feeling of "being in control" and "performing actions effectively" as stated in the UXNQ, a reason for the inaccuracy of the scale can be the limited robustness of the prototype in the outside environment. Due to the underlying technology based on emitting and measuring infrared light, sunlight negatively influences the percentage of successfully recognized gestures compared to the study in the lab environment where factors such as lighting conditions can be controlled. Despite the fact that we instructed participants to rate the experience instead of the implementation of the prototype, it might nevertheless have had an effect on the perceived feeling of being in Control.

Limitations
Despite the fact that both studies were designed following the same procedure and using the same prototype, the results of this study must be considered as first evidence towards a comparison between lab and in situ evaluations of experience prototypes. Using these insights, further studies are necessary in the future. Furthermore, the setting of the study had an influence on the reliability of some scales measuring the satisfaction of psychological needs, which does not mean that it had an impact on the experience itself. Thus, the tools we used to determine whether a positive experience has been created need further validation as well.

7.5 Implications for Experience Prototyping

GestShare allows the driver to communicate with other traffic participants in the cars nearby using freehand gestures. Another driver can be poked to establish a virtual connection, an incoming request can be accepted by waving or declined by performing a stop gesture, and with grab gestures both can exchange music or call each other. We built an experience prototype implementing the GestShare story and integrated it into two different settings. When comparing the interaction experience in a lab setting and in an in situ environment, we found no differences in the perceived experience. However, the utilization of the prototype in the actual traffic situation lead to a decreased reliability of our quantitative scales.

A stimulating technology dominates the experience

Quantitative and qualitative results showed that experiences were based on Stimulation, although it was Relatedness that was in the focus of the story. While the Periscope was a mediator for social interactions, participants were excited to find that gestures can be applied in the car. It can be concluded that a stimulating experience, e.g., based on a novel technology, attracts a great deal of attention and distracts participants from the story of the designed experience.

A limited interactivity conflicts with expectations during in situ studies

Compared to the preceding case studies, we implemented the first prototype in a high fidelity, realizing a relatively robust functionality and mature user interface. The reason was our intention to evaluate the concept concerning its potential to create meaningful experiences in a real-world context as early as possible. As a trade-off, we limited the interactivity of the prototype resulting in a low resolution. Thus, during the study participants needed to follow the interaction sequence provided by the storyboard. This did not affect the experience in the lab setting, but influenced the reliability of the scales for Autonomy and Control, which express the needs for making choices autonomously and for mastering challenges successfully. It can be concluded that a constrained interactivity of the prototype can collide with the expectations participants have when using a system in a real-world environment, which also influences the perceived experience.

Lab study vs. real-world environment

When conducting studies with early prototypes, the question arises whether a lab setting or a real-word setting is suitable to evaluate the occurrence of positive experiences. One the one hand, studies in the lab allow controlled conditions and a scripted procedure. Participants can focus on the prototype and its behavior can be tested and is thus predictable. On the other hand, in situ studies take the actual context of use into account and practically all factors influencing an experience can be part of the experience. However, in the automotive context the complexity of a study setup significantly increases due to safety and liability risks. It is essential to consider consequences in case of a materialistic or even physical damage. We compromised these trade-offs by conducting the study in a car on a busy road with realistic traffic, but leaving the car in a parked position, while one of the experimenters drove another car to simulate the dynamics of an actual driving situation. Additionally, we noticed that the realistic environment influenced the experience considering the needs for Autonomy and Competence. It can be concluded that it is valid and even necessary to evaluate experiences in both settings. However, the choice depends on the maturity of the prototype in terms of fidelity and resolution as well as a trade-off between controlled conditions and real-world situations including safety and liability concerns.

III

A Retrospective on Experience Prototyping

Chapter 8

Best Practices for Experience Prototyping

Experience Prototyping is not about the creation of a formalized toolkit or set of techniques, but is about developing an attitude and language to solve design problems.

– Marion Buchenau and Jane Fulton Suri (Interaction Designers) –

In this thesis, I present insights that I gathered as an Experience Prototyper in the course of a interdisciplinary three-year project on Experience Design. With the goal to find an approach for integrating experiences into automotive product development, we suggested an Experience Design process including its underlying tools and methods to design, develop, evaluate and iterate meaningful experiences. Within this project, I focused on the implementation of prototypes to translate designed experiences into interactive and thus experienceable representations. In three case studies elaborating different experiences for drivers as well as passengers, I conceptualized and built several Experience Prototypes. In this chapter, I will summarize the insights gathered in the course of the project and its case studies and reflect on the importance of prototyping for the Experience Design process.

8.1 Experience Prototyping in the Design Process

While developing the Experience Design process on a theoretical level based on the insights gained in the course of the three case studies, it became clear that the finalization of new prototypes constituted important milestones. Each representation of a designed experience, namely framework, story, storyboard, first prototype and integrated prototype, represented the completion of a process phase and delivered an artifact which was then transferred into the next phase.

Experience Framework

The result of the analysis phase of the process is an experience framework. It contains the results of user research and an analysis of the real-world context and provides an overview about the central themes of the interactive systems that are going to be developed. An appropriate format for the documentation of the framework is an abstract but clear visual representation containing short descriptions of the central themes. All ideas for potential experiences should originate from the framework or at least be thematically placeable within the framework.

An experience framework is a first step towards the creation of consistent experiences that are part of an overarching concept, ensuring that single experiences do not influence each other in a negative way after the integration into their real-world context.

Experience Story

Each experience should be defined before implementing interactive representations to avoid technical limitations that constrain the Experience Design. We defined experiences in written stories. These stories introduced the context of use, involved characters, their feelings and emotions as well as important interactions with a future system. A story can be considered as the first prototype of a designed experience. It features a mid-resolution as important interactions can be described. Being merely a written text that does not contain any details on the implementation of a future system, the story is a prototype with a low fidelity. The story should contain sufficient information to allow for an immersion into the described experience, but at the same time it is not interactive and thus not an experience prototype. The main purpose is the communication of an idea to team members and a first exploration of a potential experience design.

A written story defines the experience without taking implementation details into account and helps to communicate the experience to others.

Experience Storyboard

A storyboard visualizes the experience described in the story. Compared to the story, it eases the immersion into the context and the experience because the context of use and involved characters are not open to the imagination of the audience. Thus, storyboards are prototypes that allow for first evaluations of designed experiences. We suggest storyboards containing six to eight key frames with the first frame showing the context of use and the participating characters, one last frame illustrating the resulting experience and the frames in between describing important interactions leading to the experience.

Early storyboards lead to first interactive experience prototypes and in turn these prototypes inspire new and improved storyboards.

Interactive Experience Prototypes

While stories define and storyboards visualize experiences, experience prototypes allow for the exploration and communication of design ideas. These prototypes are hardware and/or software representations of a future system with the goal to involve users in the interaction. Thus, during evaluations participants can potentially relive a story and report on their subjective experiences. First prototypes with a low fidelity and a low resolution helped to explore design ideas and to collect early feedback. More mature and robust mid-fidelity and mid-resolution prototypes allow for first extensive user studies. High-fidelity and high-resolution prototypes are necessary to integrate experiences into their context of use and to conduct further evaluations.

Several experience prototypes with increasing fidelity, resolution and interactivity should be iteratively implemented and evaluated in the course of the process to make sure that the designed experience does not get lost due to technological or other constraints.

A critical step of the process is the translation of an experience into a first interactive prototype. Therefore, we derived working principles from the story and the storyboard.

Working principles represent the important aspects of the experience and serve as requirements whenever important design decisions come up while developing an interactive system.

Whenever experiences are supposed to be evaluated early in the design process, but in a real-world context such as actual driving situations, a tradeoff between fidelity and resolution is necessary. On the one hand, prototypes need to be robust enough to reliably work in a real-world context. Additionally, participants seem to expect mature prototypes when they are used in a realistic environment. On the other hand, prototypes can not provide a high fidelity and a high resolution in early in early design stages due to the high implementation effort and the limited ability to adapt these prototypes.

Prototypes with a rather high fidelity and a limited resolution and interactivity are suitable for early evaluations in a real-world situation.

8.2 Purposes of Experience Prototyping

Following the purposes listed in section 3.2, I specifically utilized prototyping techniques throughout our user-centered and iterative design process for the exploration, communication and evaluation of ideas and concepts.

Communication

Especially in the beginning of the process, potential experience designs are vague and intangible. Therefore, we used different prototyping techniques to communicate ideas within and outside of the project team. Notes and sketches helped to make ideas concrete and to express new ideas to other team members. Subsequently, discussions and refinements led to written text. The creative and iterative process of writing these stories gave all team members a solid idea about the substantial aspects of the designed experience. Further sketching resulted in storyboards constituting the first visual representations of potential experiences. Providing involved characters, a context of use and essential moments of the depicted scenario, these storyboards allowed first user evaluations concerning experiences that are triggered during interaction.

However, please keep in mind that the focus on the design of meaningful experiences instead of new functionality or technology is a novel approach. When using stories and storyboards it was especially difficult to communicate potential experiences to managers who were not involved in the project on a regular basis and who were only available to us for limited time slots. Furthermore, we observed that engineers with a strong technical background had difficulties to immerse into ideas that are represented by non-technical storyboards. The implementation of interactive prototypes thus became a central element of the design process. They allowed us to present designed experiences in workshops, during presentations and in evaluations to gather important qualitative and quantitative feedback from project managers, scientific consultants as well as real-world users.

Stories and storyboards are not suitable to present ideas and concepts to all audiences, e.g., developers with a strong technical background. Instead, early experience prototypes focusing on the interactive elements are essential to communicate concepts especially to audiences that are not familiar with a project or Experience Design in general.

Especially for early prototypes with limited resolution, fidelity and interactivity, it was helpful to introduce the audience to the storyboard before presenting the prototype.

Immature experience prototypes might not be self-explanatory and thus need the context of use that can be provided by a visualized experience story.

Exploration

Another important reason for building experience prototypes was the exploration of potential experience designs within the team. We established a successful cooperation between the

Designer and the Developer based on an iterative development of the representations of our ideas. Storyboards inspired the implementation of first prototypes, which in turn led to improved storyboards and therefore enhanced interaction concepts.

Different prototyping techniques can not only be applied in a sequential order, but can be used iteratively to improve communication between team members with different backgrounds and thus benefit the interdisciplinary exploration of ideas.

Especially early prototypes requiring a low implementation effort in terms of time and costs are suitable to initially explore design ideas. Preliminary prototypes of Heartbeat and Periscope allowed for qualitative evaluations early in the process and resulted in important feedback leading to updated and improved storyboards and interaction concepts. Furthermore, early prototypes can be used to explore how single design elements such as the combination of different kinds of feedback [59] influence the resulting experience.

Within two of the case studies I successfully applied throw-away prototyping. In case of the Heartbeat, I implemented a first low-resolution and mid-fidelity prototype with limited interactivity to explore the potential of the concept to trigger a positive experience. After evaluating this representation I developed a new high-resolution and high-fidelity prototype based on feedback and results of the exploration. Concerning the Periscope, three independent prototypes, each one developed from scratch, allowed for the incremental exploration of a social experience. However, extensive and repeated user studies are essential to evaluate the experiential value of each prototype to make sure that the important aspects of the experience story did not get lost during implementation.

Throw-away prototyping is suitable to explore the experienceability in early concept phases, but extensive evaluations analying this aspect are necessary for each new prototype.

Evaluation

As our Experience Design process applies user-centered and iterative characteristics, a user study is a vital last part of each development cycle. Each new version of a prototype comprises changes of design elements and implementation details including underlying technologies. These changes can influence the interaction experience. Thus it is essential to evaluate whether a designed experience can be relived while interacting with a prototype.

Following an Experience Design process based on the fulfillment of basic psychological needs and the arousal of positive emotion, we quantified both aspects by using questionnaires in user studies. All evaluations followed the same procedure. After an introduction to the context, the storyboard and the tested interactive representation of the designed experience, participants interacted with the prototype as long as they liked. Then, we provided a questionnaire consisting of two parts. The first part, the User Experience Need Questionnaire (UXNQ), contained three to five items for each psychological need. The second part, the Positive and Negative Affect Schedule (PANAS) provided ten items for each positive and negative affect. If desired needs were fulfilled and positive emotion did occur, we finally analyzed the relation between both scales. In an optimal case, needs that were addressed by the experience design positively correlate to positive emotion, indicating a triggered meaningful experience during the interaction with the prototype.

Quantitative results should be supported by qualitative feedback. During semi-structured interviews, we asked participants about their experiences while using a prototype. Using laddering, a method for repeatedly asking for the reason behind a certain statement, we mapped participants' answers to underlying psychological needs and compared the outcome to the quantitative results of the questionnaires. Additionally, user statements can inspire changes concerning the next version of the prototype and can be used to represent trends when presenting results to management or other audiences.

For the evaluation of the experiential value of experience prototypes, an approach combining qualitative and quantitative methods is necessary.

8.3 Different Automotive Experiences

During the three-year project and its case studies I implemented three different interactive systems. Heartbeat is a driver-centered information system for electric vehicles. The Periscope creates social experiences of the passengers in a car. GestShare allows for a communication between drivers of different cars. These case studies resulted in different insights concerning addressed psychological needs as well as distinct requirements and challenges.

Heartbeat: A Driver-Centered Experience

When designing experiences that are based on the interaction with in-vehicle information systems, the integration into the context of use, i.e. the dashboard of a car, involves difficult challenges. Especially in the automotive domain, space for new devices is limited and the introduction of new applications is complex due to the high number of functions that already exist. Additionally, the safety of all passengers is the highest priority and novel systems might influence important safety aspects such as driver distraction. Therefore, it is essential to consider these constraints early in the Experience Design process.

To address this issue, I divided the implementation of Heartbeat into two phases. In the first phase, I explored the experience in a car mock-up to stay in the context of use, but without taking the constraints of a driving simulation and the limitations of other devices and functions into account. This is a compromise allowing for an unrestricted exploration of the early prototype with low resolution and a mid fidelity and at the same time for an evaluation in the context of use, although realized in a reduced way. In the second phase, I integrated the experience into the dashboard with respect to relevant functions and given space requirements. A prototype with high resolution and high fidelity combined with a driving simulation allowed for an exploration and evaluation of the experience in a context closer to the real-world environment without being exposed to the risks of an actual driving situation.

Considering the fulfillment of psychological needs, the scales for Stimulation and Competence resulted in higher ratings for the experience triggered during interaction with the second prototype that realized a high resolution because it was easier for participants to immerse into the scenario with a less abstract interface in an environment closer to the real-world situation.

Low-resolution prototypes help to explore a designed experience without being constrained, but high-resolution prototypes are essential to evaluate the experience in their context of use with respect to other requirements such as available space and safety considerations.

Periscope: A Social Experience for Passengers

While Heartbeat is a driver-centered interface, the Periscope supports social experiences between the passengers of a car. Especially when several people are involved in the interaction, the prototype is rather a mediator of experiences rather than a direct source of meaningful events. During evaluations, it is important to observe how social interactions emerge from the use of the prototype. In our case, the property of the Periscope that it can only be used by one person at a given time triggered conversation about what this person had discovered. Additionally, sharing this discovery by handing over the Periscope created the experience of belonging to a group. This focus on social experiences needs to be considered in the design process. During user studies, participants have to be able to use the prototype in an autonomous and independent way without constraints disturbing the social interaction. Prototypes realizing a high resolution that allow for the use of all functions described in the experience design are necessary.

At the same time I observed that a low usability did not influence the experience in a negative way as participants recognized the prototype to be an experimental representation of a future system. The second prototype offered a better usability and an improved design. Nevertheless, we did not find differences in the reported experiences compared to the study using the first prototype.

Early prototypes with a high resolution and a low fidelity are suitable to prototype social experiences.

The psychological need that is addressed during social interactions is Relatedness. In the case of the Periscope, people were able to share their discoveries with others and to explore the environment as a group. In our evaluation of the first experience prototype, we invited teams of two for each trial. Results show that the fulfillment of the need for Relatedness was rated significantly higher by team members who had known each other before the study compared to the team members who were unfamiliar. When evaluating the second experience prototype, we invited teams of three, including a driver controlling the driving simulation of our car mock-up. Results show that drivers rated the Relatedness experience on the same level as the other passengers, even though they were not able to use the prototype at all.

When designing social experiences and the evaluations of the resulting prototypes it is important to take all involved individuals as well as their personal relations to each other into account.

GestShare: A Car-to-Car Experience

With the GestShare concept, we also included experiences based on an interaction modality into our research. Drivers were able to use freehand gestures to establish virtual connections to other drivers to exchange music. To enable an early evaluation of the concept in its real-world context i.e., an actual traffic situation, we implemented a robust high-fidelity prototype. To reduce the implementation effort of this early representation, we limited the resolution and defined a fixed interaction sequence during the evaluation. When evaluating the same prototype in two different settings, one in the lab environment with our car mock-up and one in situ in a car on a busy road, we made several observations.

First, we did not find significant differences when comparing the results of the two studies in different settings. The gestural interaction triggered a stimulating experience leading to positive emotion while we used the same experience prototype and followed the same procedure.

It is appropriate to evaluate early prototypes in a lab setting as well as in situ.

Second, however, the underlying technology seemed to distract participants from the designed aspects of our experience in both settings. When writing the story, we meant to create an experience based on Relatedness triggered through the interaction with other drivers around the own car. However, the reliability of the according scale was unacceptable. During the studies, participants were excited by the ability to interact with the infotainment system and with other cars by using freehand gestures.

A stimulating experience (e.g., triggered by the use of a novel technology) can prevented the focus on the actual experience the interactive system is designed for.

Third, users participating in the realistic traffic situation expected a more flexible functionality of the prototype. One reason might have been the inconsistency between the real-world situation and the limited interactivity of the system. A second reason might have been the inconsistency between the high fidelity and the low resolution of the prototype itself. This had an influence on the questionnaires measuring the fulfillment of the needs for Control and Autonomy. The reliability scores for both scales resulted in unacceptable values.

When evaluating the experienceability of an interactive system in a real-world study, the expectations of the participants in such a situation must be considered when designing the fidelity, resolution and interactivity of the prototype.

Chapter 9

Summary and Future Work

All good things (come to an end)

– Nelly Furtado (Singer and Songwriter) –

My contributions to the field of Experience Design are derived from the design, implementation and evaluation of three automotive applications. Heartbeat, an electric vehicle information system communicating the state of the electric drive and the state of charge to the driver, iteratively evolved from a first hardware sketch with limited interactivity into a high-resolution and high-fidelity prototype integrated into the dashboard of a car mock-up. The Periscope, a mobile device for discovering and sharing interesting places along the road, matured from a mid-fidelity but fully interactive and high-resolution prototype into a device with a high fidelity as well as improved design and usability. GestShare, a concept allowing the driver to interact with other drivers in cars nearby via freehand gestures, resulted in a high-fidelity but mid-resolution prototype that was evaluated in two different settings, a lab and an in-situ environment. However, my exploratory work towards establishing Experience Prototyping in the Experience Design process was accompanied by several difficulties and thus leaves several questions that need further elaboration. In this chapter, I summarize contributions of my work, but also state limitations and starting points for future work.

9.1 Contribution

With the introduction of Experience Design [30] as a discipline focusing on experiences instead of technology and the proposal of a first design process [53] it became clear that further research was necessary to further explore the importance of designing for experiences and to extend the process by relevant methods and tools. In my work I focused on Experience Prototyping. My contributions include a detailed view on prototyping within the Experience Design process, three case studies introducing new experiences for all passengers in the car as well as best practices gathered in the course of these case studies.

9.1.1 Relevance of Experience Prototyping

Considering the process developed in the CAR@TUM project "User Experience", prototyping is an essential part of Experience Design. It is relevant for the exploration and communication of design ideas in all development phases. Furthermore, experience prototypes are required to evaluate whether a designed experience is actually triggered during interaction. To make sure that the experience does not get lost in the course of the development of interactive representations, the implementation and evaluation of several prototypes is necessary. During the concept phases, a framework, a written story and storyboards help to design the experience and an interaction concept. In the implementation phases, the experience is translated into an interactive application by building several software and hardware prototypes with increasing fidelity, resolution and interactivity. Thus, iterative Experience Prototyping is a relevant activity in each process phase.

9.1.2 Examples for Automotive Experiences

Following first examples for Experience Design in the automotive domain [52] we provide three further case studies. Broadening the design space for in-vehicle applications with experiential value, I explored concepts for the driver and the passengers, different interactive systems as well as different situations and scenarios. (1) Heartbeat is an information system integrated into the dashboard of an electric vehicle communicating the state of the electric drive and the state of charge to the driver. Heartbeat provides visual and tactile feedback and lets the driver explore the special characteristics of the EV in a stimulating way. Furthermore, it conveys a feeling of being in control because the driver knows if the EV is ready to go and whether today's destinations can be reached with the current energy level. (2) The Periscope is a mobile device used during holiday trips or leisure rides. The passengers can explore interesting sights along the road and share their discoveries by passing the Periscope to others in the car. The interaction with the Periscope stimulates conversations and moved the focus to the outside environment. Additionally, the passengers find new destinations as a group leading to a meaningful team experience. (3) GestShare is a concept allowing the driver to communicate with other drivers nearby using freehand gestures. By pointing at another car, it is possible to initiate a virtual connection. Such a request can be declined by performing a stop gesture or accepted by waving a hand. Once a connection is established, a driver can now grab the music that is currently played in another car and drag it into the own vehicle. Thus, GestShare enables drivers to break the barrier set by the own car and exchange contents with others.

9.1.3 Best Practices or Experience Prototyping

By exploring Experience Prototyping on a theoretical and a practical level I found that it is a suitable approach to analyze and evaluate the potential of designed experiences early in the design process. Early prototypes of the Periscope experience show that even low-fidelity prototypes allow users to imagine themselves in a scenario and to relive a designed experience. Usability and design aspects play a secondary role for the experienceability of a prototype. The Heartbeat prototypes show how an experience can be explored using low-fidelity and low-resolution methods and how the experience can be integrated into a real-world environment by developing more mature prototypes without restricting the experienceability of the application. The exploration of the GestShare concept delivered insights into the evaluation of experience prototypes in different settings. An early prototype resulted in similar ratings of the subjective experience when applied in a lab setting as well as an in-situ environment. Thus, early experience prototypes can and should be evaluated in their real-world context, but fidelity and resolution should meet the expectation of participants, which has an influence on the perceived fulfillment of psychological needs.

9.2 Limitations and Future Work

Experience Design is an interdisciplinary approach to the development of interactive applications that has only recently been created. Its goal is to answer the question why people use technology the way they do and how we can design applications that help to create meaningful experiences and positive emotion. When I started my research in this discipline, it was still unclear how to describe or articulate what a User Experience is and which factors of a system influence the interaction experience. First attempts had been made to prototype experiences and evaluations methods for analyzing prototyped experiences were proposed but not sufficiently validated. Different disciplines contribute their knowledge to the field of Experience Design. Psychologists offer the theoretical foundation and try to find methods to evaluate experiences and emotion, designers create and visually express concepts and ideas for experiences, and HCI experts as well as engineers bring experiences to life by implementing prototypes. These preconditions caused difficulties inducing several limitations to my work.

9.2.1 A Limited Generalization of the Results

Prototyping is a universal method that is used extensively in various disciplines and wherever interactive technology is developed. Characteristics such as fidelity, resolution and interactivity have been established to describe prototypes on an abstract level independent from underlying technologies. Thus, I formulated the best practices derived from my exploratory research in a context-independent way. However, the insights on Experience Prototyping presented in this thesis result from a three-year project in the automotive domain focusing on experiences in future electric vehicles. Thus, the presented case studies focus on a particular application area with clearly defined goals. Furthermore, the applications explored in the case studies deal with specific scenarios and driving situations and the implemented devices represent different in-car functions. For these reasons, a generalization of the results is limited. I believe that the reported best practices can be transferred in other application areas. However, the specific tools and methods of Experience Prototyping have to be utilized in other domains in further case studies to analyze whether they can be applied in a similar way. We suggest a process to design and develop interactive applications triggering meaningful experiences and invite practitioners in the field to apply this process with its tools and methods in various applications areas.

Furthermore, I point to the fact that our Experience Design process cannot be seen as a complete process for developing automotive applications. Obviously, in-vehicle systems need to meet numerous requirements and are therefore far more complex. Our approach must be seen as a first attempt to integrate the focus on the interaction experience into very early development phases. Considering the automotive domain, further work attempting to integrate our findings into the internal development processes has do be done.

9.2.2 The Evaluation of Experience Prototypes is Challenging

The evaluation of meaningful experiences triggered during the interaction with prototypes has been one of the greatest challenges in the project and has caused intensive discussion. We agreed that both quantitative as well as qualitative results need consideration to capture interaction experiences, which are in the end subjective impressions of individuals including their prior experiences, possible biases, emotions and feelings. Quantitative results are needed to show that experiential values of prototypes can be evaluated in a statistically meaningful way. Qualitative statements can support these results and additionally add further inspiration to the design process. However, in our project we concentrated one a particular way to evaluate experience prototypes. We measured the fulfillment of specific psychological needs as well as aroused positive affect and analyzed correlations between these scales. When desired needs were addressed during the interaction and this caused positive emotion, we interpreted our experience design as successful. Three limitations are induced by our approach.

First, we developed our evaluation methods in parallel to the implementation of the prototypes. Thus, especially the questionnaires were adapted based on the results and observations of user studies. This needs to be considered when comparing the results of our evaluations of the Heartbeat and the Periscope concepts. An exception is GestShare, were we followed the same procedure and used identical evaluation methods in both studies to ensure comparable results.

Second, especially the UXNQ measuring the satisfaction of psychological needs seems to be prone to certain circumstances during the user studies. One example are the items comprising the need for Relatedness. For instance, "being close to people I care for" and "being part of a group" are both parts of this need, but result in different ratings whenever a prototype is used by people who did not know each other prior the experiment. They might both feel as part of the group during interaction, but they are not close to each other, causing the reliability of the scale to drop to an unacceptable level. A further exploration and validation of this evaluation method or the introduction of new methods will be necessary to be able to achieve more meaningful results when evaluating experience prototypes.

Third, in our iterative and agile process, we immediately evaluated new prototypes to receive quick results and short development cycles. The disadvantage of this approach is that designed experiences and the interaction experience with prototypes was not evaluated over a long period of time. Our user studies usually lasted between 30 and 60 minutes, providing sufficient time for participants to experience the prototype. However, long-term studies are necessary to analyze the durability of designed experiences. For instance, one interesting question is whether an interactive system based on the need for Relatedness is still able to trigger meaningful experiences after it has been used several times over days, weeks, months or even years.

9.2.3 The Drawbacks of Prototyping

Despite all advantages mentioned in this work, prototyping is not suitable to solve all remaining problems and open questions in the discipline of Experience Design. Please keep in mind that per definition any prototype only represents an unfinished part of a future interactive product. When implementing prototypes, several trade-offs in terms of fidelity, resolution, interactivity and underlying technology are necessary. These decisions depend on the targeted audience, time as well as financial budget, available prototyping tools, evaluation purposes and management decisions, just to name a view. A prototype can only demonstrate certain functions or design aspects of an envisioned system and thus results of evaluations and any qualitative feedback must always be handled with care. Thus, Experience Prototypers must be aware of the context in which a prototype is developed and consider influencing factors carefully. Further work analyzing the influence of certain aspects of experience prototypes on the subjective experience of people interacting with it is needed.

9.3 Résumé

During my education in Media Informatics with a focus on Human-Computer Interaction I quickly became aware of the advantages of building prototypes. Sometimes, it only took a piece of paper, a pen, some glue and a pair of scissors to bring an idea to life. Later, I experienced how the maturity of prototypes can evolve during an iterative process. A simple drawing became a storyboard. A paper prototype allowed a first look & feel of an envisioned application. A quick hardware or software sketch allowed to recognize input from users and to provide feedback in creative ways. Materials and illumination improved the appearance and in a matter of days, a great idea was transformed into an interactive prototype. This method taught me how to communicate my ideas to fellow students, how to explore and to improve my ideas and how to verify their technical feasibility. After finishing my diploma, I started my job as a research assistant and PhD student at the HCI group of my alma mater. Together with some colleagues, I established a workshop for building hardware prototypes at our lab. We started to teach students how to translate their ideas into interactive applications using tools such as soldering stations, Arduino boards, laser cutters or 3D printers. This enabled many of us to move our creativity from a theoretical to a practical level.

But it was not until I attended the three-year project together with four other PhD students as well as researchers and engineers from BMW that I experienced the entire potential of prototyping. Coming from different disciplines such as engineering, psychology, industrial design and HCI, we were barely able to talk about subject-specific terms. What is an experience? What is a process? And what are user needs? And how are we going to define all this? After several months of cumbersome discussion and unsatisfying results, our scientific supervisor, Donald Norman, summon us to actually start building things. So I picked up some of the idea and implemented first prototypes. At the same time, the colleague with the design background started to sketch our ideas and to draw first storyboards. Suddenly, the communication in the interdisciplinary team improved significantly and it became much easier to convince project managers of our ideas.

Prototypes speak their own language. Before and during implementation, many decisions have to made about functionality, design aspects, look & feel and purpose of the prototype. But the most important characteristic of a prototype is its experienceability. It has to invite people to use it, to explore it and to share their impression and thoughts, whether positive or negative. Its implementation or the applied technology to make it work plays a minimal role. It is important how people feel while interacting with the prototype and what kind of meaningful experiences it allows them to have.

These experiences become more important in our lives. We increasingly define our lives by the experiences we make rather than the things we own. This phenomenon has to be considered when designing and developing interactive technology and applications. Experience Design proposes important methods for integrating experiences into development processes. With this thesis, I was able to show that Experience Prototyping plays an essential role for Experience Design as it is a suitable approach to translate designed experiences into interactive representations. I hope that the case studies and derived insights I presented will convince practitioners to integrate Experience Design and Experience Prototyping into the development of interactive technology.

Appendices

A: English Version of the UXNQ

The User Experience Need Questionnaire was developed by Moritz Körber [56, 57] in the course of the CAR@TUM project "User Experience". For the studies reported in this thesis, we applied the German version of the questionnaire (see appendix B). I translated it into English with the help of Moritz Körber and Johannes Preis.

Stimulation

Making new discoveries, exciting adventures, being stimulated by life instead of being bored.

While using the system, I felt that …							
		Strongly disagree	**Rather disagree**	**Moderately agree**	**Rather agree**	**Strongly agree**	**nAp**
1	… I experienced something great.	①	②	③	④	⑤	⓪
2	… I was fascinated by making new experiences.	①	②	③	④	⑤	⓪
3i	… I was not struck by exciting new impressions.	①	②	③	④	⑤	⓪
4	… I could make new experiences.	①	②	③	④	⑤	⓪
5i	… I did not do anything interesting.	①	②	③	④	⑤	⓪

nap = no answer possible

Control

Having everything under control, feeling secure, being familiar with the situation, understanding consequences.

While using the system, I felt that…							
		Strongly disagree	**Rather disagree**	**Moderately agree**	**Rather agree**	**Strongly agree**	**nap**
1	… I had everything under control in the situation.	①	②	③	④	⑤	⓪
2i	… the situation was not sufficiently predictable.	①	②	③	④	⑤	⓪
3	… my actions were effective.	①	②	③	④	⑤	⓪
4i	… in the situation I was not safe and secure.	①	②	③	④	⑤	⓪
5	… I could successfully master the situation.	①	②	③	④	⑤	⓪

nap = no answer possible

Conservation of Something Meaningful

The feeling of preserving something personally meaningful or being reminded of something by it. Example: keeping a concert ticket; taking photos on a journey.

While using the system, I felt that…							
		Strongly disagree	**Rather disagree**	**Moderately agree**	**Rather agree**	**Strongly agree**	**nap**
1	… something personally valuable happened.	①	②	③	④	⑤	⓪
2	… the situation triggered personal memories.	①	②	③	④	⑤	⓪
3	… I could preserve personally meaningful memories.	①	②	③	④	⑤	⓪
4	… something personal, which will be remembered, was created.	①	②	③	④	⑤	⓪
5	… I could preserve something that is meaningful to me.	①	②	③	④	⑤	⓪

nap = no answer possible

Physical Thriving

A feeling of physical well-being, vitality or fitness. Example: A run in the morning.

While using the system, I felt …							
		Strongly disagree	**Rather disagree**	**Moderately agree**	**Rather agree**	**Strongly agree**	**nap**
1	…active and sportive.	①	②	③	④	⑤	⓪
2	…physically well.	①	②	③	④	⑤	⓪
3	…alive und vital.	①	②	③	④	⑤	⓪
4i	…not full of energy or physically active.	①	②	③	④	⑤	⓪
5	…comfortable within my own body.	①	②	③	④	⑤	⓪

nap = no answer possible

Autonomy

Not being constrained by external factors, feeling autonomous, being independent.

While using the system, I felt …							
		Strongly disagree	**Rather disagree**	**Moderately agree**	**Rather agree**	**Strongly agree**	**nap**
1	… that I was free in my decisions.	①	②	③	④	⑤	⓪
2i	… that I was not able to act according to my interests and values.	①	②	③	④	⑤	⓪
3	… that I was able to act the way I wanted to.	①	②	③	④	⑤	⓪
4i	… that my actions were influenced by external pressure.	①	②	③	④	⑤	⓪
5	… that I was able to act independently.	①	②	③	④	⑤	⓪

nap = no answer possible

Popularity

Social reputation, being popular, being the opinion leader, strengthening of social identity, status.

While using the system, I felt …							
		Strongly disagree	**Rather disagree**	**Moderately agree**	**Rather agree**	**Strongly agree**	**nap**
1	…that I was a popular person.	①	②	③	④	⑤	⓪
2i	…that I would not be proud when others see me with this product.	①	②	③	④	⑤	⓪
3	…I was a person who had an influence on the opinions of others.	①	②	③	④	⑤	⓪
4i	…that I was not able to improve my social image.	①	②	③	④	⑤	⓪
5	… that I was a reputable and respected person.	①	②	③	④	⑤	⓪

nap = no answer possible

Relatedness

Companionship, team spirit, meaningful relations to others, belonging to a group, sense of belonging.

While using the system, I felt …							
		Strongly disagree	**Rather disagree**	**Moderately agree**	**Rather agree**	**Strongly agree**	**nap**
1	… I was close to people who I care for.	①	②	③	④	⑤	⓪
2i	… I rather acted alone than with others.	①	②	③	④	⑤	⓪
3	… that I built a team.	①	②	③	④	⑤	⓪
4	… that I was part of a community.	①	②	③	④	⑤	⓪
5	… that I belonged to a group or other persons.	①	②	③	④	⑤	⓪

nap = no answer possible

Competition

Being better than others, overtrump others, feeling of self-worth.

While using the system, I felt …							
		Strongly disagree	**Rather disagree**	**Moderately agree**	**Rather agree**	**Strongly agree**	**nap**
1	… that I had an advantage over others.	①	②	③	④	⑤	⓪
2	… able to surpass others.	①	②	③	④	⑤	⓪
3i	… that I performed not better than others.	①	②	③	④	⑤	⓪
4	… I showed others that I was superior.	①	②	③	④	⑤	⓪
5	… I used something better than others.	①	②	③	④	⑤	⓪

nap = no answer possible

B: German Version of the UXNQ

The User Experience Need Questionnaire was developed by Moritz Körber [56, 57] in the course of the CAR@TUM project "User Experience". For the studies reported in this thesis, we applied this German version of the questionnaire.

Stimulation

Etwas Neues entdecken, aufregende Abenteuer, vom Leben stimuliert werden anstatt gelangweilt zu sein.

Durch/bei Benutzung des Systems,…							
		stimme gar nicht zu	**stimme eher nicht zu**	**Stimme mittelmäßig zu**	**stimme eher zu**	**stimme voll zu**	**kAm**
1	…habe ich etwas Tolles erlebt.	①	②	③	④	⑤	⓪
2	… habe ich fasziniert neue Erfahrungen gemacht.	①	②	③	④	⑤	⓪
3i	… habe ich keine aufregenden neuen Eindrücke gehabt.	①	②	③	④	⑤	⓪
4	… konnte ich etwas Neues erleben.	①	②	③	④	⑤	⓪
5i	…habe ich nichts Interessantes gemacht.	①	②	③	④	⑤	⓪

kAm = keine Angabe möglich.

Kontrolle

Alles unter Kontrolle haben, sich sicher fühlen, um seine Situation Bescheid wissen, Verständnis der Folgen.

Durch/bei Benutzung des Systems,…							
		stimme gar nicht zu	**stimme eher nicht zu**	**Stimme mittelmäßig zu**	**stimme eher zu**	**stimme voll zu**	**kAm**
1	…hatte ich in dieser Situation alles gut im Griff.	①	②	③	④	⑤	⓪
2i	…war die Situation für mich nicht ausreichend vorhersehbar.	①	②	③	④	⑤	⓪
3	…war mein Handeln wirksam und effektiv.	①	②	③	④	⑤	⓪
4i	…war ich nicht sicher und geborgen.	①	②	③	④	⑤	⓪
5	…konnte ich die Situation erfolgreich meistern.	①	②	③	④	⑤	⓪

kAm = keine Angabe möglich.

Bedeutsames Bewahren

Das Gefühl etwas persönlich Wichtiges zu bewahren oder dadurch an etwas erinnert zu werden. Beispiel: Aufbewahren einer Konzertkarte; Fotos auf einer Reise machen

Durch/bei Benutzung des Systems,…							
		stimme gar nicht zu	**stimme eher nicht zu**	**Stimme mittelmäßig zu**	**stimme eher zu**	**stimme voll zu**	**kAm**
1	…etwas für mich persönlich Wertvolles ist geschehen.	①	②	③	④	⑤	⓪
2	… hat die Situation persönliche Erinnerungen geweckt.	①	②	③	④	⑤	⓪
3	…konnte ich mir persönlich wichtige Erinnerungen abspeichern.	①	②	③	④	⑤	⓪
4	…wurde etwas Persönliches, was in Erinnerung bleibt, geschaffen.	①	②	③	④	⑤	⓪
5	…konnte für mich selbst etwas Bedeutungsvolles bewahren.	①	②	③	④	⑤	⓪

kAm = keine Angabe möglich.

Körperlichkeit

Ein Gefühl von körperlichem Wohlbefinden, Vitalität oder Fitness. Beispiel: Ein morgendlicher Lauf im Wald; das Aufwärmen an der Heizung im kalten Auto

Durch/bei Benutzung des Systems,…							
		stimme gar nicht zu	**stimme eher nicht zu**	**Stimme mittelmäßig zu**	**stimme eher zu**	**stimme voll zu**	**kAm**
1	…konnte ich aktiv und sportlich sein.	①	②	③	④	⑤	⓪
2	…hatte ich ein angenehmes körperliches Gefühl	①	②	③	④	⑤	⓪
3	…war ich lebendig und vital.	①	②	③	④	⑤	⓪
4i	…habe ich mich nicht energiereich und körperlich	①	②	③	④	⑤	⓪
5	…habe ich mich wohl in meinem Körper gefühlt	①	②	③	④	⑤	⓪

kAm = keine Angabe möglich.

Autonomie

Nicht durch externe Faktoren eingeschränkt sein, selbstbestimmt sein, handeln, wie man möchte, unabhängig sein.

Durch/bei Benutzung des Systems,…								
		stimme gar nicht zu	**stimme eher nicht zu**	**Stimme mittelmäßig zu**	**stimme eher zu**	**stimme voll zu**	**kAm**
1	…war ich frei in meinen Entscheidungen.	①	②	③	④	⑤	⓪
2i	…konnte ich nicht gemäß meinen Interessen und Werten handeln.	①	②	③	④	⑤	⓪
3	…konnte ich so handeln, wie ich wollte.	①	②	③	④	⑤	⓪
4i	…habe ich unter Druck von außen gehandelt.	①	②	③	④	⑤	⓪
5	…konnte ich frei handeln, so wie es für mich recht war.	①	②	③	④	⑤	⓪

kAm = keine Angabe möglich.

Popularität

Soziales Ansehen, beliebt sein, Meinungsführer sein, stärkt die soziale Identität, Status.

Durch/bei Benutzung des Systems,…							
		stimme gar nicht zu	**stimme eher nicht zu**	**Stimme mittelmäßig zu**	**stimme eher zu**	**stimme voll zu**	**kAm**
1	…war ich eine beliebte Person.	①	②	③	④	⑤	⓪
2i	…wäre ich nicht stolz, wenn mich andere mit dem odukt/System	①	②	③	④	⑤	⓪
3	…war ich eine Person, die durch ihre Meinung Einfluss auf andere	①	②	③	④	⑤	⓪
4i	…verbessert sich mein Eindruck bei anderen Leuten nicht.	①	②	③	④	⑤	⓪
5	…bin ich eine anerkannte und angesehene Person.	①	②	③	④	⑤	⓪

kAm = keine Angabe möglich.

Verbundenheit

Gemeinschaft, Teamgeist, bedeutsame Beziehungen zu anderen, Zugehörigkeit zu einer Gruppe, Zugehörigkeitsgefühl.

Durch/bei Benutzung des Systems,…							
		stimme gar nicht zu	**stimme eher nicht zu**	**Stimme mittelmäßig zu**	**stimme eher zu**	**stimme voll zu**	**kAm**
1	…war ich mit mir nahestehenden Personen in Kontakt.	①	②	③	④	⑤	⓪
2i	…habe ich eher allein als zusammen mit anderen gehandelt.	①	②	③	④	⑤	⓪
3	…habe ich ein Team gebildet.	①	②	③	④	⑤	⓪
4	…habe ich zu einer Gemeinschaft gehört.	①	②	③	④	⑤	⓪
5	…habe ich mich einer Gruppe oder anderen Personen zugehörig gefühlt.	①	②	③	④	⑤	⓪

kAm = keine Angabe möglich.

Wettbewerb

Besser sein als andere, andere übertrumpfen, Selbstwert.

Durch/bei Benutzung des Systems,…							
		stimme gar nicht zu	**stimme eher nicht zu**	**Stimme mittelmäßig zu**	**stimme eher zu**	**stimme voll zu**	**kAm**
1	…war ich gegenüber anderen im Vorteil.	①	②	③	④	⑤	⓪
2	…konnte ich jemand anderes übertrumpfen.	①	②	③	④	⑤	⓪
3i	…war ich nicht besser als andere.	①	②	③	④	⑤	⓪
4	…habe ich anderen gezeigt, dass ich ihnen überlegen bin.	①	②	③	④	⑤	⓪
5	…habe ich etwas Besseres benutzt als andere.	①	②	③	④	⑤	⓪

kAm = keine Angabe möglich.

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Eidesstattliche Versicherung

(Siehe Promotionsordnung vom 12.07.11, § 8, Abs. 2 Pkt. 5)

Hiermit erkläre ich an Eidesstatt, dass die Dissertation von mir selbstständig und ohne unerlaubte Beihilfe angefertigt wurde.

München, den 22. Januar 2015

Sebastian Löhmann