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A Context Aware Music Player

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A Context Aware Music Player

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Abstract

Context aware music systems aim to free the user from the tedious work of creating playlists. They achieve this by sensing their environment and select music that fits the current situation. People often consume music in the background, while they perform other activities, such as cooking, working on something, or having some friends over for dinner. A common problem is, that music players often get in their way, by drawing too much attention and hindering them from what they wanted to do in the first place. Context aware music systems have been the topic of many research papers in the past. Most of them focused on specific parts of the topic, like music categorization or reasoning, while neglecting design questions about the actual use of such a device. A major question of this thesis was the field of tension of giving users control over a system that makes autonomous decisions. These questions can only be addressed by observing people, using a fully functional prototype. Such a prototype, consisting of a software application and a specifically designed USB-device (including sensors and a tangible user interface), has been developed for the purpose of answering these questions. The prototype was developed using user centered design (UCD) techniques like personas, usability tests, and qualitative interviews. The main contribution of this thesis is a newly designed interaction concept for context aware music players, as well as insights gathered through the evaluation of a fully functional prototype. The interaction concept proposed in this thesis enables users to express information about their mood and activities in a subtle way, and lets them customize the system, by mapping situation descriptions to music. I also found out, that the subjective feeling of having control over a system can be strengthened by adding customization options and by making autonomous decisions transparent.

Keywords: Context awareness, UCD, HCI, TUI, sensor-based, music, personas, qualitative interviews.

Kurzfassung

Kontextsensitive Musiksysteme haben das Ziel, den/die Benutzer/in von der langwierigen Arbeit des Erstellens von Wiedergabelisten zu befreien. Das erreichen sie durch Abtasten der Umgebung und durch das Abspielen von Musik, die zur jeweiligen Situation passt. Musik wird oft im Hintergrund abgespielt, während Zuhörende anderen Dingen wie zum Beispiel Kochen, Arbeiten oder einem gemeinsamen Essen nachgehen. Ein verbreitetes Problem ist, dass Musikabspielgeräte oftmals im Weg sind, viel Aufmerksamkeit fordern und Leute damit daran hindern, jene Dinge zu tun, die sie ursprünglich vor hatten. Kontextsensitive Musiksysteme waren bisher Thema vieler Forschungsarbeiten. Die meisten davon haben sich auf einen speziellen Teil solcher Systeme, wie zum Beispiel die Kategorisierung von Musik oder das Schlussfolgern konzentriert und dabei Fragen zur eigentlichen Verwendung solcher Systeme vernachlässigt. Eine wichtige Frage war dabei das Spannungsfeld zwischen Benutzerkontrolle und einem System, das eigenständige Entscheidungen trifft. Diese Fragen können nur durch Beobachtung von BenutzerInnen beantwortet werden, die einen voll funktionstüchtigen Prototypen verwenden. Ein solcher Prototyp, bestehend aus Software und einem speziell angefertigten USB-Gerät (einschließlich Sensoren und einem Tangible User Interface), wurde zur Beantwortung dieser Fragestellungen entwickelt. Der Prototyp wurde mit Hilfe von Methoden der nutzerorientierten Gestaltung (UCD), wie zum Beispiel Personas, Usability Tests und qualitativen Interviews, entwickelt. Der Hauptbeitrag dieser Arbeit ist ein neuer Entwurf für ein Interaktionskonzept eines kontextsensitiven Musikabspielgeräts und Einsichten, die durch die Evaluierung eines funktionierenden Prototyps gewonnen wurden. Das Interaktionskonzept, welches in dieser Diplomarbeit vorgeschlagen wird, ermöglicht es BenutzerInnen, Informationen über ihre Stimmung und aktuelle Aktivitäten in unaufdringlicher Weise auszudrücken und lässt sie das System durch Verbinden von Situationsbeschreibungen mit Musik anpassen. Ich fand heraus, dass das subjektive Gefühl, Kontrolle über ein solches System zu haben, durch Anpassungsoptionen und durch Transparentmachen automatisiert getroffener Entscheidungen gestärkt werden kann.

Schlüsselwörter: Kontextsensitivität, nutzerorientierte Gestaltung, Mensch-Computer-Interaktion, Tangible User Interface, sensorbasiert, Musik, Personas, qualitative Interviews.

Contents

CHAPTER 1

Introduction

1.1 Problem Definition

Music is often consumed in the background. People use it for a variety of reasons and in different situations. Unfortunately most music players require a lot of attention from the user. Users need to create playlists fitting their current situation and mood, before they can start doing things, they wanted to do in the first place. The only other option would be to use a shuffle mode that plays random tracks. In this case chances for getting songs the user really wants to listen to are low, which will subsequently lead to skipping tracks more often and again, drawing attention from the user.

What if the music playback-device could intelligently select music for the listener? A music player could use sensors to get aware of the environment. Although metrics like humidity, temperature, time, location (GPS), ambient light, and ambient audio would provide a lot of information, there is one key factor that can not simply be measured effectively by nowadays sensor technology: the mood of the user [Seppänen and Huopaniemi, 2008, p.6]. Since we cannot look inside a user's mind, the only way to get this information is to ask the user explicitly. The problem in this case is to find a subtle way to interact with the system that will not draw too much attention. Also a user does not necessarily want to listen to songs that fit their mood. In fact there are many situations where users utilize music to change their mood [Cunningham et al., 2008, p.8]. Another problem is that a player that automatically plays music reduces user control and freedom, which according to Jakob Nielsen [Nielsen, 2012] is a very bad thing. A context aware music player should therefore provide options to overrule the system. The goal of this thesis was to find an interaction concept for a context aware music player that provides an answer to the above stated design questions, enables users to express explicit information about their current situation, without requiring too much attention from the user, and to evaluate a fully functional prototype with users. One key question is, how to give users the feeling of being in control of a system that makes autonomous decisions. The resulting prototype consists of an external USB-device that contains all the sensors as well as physical controls, and a software component that runs on a Mac, does all the reasoning and plays back music. The USB-Device includes a tangible user interface that enables the user to notify the system about mood changes and current activities.

1.2 Methodology and Research Approach

I approached the problem using user-centered design (UCD) methods and qualitative research. I started by identifying personas (fictitious representations of target users used in UCD [Adlin and Pruitt, 2010, p.1]), who were used along the whole process of prototyping. Subsequently I created a lo-fi prototype, which was then evaluated. The aim of this test was to evaluate the general interaction concept early on, so that even drastic changes could have been made. Considering the results and insights of this test, I started working on a feature complete prototype. This prototype has then been evaluated in the second usability test. All usability tests were planned in detail according to the suggestions of Jakob Nielsen [Nielsen, 1993] and Jeffrey Rubin [Rubin and Chisnell, 2008]. The usability tests also included qualitative interviews to enrich feedback information. Besides the actual design of the user interaction a lot of programming and tinkering has been done. Luckily the Arduino Project [Banzi and Massimo, 2008] offers an accessible way to realize such prototypes within a reasonable time.

1.3 Source for Music

One early task was to decide on a music source. A possibility would have been to create software that digs through local music or online streaming platforms such as SoundCloud [SoundCloud, 2012], analyzes it and appends tags according to their atmosphere. This topic would have been a research topic on its own. Also decisions about music made by an algorithm don't necessarily coincide with the way a user would tag music. Since this thesis was focused on the interaction and not musical analysis I needed to find a source that provides a variety of sets with different music, where each set has a consistent atmosphere. Gallardo and Jordá say that playlists have become the new unit in music [Gallardo and Jordà, 2010]. With the shift toward digital music in the past couple of years single songs have become more popular than albums. These songs are typically organized in playlists. During my search for a possible source I learned that there are thousands of genre specific web-radiostations available. They range from lounge music to death metal. There is even a radio station that plays only instrumental songs with acoustic guitars (no other instruments allowed), or one that broadcasts sounds from a microphone placed in the Brazilian rainforest. I found this to be a perfect source for music, at least for the purpose of research. One thing I want to point out though, is that these radio stations can be easily replaced by any kind of playlist. They can be playlists created by users with digital files they own, or collaboratively created playlists online. The last-mentioned would be an interesting expansion to the prototype that resulted from this master thesis. Users could create playlists, tag them according to the tags used in this system, and share them online.

1.4 Structure of this Thesis

This master thesis is subdivided in seven chapters, with the current introduction being the first one. Chapter two gives an overview of the state of the art and introduces various research projects with the topic of context awareness applications in music. Also the term context awareness is explained in detail in this chapter and its applications are reviewed. Chapter three outlines the methodology used to research this topic. Issues like User Centered Design, prototyping, qualitative interviews, and usability tests are discussed. Chapter four presents the personas created for this project. Chapter five depicts the process of developing the prototype and includes insights into hard- and software. It also includes a detailed description of how the algorithm that chooses suitable music for specific situations, operates. In chapter six both usability tests are described and a summary of the results is presented. Chapter seven summarizes the findings and insights gathered in the course of this master thesis and gives an outlook on how the prototype could be improved in the future.

CHAPTER 2

State of the Art

2.1 Existing Context Aware Music Systems

Tough I could not find any context aware music players on the market when I started my master thesis, they are topic of many researches. Scientists of the Nokia Research Center provide a high level architecture and a three domain model for context aware music recommendation in their work [Seppänen and Huopaniemi, 2008, p.8]. They identified user (information about the user, community, and relationships), context (mood, location, activity, time, identity), and music (information about the tracks such as genre, tempo, artist, etc.) as three domains. They also created a prototype of a mobile recommender. Cebrian et al. focus on filtering methods for context information in recommender systems [Cebrián et al., 2010, p.433]. They say that using context information transforms a 2-dimensional user/item problem into an n-dimensional problem. In their prototype they only use time as input factor. Cunningham et al. state that context awareness is an opportunity for enhanced user experience [Cunningham et al., 2008]. They use a fuzzy rule based system for music selection and suggest to add self learning capabilities for future research. In contrast to research projects mentioned above, they suggest using sensors to gather information about the listener in addition to the environment. Skin conductivity-, heart rate- and accelerometer-sensors can provide this information. Although the work of Han et al. is focused on music classification, based on audio analysis, which I am not planning to do in my master thesis, they also provide two interesting models that can at least partly be used for any context aware music player [Han et al., 2010, p.433]. The first one is an emotion state transition model that describes human emotion in a formal way. The second model is a music ontology called COMUS, which tries to express all the relations between musical information, moods, situations, and users [Han et al., 2010, p.439]. Jae Sik Lee and Jin Chun Lee propose a music recommendation system based on listening history and weather data [Lee and Lee, 2006]. They use case-based reasoning and a k-Nearest Neighbor algorithm to search historic data for music that fits the current situation. Another research that lays emphasis on the reasoning part is the work of scientists of the Yonsei University in Seoul [Park et al., 2006]. They propose a system that uses Bayesian networks and utility theory for music recommendation. Some research is specifically focused on mood detection of music [Feng et al., 2003].

There also exists a project called Lifetrak from the University of California that uses GPS-data and time as input parameters for context sensing on an Nokia 770 Internet tablet [Reddy and Mascia, 2006]. They use GPS data to derive velocity and to gather environment information like weather and traffic online. They suggest that streaming music online, or using radio stations (satellite and normal) would create a better user experience, because it avoids the risk of replaying songs. They also stress the importance of giving the user tools to adjust playback and introduce a context equalizer that allows users to decide, which factors are most important for them.

Guan et al. propose a music recommendation agent, which tries to automatically sense the mood of users [Guan et al., 2006]. They try to achieve this, by looking at a user's location, time, weather, which other people are around him and his stock portfolio. Although this approach may be a practical solution in their research model, such an understanding and harsh simplification does not reflect the real world.

Baltrunas et al. proposed an Android mobile application for context aware music recommendations in cars, but state that they have not yet validated the usability of their prototype in a test [Baltrunas et al., 2011].

Most of the projects presented in this section are not really meant to be ready to use by real users outside the research environment. In some cases only concepts or models are presented, in others systems are limited in some features, e.g., outcomes are mapped to only 10 songs, or users have to hold a Wiimote controler [Cunningham et al., 2008]. A lot of projects tend to be specialized in the specific task of reasoning. To the best of my knowledge there has not been any user centered approach in creating a context aware music system that has evaluated a fully functional prototype in an usability test.

During the making of this master thesis the Japanese company Neurowear released a product called Mico [neurowear, 2013]. Mico is a system that uses headphones developed by Neurowear that sense and analyze brainwaves. The patterns gathered by the device are mapped to pool of 100 songs. This could be a way to automatically detect a user's mood. Unfortunately Neurowear does not provide any details about the sensor or the algorithm.

2.2 Context Awareness

The term context awareness can be described by looking at the meaning of both words. The cambridge dictionary defines context as "the situation within which something exists or happens, and that can help explain it" [Cambridge-Dictionary, 2013b], and awareness as "knowledge that something exists, or understanding of a situation or subject at the present time based on information or experience" [Cambridge-Dictionary, 2013a]. Context awareness is a term used in human computer interaction as a property of a system. A system that is aware of its situation and surroundings. Anind K. Dey has published the following definition: "A system is context-aware if it uses context to provide relevant information and/or services to the user, where relevancy depends on the user's task" [Dey, 2001, p.4]. In the past it has been used mainly to describe computers that are aware of one's location [Schmidt, 2013]. Even today location awareness is the most common use of context awareness. Context awareness is often used in mobile computing because situations, and therefore context changes often, for user that are on the go. An example for using context awareness in mobile computing, is a phonebook [Schmidt et al., 2001] that provides a caller with additional information about the situation of the person he wants to call, like connection status and location. Context awareness is not limited to this kind of awareness. Schmidt provides a model for context, in which he organizes context hierarchically [Schmidt et al., 1998]. He subdivides context into human factors such as information about users, their social environment and tasks, and properties of the physical environment, such as conditions (light, temperature, audio, etc.), infrastructure, and location. In this model, location is only one of many features. Information can be gathered explicitly, by asking the user, or implicitly via sensors. In a publication in 2011 [Schmidt et al., 2011], he suggests that a sensor equipped system even should extend human perception (e.g., ultrasound). Sensor data itself is not a complete description of a situation. It needs to be processed first. A simple architecture [Schmidt et al., 1998] for a system that derives context awareness from sensor data, involves four layers. At the lowest level sensor data is gathered. In the cue-layer a set of possible values for each sensor is defined. Using those cues a context description for the whole situation can be derived in the context-layer. Finally the system needs to take some actions according to the information about the context that it now has. The scripting layer does exactly that. It triggers some routines while entering or leaving a defined context.

For a better understanding of this architecture here is an example: A user interface of a mobile device changes its appearance, depending on whether a person is located inside or outside a building. This means that the scripting-layer has a rule that says something like “if user is outside change UI”. The two contexts defined in such an application would be “outside” and “inside” and are derived from cues. The underlying sensors used are a microphone, a light-sensor, and a motion sensor. Sensor data is usually some electronic signal that viewed on their own have no meaning. Cues now define that a certain signal from a light-sensor means “bright” or “dark”. Within the context layer the context “outside” can now be defined as “when it is bright, noisy and the object is in motion”. In a complex system that deals with multiple sensors' input sources need to be monitored regularly. Hackmann et al. present a middleware that hides details about context collection and monitoring [Hackmann et al., 2004]. Providing awareness information to users can be tricky. Awareness cues are interpreted by users with respect to their goals and their pre-knowledge [Oulasvirta, 2008].

2.3 Tangible User Interfaces

It is human nature that we sense and interact with physical objects in our environments. However most of these skills we obtained are not represented in the digital world [Sears and Jacko, 2009]. To overcome this issue tangible user interfaces (TUI) have emerged since the early 90s. Fishkin states that tangible user interfaces are characterized by the way they operate [Fishkin, 2004]. They all have some kind of input event that is typically performed via manipulation of a physical object. The system senses this input, alters its state, and gives some feedback to the user. Feedback might be given on a display, as sounds, or also of physical nature. Although their physical presence can be seen as biggest advantage of TUIs, it is also a disadvantage when it comes to flexibility and changing their shape [Israel, 2006]. One possible way to implement a tangible user interface is by using *tokens*. Tokens are physical objects that can be manipulated by users and represent digital information [Ullmer et al., 2005]. Tokens are typically combined with mechanical constraints. Constraints limit the movement of tokens. In some interfaces tokens can't be moved once they are placed, in others constraints limit their movement to a single physical degree. The concept of simply placing tokens is called presence. Other forms are transition, which means they can be relocated along one axis (limited by a constraint), or rotation (e.g., in case of a circular token). Token+constraint interfaces can consist of [Ullmer et al., 2005]:

- a single token and multiple constraints in which it can be placed,
- multiple tokens and one constraint, which means that all or a selection of tokens can be placed, or
- one or several nested tokens. this means that tokens have constraints and can receive other tokens.

One important design ingredient when it comes to tangible computing is *metaphor*. As soon as interfaces are made tangible metaphors are created [Fishkin, 2004]. The job of a designer is not to leave this to chance, but to actively shape metaphors. They can use all kinds of properties that are immanent to physical objects, such as size, color, weight, texture, shape and smell. For example in token based systems the quality of a token can influence how users are going to interact with it. Material should be chosen according to what they should represent [Holmquist et al., 1999]. Holmquist et al. say that for example tokens, which are made of fragile material, may be used for information that should be carefully handled. Size and shape should also be selected with care. Tokens that are meant to be passed between users should be designed in a way that they can easily grabbed. Some shapes, invite users to stack them. This can especially be useful when a system uses a large number of tokens. The most important thing about size and shapes is that, when mindfully, designed they can help to prevent mistakes. When shape and size determine where a token can be placed, users can hardly use them in a non-intended way.

Since this thesis is about a context aware music player, it is important to take a look at implementations of music devices with tangible user interfaces. There is a strong connection between music and haptic experiences. First of all, in the past century, music has been distributed mostly via physical media [Gallardo and Jordà, 2010]. People bought gramophone records (first out of shellac, later vinyl), cassette tapes, and CDs. All of those had special qualities, which addressed more senses than just the perception of sound. Listeners could look at the artwork and in case of gramophone records even feel the music. Further it was possible to sort them, pass them around, or display them on a shelve. Musicians also have a haptic experience when playing their instruments. The experience can also be the other way around. Music can cause all kinds of physiological changes and potentially affects the autonomic nervous system [Fagerlönn and Lefford, 2006]. In the last couple of years the music industry shifts toward digital downloads, with the consequence that some of that physical qualities are lost. There are some research projects that try to give digital music some of that experience back. Gallardo and Jordá propose a tangible user interface with music cards that represent the role of music containers [Gallardo and Jordà, 2010]. Graham and Hull took a similar approach, but instead of using RFID, they let users print out cards with QR-codes [Graham and Hull, 2008]. A card can contain a song, a playlist, or an album and has artwork printed on them, which makes them recognizable for humans too. Users can hold the QR-codes in front of the camera and thereby control iTunes. All of the previously mentioned prototypes have in common that, although the cards represent digital data, there is actually no data stored on them. The same applies to mediaBlocks [Ullmer et al., 1998], a project that uses small wooden blocks, to represent music and videos, in order to use them in a sequencer.

There are many more projects that follow the same concept, and RFID seems to be most used technology for identifying real world objects. One downside to the use of this technology is that when multiple RFID-tags are read simultaneously by a single RFID-reader, anti-collision protocols are needed. This leads to some delay and makes realtime control of a music device slow [Paradiso et al., 2001].

2.4 Moods

Since mood is one of the most important selection criteria when it comes to music, it is obvious that it needed to be part of the context aware music player. Over the past decades many mood models have been proposed by a variety of researchers. Most of them originate from the field of psychology [Russell, 1980, Ekman, 1992, Thayer, 1989]. One considerable recent approach is the work of Lövheim, who proposed an emotion model based on the neurotransmitters serotonin, dopamine, and noradrenaline [Lövheim, 2012].

Plutchik's emotion model consists of eight primary emotions: joy, trust, fear, surprise, sadness, disgust, anger, anticipation [Plutchik, 2001]. In his three-dimensional model he describes many more emotions as a mixture of the given basic emotions. In context aware music recommendation Rho et al. [Rho et al., 2013] and Han et al. [Han et al., 2010] modified Thayer's two-dimensional emotion model [Thayer, 1989]. This resulted in a model with 11 moods. Since users of the context aware music player presented in this thesis should be able to express their emotions quickly, I decided to take Han's model [Han et al., 2010] and simplified it, by narrowing the number of moods down to six, while still keeping the basic idea of having two dimensions. I decided to mainly reduce moods that were placed in the center, while keeping the more extreme ones. The idea behind it was that moods like pleased, relaxed, calm, and peaceful may look very similar to the user, and therefore making decisions harder. Using to many moods may especially be an issue for the tagging process when radio stations are configured. Figure 2.1 shows the simplified mood model used for the implementation in this master thesis.

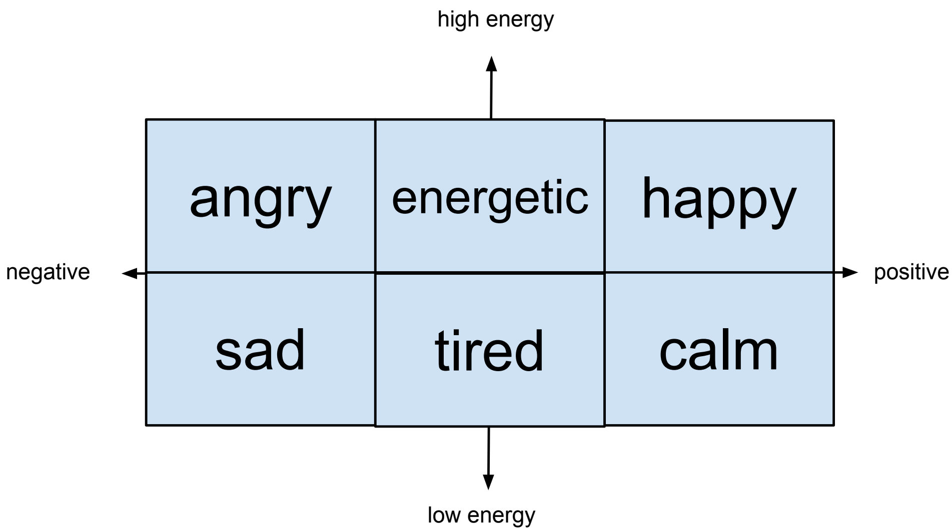

Figure 2.1: Simplified emotion model

CHAPTER 3

Methodology

This chapter outlines the methodological background of my work. An introduction to the topics user centered design, prototyping, personas, and tangible user interfaces is given and research methods like qualitative interviews and usability tests are discussed.

3.1 User Centered Design

"'User-centered design' (UCD) is a broad term to describe design processes in which end-users influence how a design takes shape." [Abras et al., 2004, p.1]. There exists a variety of methods and approaches in user centered design that all have one thing in common. Unlike technology centered design that is focused on features and functions, in UCD the perspective of the user is more important. Donald Norman, one of the pioneers of UCD calls it "[...] a philosophy based on the needs and interests of the user, with an emphasis on making products usable and understandable." [Norman, 2002, p.188]. Norman also presented suggestions of what design should be. According to his book, The Design of Everyday things, design should [Norman, 2002, p.188]:

- "Make it easy to determine what actions are possible at any moment (make use of constraints)."
- "Make things visible, including the conceptual model of the system, the alternative actions, and the results of actions."
- "Make it easy to evaluate the current state of the system."
- "Follow natural mappings between intentions and the required actions; between actions and the resulting effect; and between the information that is visible and the interpretation of the system state."

Those simple guidelines can help a designer with creating a prototype of a product. It also helps making design decisions. One might think it is sufficient to just ask potential users, what they want and then build exactly that. Unfortunately this proved to be ineffective in practice. One problem is that users only have partial ideas of what they want. They derive their ideas from tools they already use. They also have limited knowledge about information design and human computer interaction [Endsley, 2003, p.7 pp]. Another problem is that a system is usually used by many different people, who may have different opinions and most certainly have different needs. Implementing all inputs from users unfiltered will probably lead to an oversized highly complex system that is never finished because new ideas keep coming in. Despite all of that, users are a valuable source of information when it comes to identifying problems and functions they need. The big questions are, how to involve users in the process of creating products and what does a UCD process look like. According to DIN-EN-ISO-9241 [DIN EN ISO 9241-210, 2011] in a UCD process design is based on understanding about your users, tasks, and environment. Users are involved in the whole process of development. Refinements are impelled progressively based on user centered evaluation. The DIN standard also states that the whole process is iterative and that user experience is important. Additionally they suggest that a multidisciplinary approach should be taken. The standard defines four major design activities in the process of UCD [DIN EN ISO 9241-210, 2011, p.14]:

- understanding and describing the context of use
- specifying the requirements of use
- designing a solution
- evaluation of the solution

All of the activities described by the DIN-standard can be found in this master thesis. The context of use, is analyzed and described in chapter four and results in personas, a UCD technique that I will describe in detail later in this chapter. The prototype has been designed and evaluated in 2 iterations. Chapters five and six describe this process in detail.

Now that we know how the process looks like, there is still one open question: How are we going to involve users? Preece gives an overview about techniques that will help you gather information about users [Preece, 2002]. One technique that most people are familiar with is questionnaires. *Questionnaires* range from yes/no questions to questions where participants need to comment. Usually the kind of data that is gathered from questionnaires is quantitative. Pre-supplied answers and yes/no questions can be evaluated statistically. The only qualitative response one could get is when a participant is asked to comment on a question. The problem with this is that there is no dialogue between the researcher and the participant. If an answer happens to be unclear for the researcher, she won't be able to ask the participant about it. An advantage of questionnaires is that one can reach lots of people with little effort (e.g., online questionnaires). Since the quantitative part makes only sense if you have many participants, this technique is not feasible for this project. The reason for this is that I created a prototype of a physical device. Unlike in a pure software-based system, where copies can be distributed easily, a physical product is limited by number of produced entities of itself. The only part of the process where it would be possible, is in understanding the context of use. A technique that provides the researcher with more qualitative and rich information is *interviewing*. A major advantage of an interview is that it has that dialogue component questionnaires lack of. The only real disadvantage of interviews is that they are time-consuming. Since the prototype can only be tested by a small number of users, due to a lack of resources, interviews seem to be a valid technique for this project. More information about interviews and how they are used in this project can be found in section 3.3. Another technique presented by Preece is *focus groups* and *workshops*. Unlike interviews which tend to be one on one, workshops and focus groups involve more people. They can be structured with topics and tasks, or unstructured. The main advantage of this technique is that it one can find conflicting areas quickly. Although the problem with this is that dominant characters could impose their opinions. This is also the reason why I decided to not use workshops, because I wanted to get uninfluenced information. Another technique is called naturalistic observation. A lot of information originates from the use of a system. Users can be observed while they interact with it. They are unable to pass all of this information during an interview or a questionnaire, because they may not be aware of every detail, or simply can not express it verbally. The downside of this technique is that it is very time consuming, not only in collecting, but also in the process of analyzing, since it produces massive amount of data. Since I planned to gather in depth-information this was the technique of my choice. Detailed information about observations are outlined in section 3.4. and results are presented in chapter six. Preece also mentions a technique called studying documentation, which is not relevant for this thesis, because there are no manuals or similar artifacts available.

3.2 Prototyping

Since UCD is an iterative process based on design and evaluation, it is obvious that some kind of *prototyping* is needed. Prototypes can be categorized according to their fidelity. Roughly speaking, we can distinguish between low- and high-fidelity prototypes. Low fidelity prototypes are limited in their functionality and in their interaction. They are also not feature complete. Low-Fi prototypes can be a simple mockup created with pen and paper. The idea behind them is to show the general look and sometimes feel. They are usually a good communication medium, but less useful when it comes to evaluation, because of their limited interaction capabilities [Rudd et al., 1996]. In contrast to this, hi-fidelity prototypes are interactive objects that are very suitable for user evaluation. A problem with them is that they are much more time consuming in the making [Jones et al., 2007]. This is particularly bad, when the evaluation results indicate that it would be better to design key elements from scratch. Since we want to evaluate our design in every iteration, the first prototype should not be a complete low-fi prototype. Also a hi-fidelity prototype would be impractical for already mentioned reasons. An alternative approach that eliminates some of the time-consuming elements of the hi-fidelity prototype is called *horizontal prototype* [Rudd et al., 1996]. In this case only high-level functionality is implemented. This enables the user to fully interact with the system without having to implement all the underlying details. Yasar discusses the possibility of taking best of both worlds, by combining low- and high-fidelity prototypes to a mixed fidelity prototype [Yasar, 2007]. In this case some parts of the prototype are fully functional, while others are just mockups. He also uses the term *expe-*

rience protoype for objects that at least show some sort of interaction capabilities. When we look at the terms above it is clear that fidelity alone is only a vague description for a prototype. Houde and Hill suggest to describe prototypes, by asking the question what prototypes prototype [Houde and Hill, 1997]. Any interactive artifact can be specified with three aspects: role, implementation, look and feel. Role refers to the purpose of an artifact, the question of how it is useful to people. Look and feel refers to the (multi)sensorial experience of a prototype. What does it look like and how does it feel in the hands of the user. Implementation is about questions from a technological perspective, about materials and components. Prototypes can be visualized according to three aspects in a triangle (see Figure 3.1). When a prototype is more focused on a single aspect it tends towards this aspect inside the triangle. Artifacts that are located close to centroid are called *integration prototypes* and represent the complete user experience. Finding

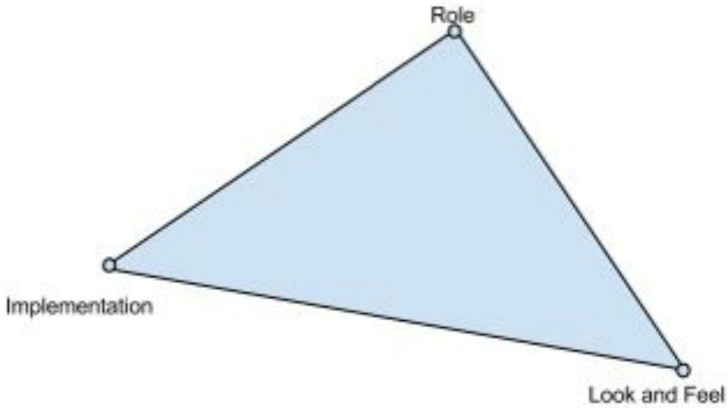

Figure 3.1: Visualization of prototype aspects [Houde and Hill, 1997]

the right prototype for the first iteration of the context aware music player is not an easy task. Moussette [Moussette, 2009] states that finding the right amount of fidelity is really a challenge for non-traditional interfaces, and asks how simple is appropriate when someone designs tangible interfaces for multiple senses. Since the goal of the first prototype was to evaluate the general interaction concept, while still being able to discard it without having wasted a lot of time, a concept for evaluation of low-fi prototypes is needed. In order to give users the look and feel of the final product, all of the tangible elements have been created. The USB-device and all the cubes have been created, in the way they were intended for the final product. While users could already use cubes in the first prototype, there was no complete interaction, since the system did neither respond to user input, nor did it gave any feedback. One technique that is used in this thesis to overcome this problem is called *Wizard of Oz*. This technique originates from papers written in the 80s by John F. Kelly [Kelley, 1983]. He calls it an experimental simulation where users are made to believe that they are interacting with a system that understands English like a human, while the researcher secretly intercepts communication between user and system and performs the tasks the system would [Kelley, 1984]. In current UCD-projects this technique is not only used for simulation of speech recognition, but to perform functions that are not already implemented. Researchers from Finland [Höysniemi et al., 2004] even used it for children games that should be controlled with body movements. They simply observed the users and controlled the system with a mouse and a keyboard. Schieben et. al. [Schieben et al., 2009] extended it so that the wizard is no longer completely hidden, but rather plays a role together with the user, like in a theater. In this technique, which they call theater-system, there is a curtain in the line of sight between user and researcher. They suggest that this curtain can be opened so that the researcher can communicate with the test participant in order to create an open dialogue. The Wizard of Oz technique has also been used recently, for evaluation of a music application during the stage of development. Seeburger et al. used it to simulate other users in a collaborative song-sharing mobile application [Seeburger et al., 2012]. In the research project of this thesis, the only functionality emulated by the Wizard of Oz technique was the playback of music during the first usability test. The researcher simply held a tablet computer hidden behind his scratchpad. This way one can communicate with the user while changing music simply by tapping on the tablet computer. While the first prototype can be seen a low-fidelity prototype, it already had look and feel. Also it could play its role, at least when you count Wizard of Oz as part of the prototype. Implementation did not play a major role in this prototype, but it was still considered a little, as some thoughts went into selecting technology (c.f. chapter five). The second prototype can be described as integration prototype with slightly less focus on implementation, because the used materials may not be the ones used in a final product. Figure 3.2 shows prototypes of both iterations using the triangle visualization. In order

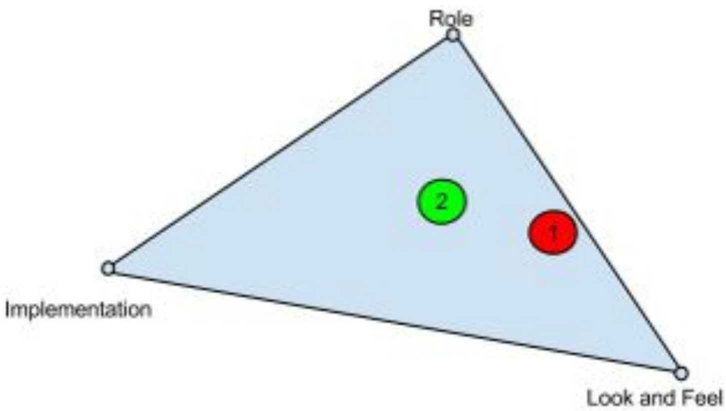

Figure 3.2: Visualization of first and second prototype

to create a music playback device that is aware of context, we need to build an interactive device that is capable gathering information about a situation. It needs to sense the world in a way, typical home computers usually can't. Giving a computer such capabilities, of sensing and controlling the physical world is called *physical computing* [O'Sullivan and Igoe, 2004]. Physical computing is performed through the use of microcontrollers, sensors, and actuators. O'Sullivan and Igoe suggest that when deciding on a microcontroller one should consider price, time, expandability and electrical characteristics (e.g., how many inputs/outputs are needed) [O'Sullivan and Igoe, 2004, p.416]. A popular microcontroller in interaction design is the Arduino, but Arduino is more than just a microprocessor. It "is a platform for prototyping interactive objects using electronics." [Mellis et al., 2007, p.2]. Their goal is to create computers that can sense more of the physical world [Arduino, 2013]. It consists of an open source development platform and a microcomputer. The software can run on OS X, Linux, and Windows and the hardware can be used as an USB-Device for one of the mentioned operating systems, or as an stand-alone object. Arduino also supports a wide range of sensors and even supports shields, circuit boards that can be mounted on top of an Arduino without any additional wiring. Figure 3.3 shows how an NFC-shield is mounted on an Arduino UNO.

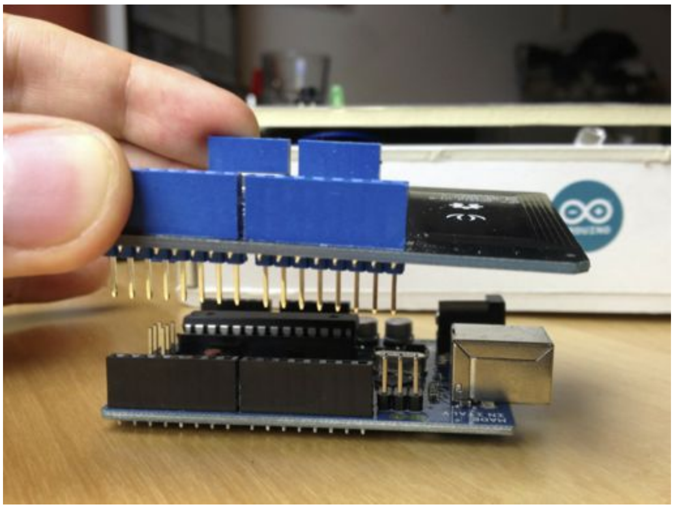

Figure 3.3: Arduino with NFC-Shield

What makes Arduino unique is that it is not designed for experts in the field of electronics but for designers and artists [Banzi and Massimo, 2008]. Another advantage is that they come at a very reasonable price. All of these facts make them ideal for prototyping an interactive object.

3.3 Qualitative Interviews

Qualitative research originates from social science, but has been adopted and reinterpreted by human computer interaction [Rode et al., 2012]. Unlike quantitative research, which tries to quantify data, qualitative research aims to get in depth information. The most common methods in qualitative research are observations and interviews. Interviews are an indirect method, since no data about a prototype or an interface itself is gathered, but rather the opinion of users about it [Nielsen, 1993, p.209]. This is something that should be taken into consideration, when choosing research methods for evaluation, since the aim of evaluation is to get more insights about what areas and features still have problems. A researcher can interview either a single person or a group. Interviews are further categorized, by how much control the interviewer has on the dialogue (unstructured, structured, semi structured) [Preece, 2002, p.390]. In unstructured interviews the interviewer has not much control on the conversation and the interviewee can answer to questions as he likes. This means he might just give a brief answer or even transition the conversation towards a new direction. In interviews like this a lot of rich information can be collected, but analyzing such information can be very time consuming, because it is very unstructured. When you are planning to interview more than one person, outcomes are hard to compare. Structured interviews are on the other end of the spectrum. Questions are planned in detail and responses may also involve selecting from predefined answers. In these kind of interviews, interviewees won't mention things that are not covered by questions planned from the researcher. Finally there is a third type, called semi-structured interview that combines features of both. In semi-structured interviews questions and topic are prepared, and the interviewer usually starts a new topic with a scripted question. Then he lets the interviewee speak freely about the topic until there is not more information. The interviewer is also free to ask spontaneous questions, when a new topic emerges during the conversation. This is the kind of interview that was used in the course of this master thesis. The main reason for this was to make sure that every planned aspect is going to be answered, which let me compare answers given by different participants. In semi-structured interviews, there is still enough room for comments and remarks of the participant, which is really helpful if you want to get rich information about user experience. Whether structured, unstructured, or semi-structured, an interview must be prepared beforehand. Participants have to be selected carefully and researchers should be aware of what they want to try to find out in the interviews. When creating interview questions one should avoid asking questions that can be answered with yes or no. Jargon, long sentences, and suggestive questions should be avoided.

Hopf says that, although all of the rules for good interviews should be applied to qualitative interviews also, things one should avoid, like long questions, suggestive questions, etc. cannot be fully avoided, since they are part of everyday conversation and qualitative interviews aims to be more like a natural conversation [Hopf, 1978]. Most of the time it makes sense to record interviews. This helps reviewing them in detail later. Sometimes the interviewer will find new insights when listening to the interview for the second or third time, because during a conversation some details may have not been recognized. Froschauer and Lueger stress the importance of giving the participant detailed information about the recordings [Froschauer, 1992]. The interviewee should be informed about why a recording is necessary and what will be done with it afterwards. Interviewees might want to know if somebody else will have access to the data. Also telling them how long an interview will take, makes them more comfortable about the situation. Nielsen suggests a number of five people, if one wants to use interviews [Nielsen, 1993] as a research technique. This makes them perfectly combinable with observations and thinking aloud, two techniques that will be discussed in the next section.

3.4 Usability Tests

Evaluation should not be based purely on interviews, since they only reflect user opinions [Nielsen, 1993]. This is why there is also some data gathered based on observation in the evaluation of the context aware music player. A typical technique based on observation in user centered design and human computer interaction is a usability test. Rubin and Chisnell define usability testing as “a process that employs people as testing participants who are representative of the target audience to evaluate the degree to which a product meets specific usability criteria.” [Rubin and Chisnell, 2008, p.21] In usability (user-)tests, selected participants typically solve some predefined tasks, while they are observed by one or many researchers. There are other types of usability tests like heuristic evaluation, where experts perform tests, but in this section we refer to user-tests, when speaking about usability tests.

One of the first things that need to be done, in order to conduct a usability test is to find participants. They should represent users that the system was actually intended for. In order to do that, one must know what the target group of the software or device is. As mentioned in section 3.1, the DIN-standard names understanding and describing the context of use, as one of the major design activities [DIN EN ISO 9241-210, 2011]. By the time a usability test is conducted, this has already been done. Knowing the context of use implies knowing who the potential users are. Preece states that it is very important to know users’ characteristics, in order to select users for testing [Preece, 2002, p.440]. Once users are selected, it might be helpful to categorize them. Rubin and Chisnell state that one should group users into different categories, based on their characteristics [Rubin and Chisnell, 2008, p.124]. This may also help to see if some problems affect only a specific type of user. For the usability tests conducted in this project, users have been categorized in three groups based on the identified personas in chapter four.

Usability tests need to be planned carefully. Researcher should be aware of their aims and also their budget when they start planning. They should also know what they want to measure. There are quantifiable and qualitative measures. Quantifiable measure may include things like: number of errors, time consumed in order to perform a task, number of used or not used features, time consumed for recovering from an error, ... and so on. Tasks should be collected and described in a list during the planning phase [Rubin and Chisnell, 2008, pp.79]. A well documented task consists of four components:

Task-Description: A one line description that tells the test participant what to do.

State: A list of materials and tools listed that are needed in order to perform the task. Also in which state the system should be, before the task starts.

Success criteria: The criteria for a successful completion of the task.

Benchmark: Additional measurements, e.g., time.

Other things that should be considered during the planning phase are, what materials are needed and where the test will take place. A detailed schedule can help with time management.

The questions about planning details lead us to the question of how a typical usability test should look like. Before actually testing users running a pilot session is highly recommended, since it prevents errors during the real test. When conducting a usability test the researcher should first prepare the room, make sure all the materials needed are on their place, the camera (if one is used) is working, and everything is set up. Then s/he should introduce participants to the test, meaning that he should tell them what the test is about and inform them about the procedure. It is also important to stress that not the user is evaluated, but the usability of the system. If background interviews have not been done before, after the introduction would be a good opportunity to do so. During the actual test researchers should be reserved and try not to influence participants by gestures or comments. Helping a user should also be avoided, unless the situation is stuck. In this case it should be documented that and how a participant received help. After the test there may be a debriefing phase where questions can be asked to collect qualitative data. This is also a good opportunity to follow up on problems that occurred during the test [Rubin and Chisnell, 2008, p.78].

An important technique that was used in usability tests presented in this thesis is *thinking aloud*. Thinking aloud is a usability technique, where user are encouraged to verbalize what they are thinking while using the system. This helps researchers to identify misconceptions [Nielsen, 1993] and also gives an insight about how they approach tasks, and what mental models they use. Thinking aloud provides the researcher with lots of additional qualitative data. The only downside is that it might interfere with performance measures like timekeeping. Not every test participant may be good at talking about what they think. Researchers should explain the method in detail before the test. Rubin and Chisnell add that users always filter their thoughts to some extent [Rubin and Chisnell, 2008, p.54]. This is not a serious problem, but one should be aware that encouraging people to speak about their thoughts, does not mean that their whole process of thinking will be revealed.

Although Nielsen [Nielsen, 1993, p.203] states that there is often no need to record a video of the usability test, since the major problems will be found during the test session, it would have been impractical for me not to have videos, because I was the only researcher. When conducting a test alone, there is simply no time to note all the issues and remarks. Having video is also an advantage, if one wants to compare how different test participants performed at a specific task. If a usability problem is identified during a test, researchers can review tapes of other users, where this problem did not occur, and investigate the reason for it. Often additional to filming the user, capturing the screen might be helpful. This has not been done in this research project, since most of the interaction took places on a physical prototype.

Some researches suggest usage studies to have more quantifiable data about usage [Hornbæk, 2006]. This can be done by automatically counting user actions, such as clicks or actions that were performed. The idea behind it, is to get deeper insight about how the system is actually used.

3.5 About Personas

Personas are models of users. Like other models they depict a simplified version of the real world. Personas can help with organizing information one has gathered about potential users. Cooper stresses that designer who want to create a product for a broad audience should rather design it for specific types of users [Cooper et al., 2007]. Trying to satisfy the needs of every user, usually leads to a complex system overloaded with features. Many users have conflicting ideas of what the product should look like, therefore wanting to satisfy everyone might lead to low satisfaction in all users. There is a lot, one can do with personas. First they are a great communication medium [Adlin and Pruitt, 2010]. They can be used in meetings with stakeholders and also when talking to developers. Here they can help to focus on design decisions that really reflect the target audience. Developers tend to bend the user to whatever is suitable for justifying their decisions. This leads to a phenomenon called the elastic user. In user centered design not the user should be stretchable but the product. Personas help to prevent this issue [Cooper, 1999]. Also personas can help during the design stage to focus on the target groups. That will help improving the user experience [Adlin and Pruitt, 2010]. They can also be helpful for checking and prioritizing features and functions. By asking “Will ’persona X’ use this feature”, one can help eliminate unnecessary features and focusing on those that really matter. One can also use them for evaluation. Personas are helpful in the process of creating tasks and scenarios in usability test. By understanding what the core functions of a product are one can put more emphasis on those. Personas can also be used to perform a quick user test [Cooper et al., 2007]. One of the things I used personas for in this project was to group test users, since each persona represents a group of users with similar characteristics. There are a few qualities personas should have. They must appear realistic and should have motivations and goals. Cooper distinguishes between three types of goals [Cooper et al., 2007]:

Experience goals: Describe how a person wants to feel.

End goals: Describe what a person wants to do.

Life goals: Describe who a person wants to be.

Cooper further suggests to pick one persona for every interface as primary persona [Cooper et al., 2007, pp.104]. This is the persona one should try to make happy, since it represents the target audience best. Having only one persona for every interface makes design decisions easier, especially in situations where personas have conflicting goals about a feature. In addition to a primary persona there can be up to four secondary personas. The problem with having more secondary personas is that results can get unfocused. A secondary persona can usually live with using a product that was the designed for the primary user, but has some additional needs that are not represented in the primary user. Sometimes it can be helpful to create a negative persona, to communicate what kind of people a product is not made for. In some cases it can be helpful to create personas that do not represent users, but other people who are related to the product. Such a non-user can be someone who is involved in purchase decisions of the software. An important thing to add about working with personas is that the whole project team needs to accept them in order to be useful [Blomquist and Arvola, 2002].

Although its is better to create personas based on empirical data, there are some cases where so called data-driven personas can not be created. An alternative would be to create ad-hoc personas based on assumptions. Adlin and Pruitt say that assumptions always exist and ad-hoc personas help articulate them [Adlin and Pruitt, 2010]. Pruitt and Grudin also say that creating personas has helped them making their assumptions about the target audience more explicit. [Pruitt and Grudin, 2003].

Since there is no historical company data and no information about existing customers in a research project like this plus there is also no similar device to the context aware music player on the market, it was almost impossible to create personas purely based on data. Although I tried to get information about the current music market [eMarketer, 2013, NPD-Group, 2013], I had to fill in some gaps based on assumptions, experience, and observations in my social environment. The following chapter will give a brief description of the created personas.

CHAPTER 4

Personas

4.1 Context of use

Before discussing personas, I want to give a brief description of the context of use. The context aware music player is a product that is intended to be used for listening to music in the background. It is also intended to be used in a room. Although one can carry it between rooms, it is not for mobile usage on the go. The term background music indicates that it is not built for actively exploring and browsing through music catalogues. As stated in the introduction one reason to use such a player is to delegate the work of creating playlists to an automatic system. Also the system is designed to be used as an USB-device for a computer.

Some restrictions about users can be derived from this. People who would be interested in using such a player:

- (at least sometimes) enjoy listening to music
- listen to music, while they are doing something else
- own and use a computer.

4.2 Max the enthusiast

Age: 24

Priority: Primary user of advanced settings. Secondary user of the tangible user interface.

Quote: "My friends say that I'm a gadget geek. I guess they are right! I love to buy new technology devices!"

Meet Max: Max is 24 and works as a software developer. He is fascinated by technology and loves to buy the latest gadgets. As a fan of science fiction, he likes things that look

Figure 4.1: Max at home.

[Brady, 2010]

futuristic. Max is not only a tech- but also a music enthusiast. He has a well-developed taste of music and uses a high-end sound system that is connected to his media PC in the living room. He listens to music while working on software projects and while using his stationary bicycle. Sometimes it is hard for him to get up in the morning. In this case, he listens to energetic music. Max also uses music to motivate himself. When he buys a new gadget, the first thing he is doing is trying out all functions and settings. Exploring new things in a playful way is part of the fun for him.

Abilities, skills, knowledge: Advanced tech- and computer knowledge: as a software developer and tech-enthusiast he is not only a experienced user, but also designer of technological devices himself. Advanced domain knowledge: Max knows the difference between free jazz, fusion, and progressive rock. Music has always been an important part of his life.

Goals:

- I want to be astonished by technology!
- I want to try out every function and setting on a new device.
- I like things that look futuristic.
- I want to listen to music that fits my current situation and mood.
- I want something that helps me beat my tiredness in the morning.
- I want to listen to my favorite music genre

Max's Questions:

- What will music players in the future look like?
- What exciting new features will music players get next?
- Who can help me beating my tiredness in the morning?

4.3 Nina the casual music listener

Figure 4.2: Nina at work.

[nan Ealan, 2007]

Age: 31

Priority: Primary user; Nina is exactly who we want to help with our main feature. If we don't make Nina happy, we have failed.

Quote: "When I am reading I like to listen to music in the background, but I hate creating playlists!"

Meet Nina: Nina is 31 years old. She currently works as an assistant for a large insurance company. She is not very happy with her stressful job. When she was younger she always wanted to work in the creative industry. When Nina comes home after work, she likes to relax while listening to music and checking her facebook. In her spare time she loves to read books. Sometimes she creates music playlists on her computer and listens to them in the background while she is reading a book or a magazine. It often takes her 30 minutes to select songs that fit her current mood. She is also a very indecisive person and hates too much choice. Sometimes she even gets stuck on her computer after creating playlists, which annoys her, because what she really wanted to do in the first place was to read a book.

Abilities, skills, knowledge: Average tech- and computer knowledge: she uses her computer for her daily work (e-mail, office), for media (music, video), social networks, and games. Low domain knowledge: she enjoys listening to music but is not familiar with detailed genre names or musical terms. Nina has a color vision deficiency (red/green).

Goals:

- I want a less stressful life.
- I want to spend my spare time on things I really like.
- I want to be able to skip songs on the radio.
- I want to be able to make decisions more quickly.
- I want to take things out of the box and use them, without reading a manual.
- I want to listen to music in the background.
- I want to listen to music that fits my mood.

Nina's Questions:

- Where can I find good music for reading?
- Why can't iTunes just know what I want to listen to?

4.4 Franz the retired music-lover

Figure 4.3: Franz

[Lowry, 2004]

Age: 60

Priority: secondary

Quote: “When I was young we had to go to the records store to buy vinyls. Today people have so much more options. If only they were more accessible.’

Meet Franz: Franz is 60 years old and worked most of his life as a clerk. Six month ago he retired. Now he has more time to spend on his hobby: music. He plays guitar and has a huge collection of old vinyls. He is also curious about discovering new music on the internet. Unfortunately he does not enjoy using PCs, because he thinks that most software is difficult to use. During his daily routine he always listens to music in the background: while he is cooking, reading a newspaper, etc. He likes to listen to webradios, but has not found webradio-software he really enjoys to use. Without his reading glasses he is not able to read small text on a computer screen.

Abilities, skills, knowledge: Low tech- and computer knowledge: he knows how to send e-mails and surf the web, but needs assistance for more difficult tasks. High domain knowledge: Franz knows how to read sheet music and is familiar with most of the terms and genre names. He is hyperopic and usually need to wear reading glasses when he uses a computer.

Goals:

- I want to discover new music.
- I want to control music software without wearing my reading glasses.
- I want music software that is easy to use.
- I want to listen to music that fits my current mood.

Franz’s Questions:

- Why can’t music software be as simple as my old radio?
- Where can I find good music?

CHAPTER 5

Prototype Developement

This chapter provides insights into various parts of the prototype. Section 5.1 gives an overview of the hardware development, from industrial design decisions to the used components. Section 5.2 shows how the user interface progressed over time and what it looks like at the end of this project. Sections 5.3-5.5 provide deeper insight into the software. Section 5.3 gives a brief introduction to the software-architecture. Section 5.4 shows how sensor- and other context data is mapped to characteristic-tags. Finally 5.5 shows how the algorithm decides which music it selects at a given situational context.

5.1 Hardware

The Arduino platform was the ideal choice for this project, because one can have first usable results very quickly. After a little research it was clear that the SeedStudio NFC-Shield with a range of approximately 1cm would be a good solution for identifying cubes, because it wouldn't accidentally read other cubes close to it. The 13.46 Mhz self adhesive Mirfare tags used for this project have a diameter of 3cm. Given this constraint, it was clear that the minimum size of a cube had to be 3cm. After experimenting with different sizes, I felt that adding another 1cm to the cube's dimension made it feel better in the hand. Also the readability of the symbols was enhanced because of that, which is good for our persona Franz. The resulting 4x4x4cm cube can be seen in Figure 5.1.

All of the electronics need to be protected from damage and should also be hidden from the users. Since simplicity does not negatively affect expressivity of interfaces [Chang et al., 2007], I wanted to keep the casing as simple as possible, honest, and understandable. The first draft of the housing was just a white box. After playing around with it, it was clear to me that there might be some confusion about where to place a cube exactly. One early attempt to fix that was to mark the spot with an half open frame as shown in Figure 5.2. Also this approach did not feel right. I wanted to create a system with an obvious affordance. This is why I used the metaphor of a shape sorter, a common wooden toy for children that almost everyone knows how to use.

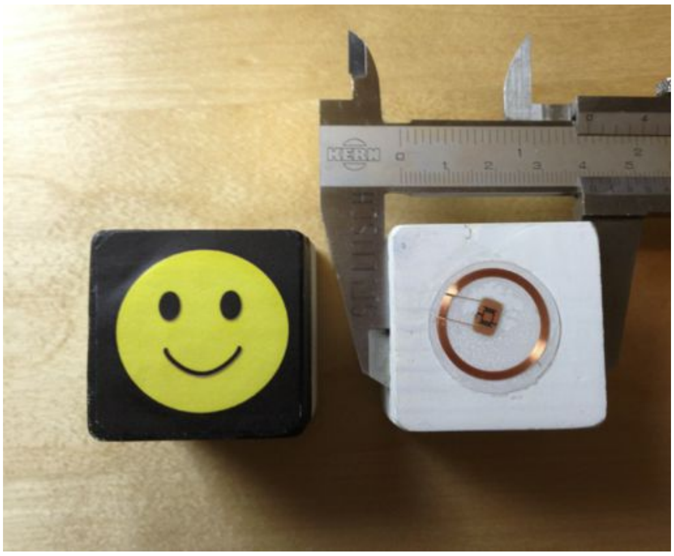

Figure 5.1: Dimensions of a cube

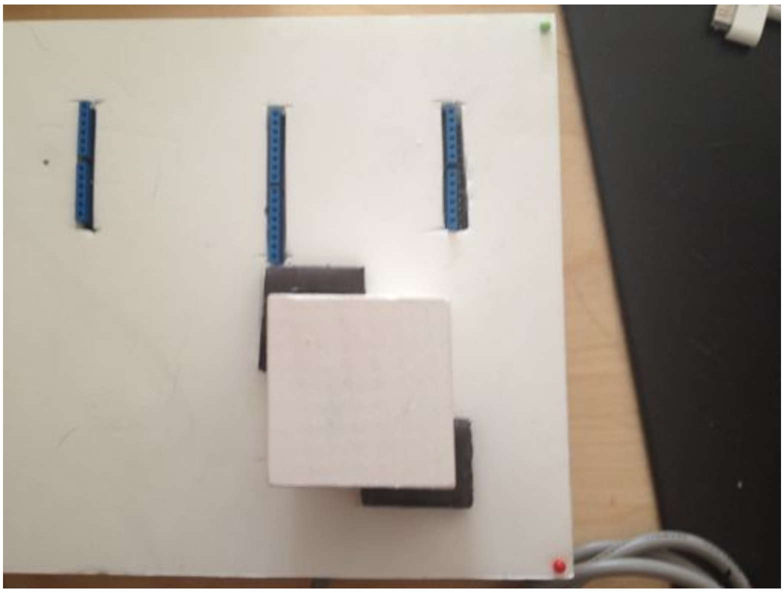

Figure 5.2: Early version of the prototype without indentation

To achieve this I made two cavities that match the dimensions of a cube in the middle of the housing. By doing this I limit the movement as discussed in token+constraint interfaces [Ullmer et al., 2005]. I also decided to derive the shape and dimension of the housing from the cube. The final device has a size of 5x5 cubes and the cavities are placed exactly in line with the third cube (see Figure 5.3).

Figure 5.3: Dimensions of the USB-device compared to a cube

The depth of a cavity is half the height a cube. The reason for this is that mood-cubes are half black and half white. The white side represents the mood the user is currently in, while the black side stands for a mood the user wants to be in. When a cube is placed inside the cavity, only one of the two colors can be seen. Figure 5.4 shows a cube placed with its black side on top.

After the usability test I also created a case for the cubes, so that they can be easily carried around. The case, which was made out of foam can seen in Figure 5.5.

Inside the housing there are two Arduino Uno microcontrollers with two SeedStudio NFC-shields, one on each Arduino Uno. As you can see in 5.6 one of the shields has additional components connected to it. There is a photoresistor connected via an appropriate pre-resistor connected to an analog input pin of the Arduino. A button and a green LED are connected to digital pins of the Arduino. The LED is used to indicate that the device is plugged in and ready to use. It is dimmed via pulse width modulation in order to give it a pulsing look. During the development one problem with the NFC-Shield occurred. The original drivers provided by SeedStudio tried to reconnect to a tag, once it was removed. This caused a delay, before the NFC-Shield could report that no tag was placed. Since a delay would impair the user experience I had to rewrite that part of the driver. Another challenge was to create cubes that can be easily

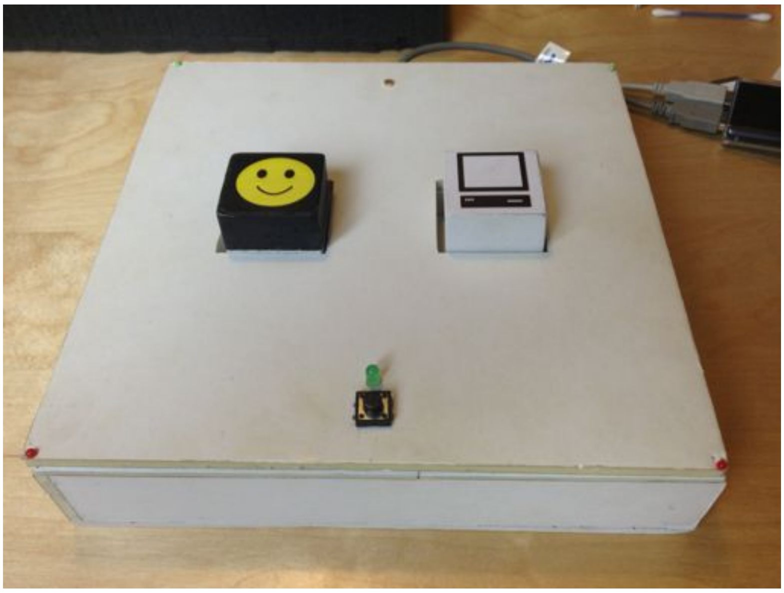

Figure 5.4: Final prototype

Figure 5.5: Foam Case with activity and mood cubes

identified by the user. Since there were no coherent symbols for moods and activities I wanted to depict available, I had to design them on my own. With the the mood-cubes I tried to follow the design of common emoticons. I colored them to intensify their impression. Colors were chosen according to their meaning in western culture. For the black version of the symbols, some colors in the tired and energetic symbol needed to be changed (see Figure 5.7). Activity symbols were designed with a flat line-design approach. They are mainly black and white to

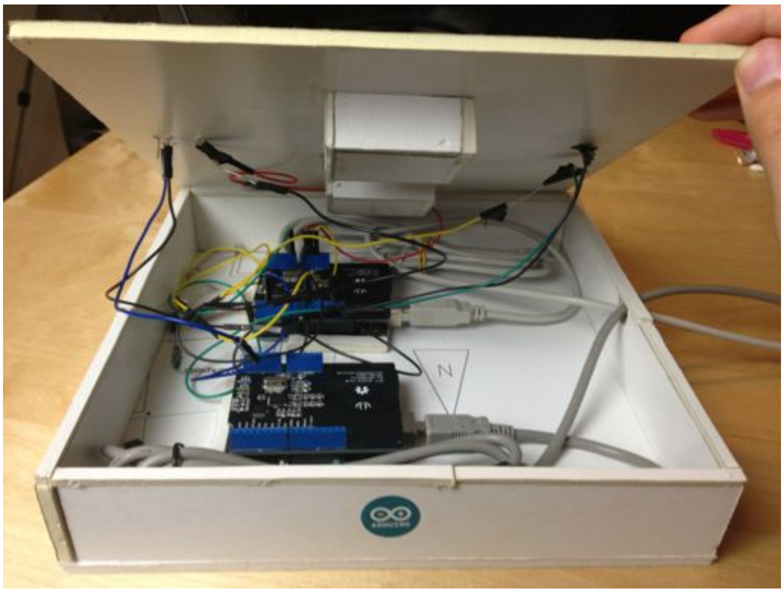

Figure 5.6: A look inside the final prototype

make them distinguishable from moods. The resulting activity symbols can be seen in Figure 5.8.

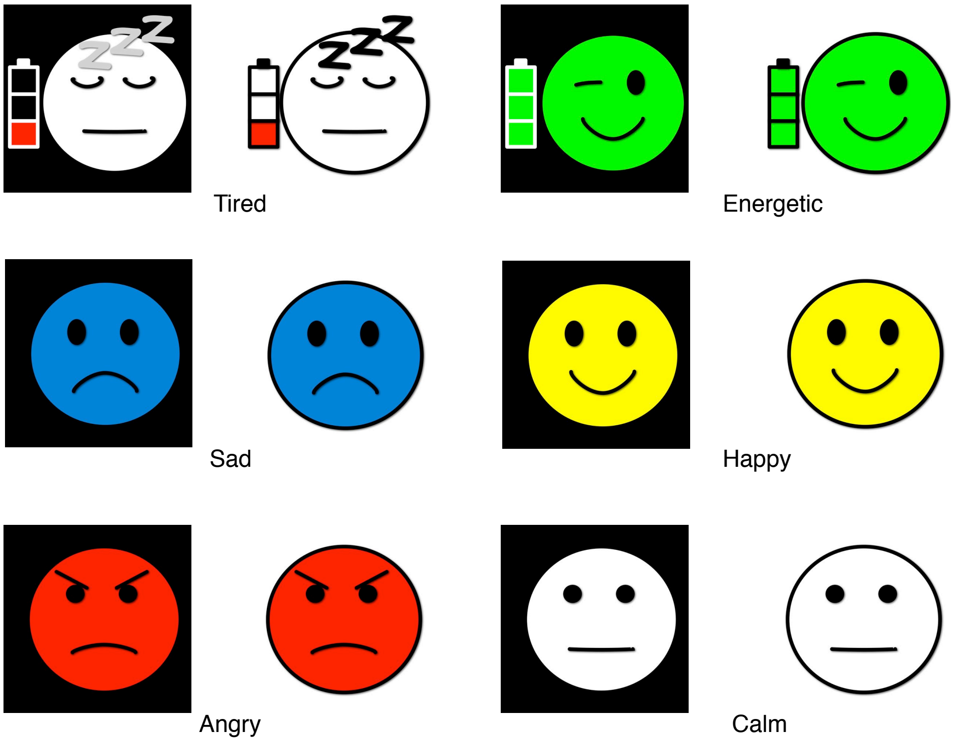

Figure 5.7: Mood symbols

Figure 5.8: Activity symbols

5.2 User Interface

Apart from the USB-device there is also some interaction on the computer. The idea is that once users have configured and customized the system via the graphical user interface, they don't need to touch the computer again, until they want to refine their adjustments. This means that the main function of the GUI is to provide access to configuration of radio stations. Figure 5.9 shows an early sketch of the former main interface. Names and genres of radio-stations can

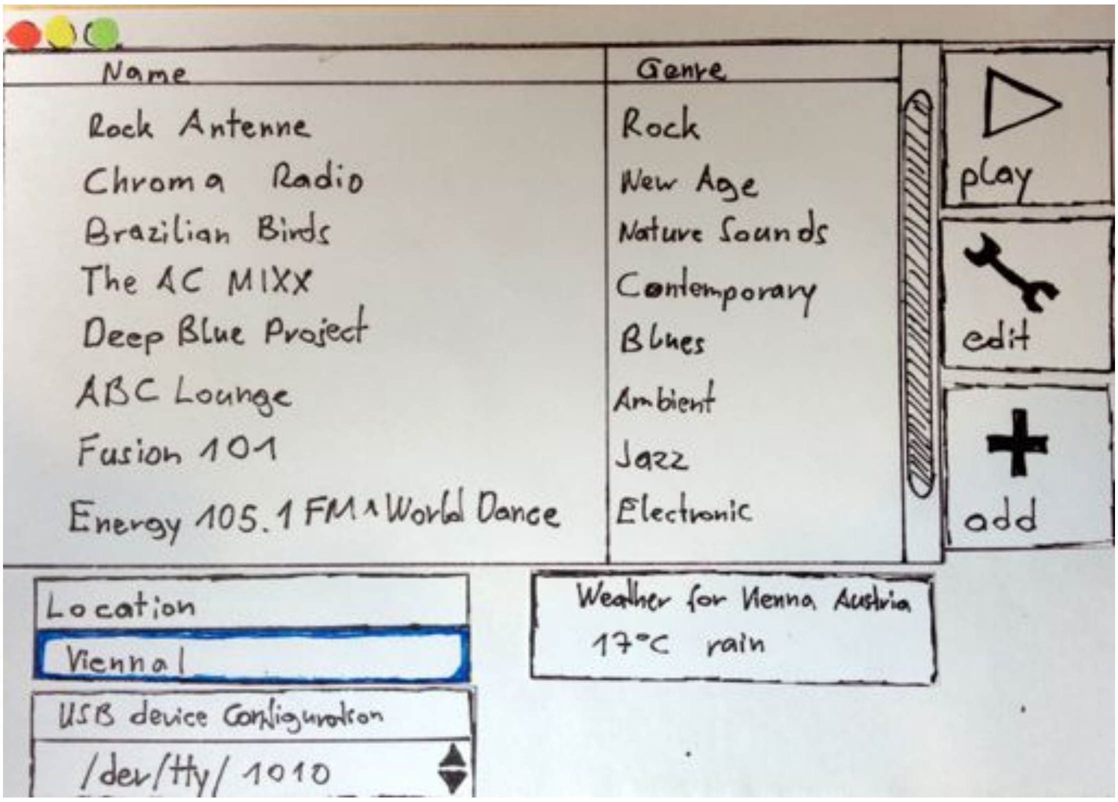

Figure 5.9: Sketch of the user interface

be viewed in a scrollable list. Users can preview radio-stations by selecting them and clicking the play-button. The same way they can also edit them, by clicking on the edit-button. Users can also add new radio-stations. When the edit- or add-button is pressed a window showing the radio-station configuration is opened. While add opens the windows with empty fields, edit loads the existing setting. An example for the channel ABC-Lounge can be seen in Figure 5.10 Name, genre and URI can be filled in by a user. By clicking on a characteristic, the tag gets highlighted. When the window is closed, changes get auto-saved.

In the final user interface I added another window that shows information about the current music that is placed, and also what information the system uses for the current situation. Figure 5.11 shows this interface. When information about the current situation matches the radio-station that is currently playing, the text gets highlighted green. This should help users to reconfigure

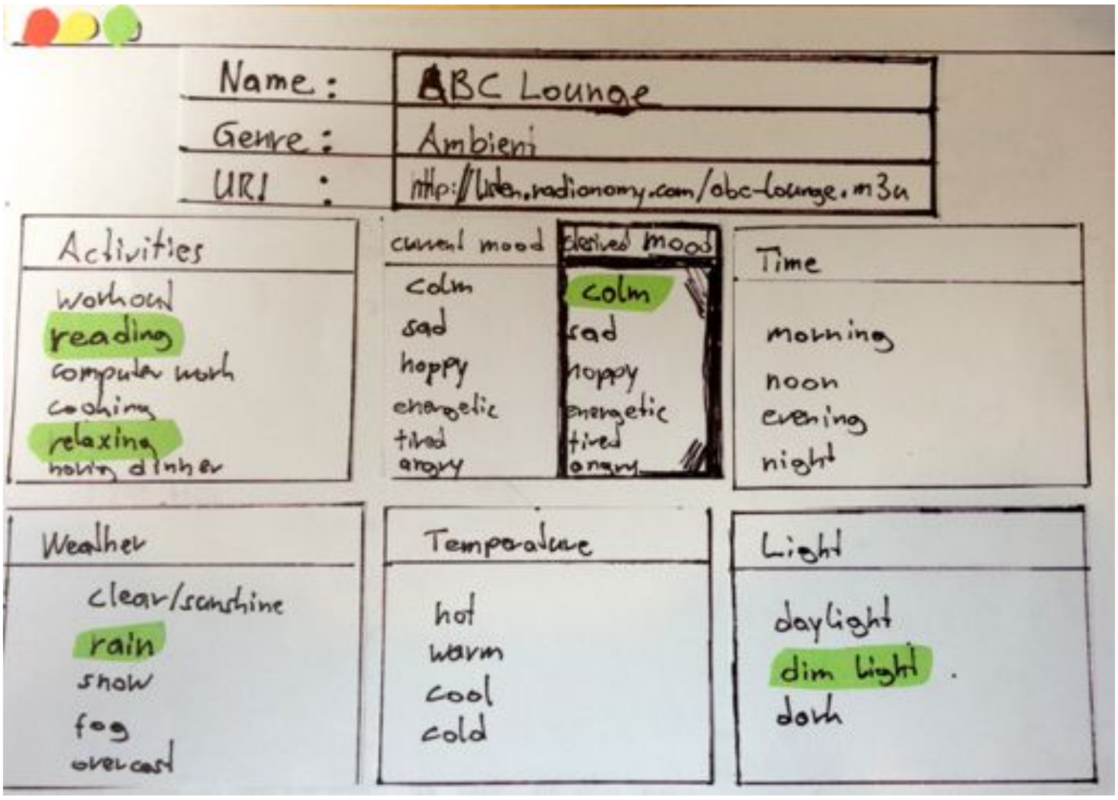

Figure 5.10: Sketch of the user interface

Figure 5.11: Screenshot of the main interface

radio-stations when they find them inappropriate. From this main interface users can get to a weighting interface (Figure 5.12) where they can change the importance for categories like activities, moods, weather, temperature, light, and time. When the cogwheel-button is pressed,

Figure 5.12: Screenshot showing the weighting interface

a list with radio stations gets displayed. When you look at Figure 5.13, you will notice some changes compared to the sketch. A delete-button is now included and some of the settings, like location, and serial-port settings are not available anymore. All of those settings are now set automatically. Location is determined via the IP-address of the internet connection and the used serial port is now also detected by the software itself. Port detection has only been implemented for OS X systems for this prototype.

The radio station configuration interface has only been changed slightly in the final version. As shown in Figure 5.14 categories are now lined up. After testing both alignments, this way appeared more clear at first glance.

Figure 5.13: Screenshot showing the radiostation list

Figure 5.14: Screenshot of the radiostation configuration interface

5.3 Architecture

The application is distributed over two devices, a computer running Mac OS X, and a USB-Device. The USB-Device is powered by two Arduino Uno microcontrollers, equipped with Seed Studio NFC-shields. One of them also handles input from a physical button (the skip-button), a light sensor and a status LED. The two microcontrollers collect all the data from the sensors and transfer them via serial communication to the Mac. The Mac runs a Java application with a 4-tier architecture (c.f. Figure 5.15). A persistence tier that is responsible for accessing configuration files, an access tier that handles the serial communication with the microcontrollers as well as the communication with the web-service [Wunderground, 2013] that provides weather data. In the logic tier the rating described in 5.4 takes place. Also the Player Handler, which synchronizes all kinds of play- and next-commands and triggers audio-playback can be found in this tier. Finally the top level is the presentation tier that includes all the user interfaces. When you look at the architecture from the perspective presented by Schmidt [Schmidt et al., 1998], there is one layer missing. Sensor data is passed by the Arduino to the access tier, where it is transformed into cues. The logic tier operates directly with cues, since there is a very huge amount of possible situations that cannot be narrowed down to a handful of predefined context situations.

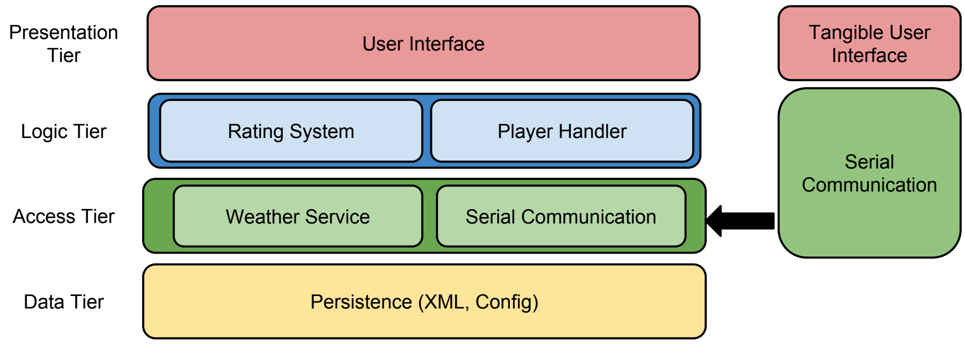

Figure 5.15: 4-tier architecture of the software

5.4 Interaction

The context aware music player consists of an USB-device, software on a computer and a bunch of cubes. Figure 6.6 shows the setup of the system. Cubes can be subdivided into mood-cubes and activity cubes. Activity cubes represent what the user is currently doing, while he listens to music in the background. Activity cubes have only one side and are white with a black symbol on them. Mood cubes on the other hand have two sides, a black and a white one. The color separation is illustrated in Figure 5.16. The white side of a cube represents the mood the user is currently in. Since research suggests that music can induce feelings in human beings [Hallam, 2008] and many people use music, to transition from one emotional state into another, there needed to be an expression for the desired mood. The black side of the cube represents exactly that. Once the system is customized to needs of a user, only the USB-device is relevant for the interaction. On this device, a user can perform the following actions shown in Figure 5.17. On the top of the figure you can see a user placing a mood cube on the desired mood side. An input of a cube will always result in a change of music. In the middle, a user placing current mood cube is depicted. The bottom picture shows the use of the skip-button, a physical button that allows a user to change to the next radio station in the priority list. Also in this picture a second cube (an activity cube) is placed. Users may put no cubes, one cube, or two cubes on the device and may freely combine any kind of cubes. This includes two mood cubes or two activity cubes.

Research showed that music attributes like intensity, mode, pitch, rhythm, tempo, and texture influence our emotional state [Webster and Weir, 2005]. One would think that people choose music that is linked to a certain influence in scientific literature. For example up tempo music sounds like an obvious choice for workout. But a 2012 survey shows that most college students prefer Hip Hop music when they exercise [Barney et al., 2012]. This is interesting because

Hip-Hop typically is rather slow in tempo. Given these facts it is clear that a user centered music system, must have ways to let users decide what kind of music they like to listen to in certain situations. This led to the design decision of having configurations for radio-stations. To do so, a user must use the computer that is connected with the USB-device. In the main interface shown in Figure 5.11, s/he must click the cogwheel symbol. This leads to the list of radio stations in Figure 5.13. Here the user may select one of the radio stations and preview them, delete them, or edit them. Adding another radio station or editing an existing one leads to the configuration interface in Figure 5.14 . By clicking on tags a user can add or remove characteristics and thereby customize radio stations. Also accessible from the main interface is the weighting interface (via scales symbol). Here users may change their preference for the importance of different categories. Rating a category high, will make it more important for the algorithm during the music selection.

Figure 5.16: Photo illustrating black and white side of mood-cubes

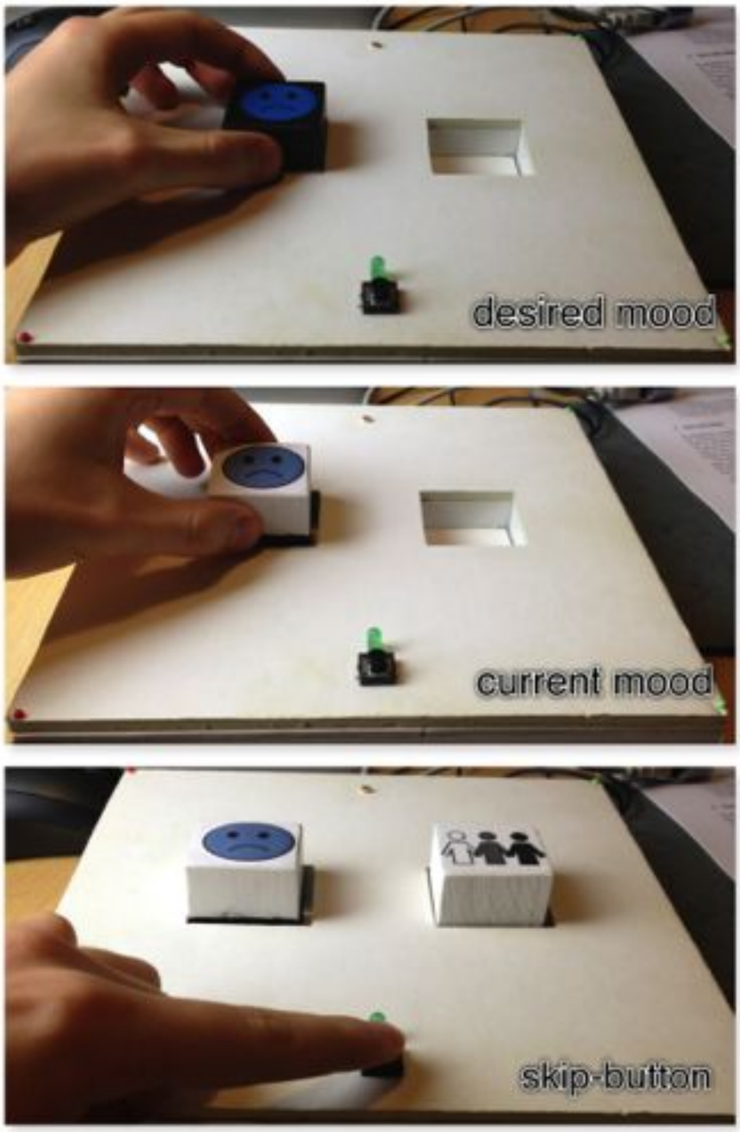

Figure 5.17: Interaction

5.5 Data Binning

Since context- and sensor data is way to comprehensive to be assigned to radio stations by a user, they needed to be narrowed down to a manageable number of characteristic-tags. This procedure is described by Schmidt in the Cue-Layer [Schmidt et al., 1998]. Weather Underground provides a list of nearly a hundred possible weather conditions. Most of them differ only slightly from each other. This is why I decided to group them using the basic categories: clear, rain, snow, fog, overcast, and unclassified. The unclassified category consists of very unlikely weather events, like volcanic ash and sandstorms where people won't necessarily think about having a soundtrack to such events. This is why this category can not be configured by users and is treated by the algorithm as if no condition can be determined. The following list shows the segmentation of weather conditions:

clear: Clear

rain: [Light/Heavy] Drizzle, [Light/Heavy] Rain, [Light/Heavy] Hail, [Light/Heavy] Rain Mist, [Light/Heavy] Rain Showers, [Light/Heavy] Thunderstorms and Rain, [Light/Heavy] Thunderstorms with Hail, [Light/Heavy] Thunderstorms with Small Hail, Small Hail, [Light/Heavy] Hail Showers, [Light/Heavy] Freezing Drizzle, [Light/Heavy] Freezing Rain

snow: [Light/Heavy] Snow, [Light/Heavy] Snow Grains, [Light/Heavy] Ice Crystals, [Light/Heavy] Ice Pellets, [Light/Heavy] Blowing Snow. [Light/Heavy] Snow Showers, [Light/Heavy] Snow Blowing Snow Mist, [Light/Heavy] Ice Pellet Showers [Light/Heavy] Thunderstorms and Snow, [Light/Heavy] Thunderstorms and Ice Pellets

fog: [Light/Heavy] Mist, [Light/Heavy] Fog, [Light/Heavy] Fog Patches, [Light/Heavy] Haze, [Light/Heavy] Spray, [Light/Heavy] Freezing Fog, Patches of Fog, Shallow Fog, Partial Fog

overcast: Overcast, Partly Cloudy, Mostly Cloudy, Scattered Clouds, Funnel Cloud

unclassified: [Light/Heavy] Smoke,[Light/Heavy] Volcanic Ash, [Light/Heavy] Widespread Dust, [Light/Heavy] Sand, [Light/Heavy] Dust Whirls, [Light/Heavy] Sandstorm, [Light/Heavy] Low Drifting Snow, [Light/Heavy] Low Drifting Widespread Dust, [Light/Heavy] Low Drifting Sand, [Light/Heavy] Blowing Widespread Dust, [Light/Heavy] Blowing Sand, [Light/Heavy] Small Hail Showers, [Light/Heavy] Thunderstorm, Squals, Unknown Precipitation, Unknown

Since temperature is measured in real number they need to be binned in intervals. This is how the binning of temperatures looks like:

temperature

- hot: $t > 30$ degrees Celsius
- warm: 17 degrees Celsius $< t \leq 30$ degrees Celsius
- cool: 0 degrees Celsius $< t \leq 17$ degrees Celsius
- cold: $t < 0$ degrees Celsius

Like temperature data also time was divided in intervals:

time

- night: 22:00-03:59

- morning: 04:00-10:59
- noon: 11:00-14:59
- evening:15:00-21:59

The light sensor returns an integer value as description of the lighting conditions. The change of the integer value has been observed and tested in various lighting conditions and was then subdivided in three characterstics:

light (sensor data)

- daylight: s <300
- dim light: $300 \leq$ s <800
- dark: s $\geq$ 800

5.6 Business Logic

Music is selected from a priority list, which is ranked by a calculated score. The initial idea was to create an evaluation function that would rate radio stations with more matching characteristics higher than others. But there are some obvious problems with just counting matching characteristics. First a radio station that is tagged with all characteristics, would always be the number one choice and therefore get the same score as an radio station that has just the exact configuration as the actual real world situation. For example, if it is raining outside and radio station A is tagged with rain, clear, cloudy it would have the same score as radio station B tagged with rain, although radio station B should clearly be ranked better than A, because it is specifically configured for rainy weather. This is the reason why I designed the evaluation function so that non matching characteristics will be subtracted from the total score. Since the exact value that should be subtracted for every non-matching characteristic is arguable I decided to introduce two variables, a reward factor with a preconfigured value of 5, as well as a penalty factor, with a preconfigured value of 1, which can be changed by experienced users such as the persona Max, who likes to tweak systems to get the most out of them. The second problem is that not every category is equally important for every user. This assumption was also confirmed by the test participants during the interviews of the usability tests. This is why I introduced weighting factors for every category (see Table) 5.2. The factors can be altered by users in a graphical user interface seen in Figure 5.12. Since all asked users said that categories that they can actively change, such as mood and activity are more important to them, I assigned a much higher default value to those categories, see Table 5.1. The final score is the sum of all category-scores (5.1).

$$rating_x = \sum_{n=1}^{7} WF_n * (NMC_{x,n} * rf - (TNC_{x,n} - NMC_{x,n}) * pf) \qquad (5.1)$$

Radio: Blues FM

Activities	current mood	desired mood	time	weather	temperature	light
workout	**sad**	sad	morning	clear	hot	daylight
reading	happy	happy	noon	**rain**	warm	**dim light**
computer work	energetic	energetic	**evening**	snow	cool	dark
cooking	**tired**	tired	night	**fog**	cold	
relaxing	angry	angry		overcast		
having dinner	**calm**	**calm**				
physical work						
social gathering						
custom activity						

Radio: Heavy Metal Nation

Activities	current mood	desired mood	time	weather	temperature	light
workout	sad	sad	morning	clear	hot	daylight
reading	happy	happy	noon	rain	warm	dim light
computer work	energetic	**energetic**	**evening**	snow	**cool**	dark
cooking	**tired**	tired	night	fog	**cold**	
relaxing	angry	angry		overcast		
having dinner	**calm**	calm				
physical work						
social gathering						
custom activity						

Figure 5.18: Example

Symbol	Name	Value
WF_1	activity factor	10
WF_2	current mood factor	10
WF_3	desired mood factor	10
WF_4	weather factor	5
WF_5	light factor	2
WF_6	temperature factor	2
WF_7	time factor	2

Table 5.1: Weighting-factor (WF)

Symbol	Name	Value
rf	reward factor	5
pf	penalty factor	1

Table 5.2: Constants

Sym.	Explanation	Sym.	Explanation
$NMC_{x,1}$	number of activity matches with radiostation x	$TNC_{x,1}$	total number of characteristics in activity
$NMC_{x,2}$	number of c. mood matches with radiostation x	$TNC_{x,2}$	total number of characteristics in c. mood
$NMC_{x,3}$	number of d. mood matches with radiostation x	$TNC_{x,3}$	total number of characteristics in d. mood
$NMC_{x,4}$	number of weather matches with radiostation x	$TNC_{x,4}$	total number of characteristics in weather
$NMC_{x,5}$	number of light matches with radiostation x	$TNC_{x,5}$	total number of characteristics in light
$NMC_{x,6}$	number of temperature matches with radiostation x	$TNC_{x,6}$	total number of characteristics in temperature
$NMC_{x,7}$	number of time matches with radiostation x	$TNC_{x,7}$	total number of characteristics in time

Table 5.3: Number of matches in category (NMC), Total number of characteristics in category on this radiostation (TNC)

Current Situation:

- Cube 1: NFC-tag: 0x01201201201 ⇒ activity: reading
- Cube 2: NFC-tag: 0x06201201223 ⇒ current mood: sad
- time: 19:05 ⇒ evening
- weather: heavy rain ⇒ rain
- temperature: 9 degrees Celsius ⇒ cool
- light -> 85 ⇒ dim light

Radio Blues FM: 10*(1*5-1*1)+10*(1*5-2*1)+10*(0*5-1*1)+5*(1*5-1*1)+2*(1*5-0)+2*(0-0)+ 2*(1*5-0)=40+30-10+20+10+0+10=100

Radio Heavy Metal Nation: 10*(0*5-2*1)+10*(0*5-2*1)+10*(0*5-1*1)+5*(0)+2*(0)+2*(1*5-1*1)+ 2*(1*5-0)=-20-20-10+0+0+8+10= -32

Ranking:

1. Blues FM
2. Heavy Metal Nation

During the development of the evaluation-algorithm, I had the idea to collect data of early skipped radio-stations in order to extand the algorithm with a learning feature. The idea was that if a user skips a radio station within a short time span (a couple of seconds), the system could record the situation and give the radiostation a lower rating, if the next time the same situation occurs. There are multiple problems with this approach. The first one is that one can only assume that a skip means that the user does not like the music in this situation. In fact, there could be other reasons for that, e.g., there is another influencing factor that is neither modeled, nor measured in the system. Such a factor could be another person in the room, who dislikes the music, or an aversion to a specific song, not the whole playlist or radiostation. Or a user might be skipping playlists, because he wants to explore what else the system suggests. Even if we can savely assume that a skip-command can be compared to a dislike, the only reliable information we can obtain is that the radiostation does not fit this specific situation. In order to learn the preferences of the user, the system would need to collect information about the same situation multiple times. Unfortunately there are 108.240 possible situations: 2 slots for cubes in 22 possible meanings each (minus double occurences, since every cube can only be placed once, and desired- and current mood must differ), 4 time-categories, 5 weather-categories, 4 temperature-categories and 3 light settings.

$$possiblesituations = (22 * 22 - 21 - 12) * 4 * 5 * 4 * 3 = 108.240 \quad (5.2)$$

Assuming that situations will be approximately equally distributed, this means that the acquired information will be only useful after more than a hundred thousand uses. Given the above stated reasons, it is obvious that the recording and learning from skip-commands will not result in improved user-experience.

Since we want to enhance the user experience and present the best music choice, another solution that will prevent the user from skipping specific radio-channels too often, is needed. I approached this problem by making the system highly customizable and by trying to make the autonomous decisions as transparent as possible. Every radio-station has $1.37*10^{11}$ possible configurations. In every category zero, some or all tags can be assigned. This can be seen as combination without repetition for every category [Drmota et al., 2007].

$$1 + \sum_{k=1}^{n} = \frac{n!}{(n-k)! * k!} = 2^n \tag{5.3}$$

For given 37 tags this means a total number of 2^{37} = $1.37*10^{11}$ possible configurations.

CHAPTER 6

Evaluation of the Prototype

In the course of this master thesis, two usability tests have been conducted. The aim of the first test, was to evaluate the general interaction with cubes. This has been done early with a low-fi prototype in order to have the option to make drastic changes, if the results were bad. The second usability test was conducted with a working prototype (see prototype discussion in chapter 3). Section 6.1 gives a brief introduction of the test participants and why they were selected as such. Section 6.2 and 6.3 give an overview of the first and second usability test.

6.1 Test Participants

Out of a pool of volunteers six people were selected for the usability tests. The criteria for qualifying as a test participant was to have some matching characteristics with one of the three personas. For every persona two test participants were picked. Three test-users (TP1, TP2, TP3) participated in the first usability test. Six users participated in the second test. Three of them already assisted in the first (TP1, TP2, TP3) test and three new participants (TP4, TP5, TP6) were invited for the test. The reason for this was to minimize learning effects, transferred from the first test and also to have a broader scope of opinions, since the second test used a working prototype with a lot more features than the first.

Below you will find a short profile of the test participants, including their related persona.

Test participant 1 (TP1)

age: 56 years old

gender: Male

profession: Retiree

related persona: Franz

PC activities: Listening to web-radios, office, e-mail, surfing the web

Test participant 2 (TP2)

age: 25 years old

gender: Female

profession: Student

related persona: Nina

PC activities: social media, e-mail, office, listening to music,..

Test participant 3 (TP3)

age: 26 years old

gender: Male

profession: Software developer

related persona: Max

PC activities: Software development, social media, e-mail, listening to music, watching movies..

Test participant 4 (TP4)

age: 28 years old

gender: Female

profession: Secretary

related persona: Nina

PC activities: Office, listening to music, watching tv shows, games, social media

Test participant 5 (TP5)

age: 29 years old

gender: Male

profession: Draftsman

related persona: Max

PC activities: Social media, office, e-mail, surfing the web, CAD

Test participant 6 (TP6)

age: 52 years old

gender: Male

profession: Clerk

related persona: Franz

PC activities: Office, e-mail, surfing the web, Skype

6.2 First Usability Test

The first usability was conducted using a low-fi prototype of the USB-device only (see Figure 6.3). The idea was to identify problem concerning the general interaction early on in the design process.

Test procedure: First users got some information about the project, as well as the test procedure. An info-graphic (see Figure 6.1) that provided some basic information about the interface was handed to them. Then they had to solve some predefined situations (see taks below). After they completed the tasks, there was another test situation where they used the device to listen to music in the background while completing another task. In this section it will be called real world test. Since the prototype was not fully functional at the time this test took place, it was mocked using the wizard of oz method. The researcher observed inputs on the prototype and played music from a tablet computer whenever the test participant made inputs on the prototype. The tablet computer was prepared with about 20 different radiostations in playlist beforehand. After the real world test the participants were interviewed in an semi-structured interview covering the following topics:

- Were the symbols easy to identify?
- Is the info graphic sufficient?
- Did the person like using the device?
- Would the person use such a device?
- When does the person usually listen to background music (are there tasks missing)?

During the test and the interview handwritten notes were taken. There were also video and audio recordings of both interviews and tests.

Aim: The purpose of this test was to see if potential users are able to identify the symbols, how the interaction works for them and to determine whether the device is easy to use while working on something else. Design decisions were derived from encountered problems.

Metric: Relevant for evaluation were statements during the test and interviews. Also mistakes they made in the predefined situations. Also the general interaction with the device was observed and analyzed.

Test Setting: As can be seen in Figure 6.2, the test participant sat in front of a table with the USB-device on it. The researcher observed the test from the left side. Also the cubes and the info graphic was placed on the table (see Figure 6.3)

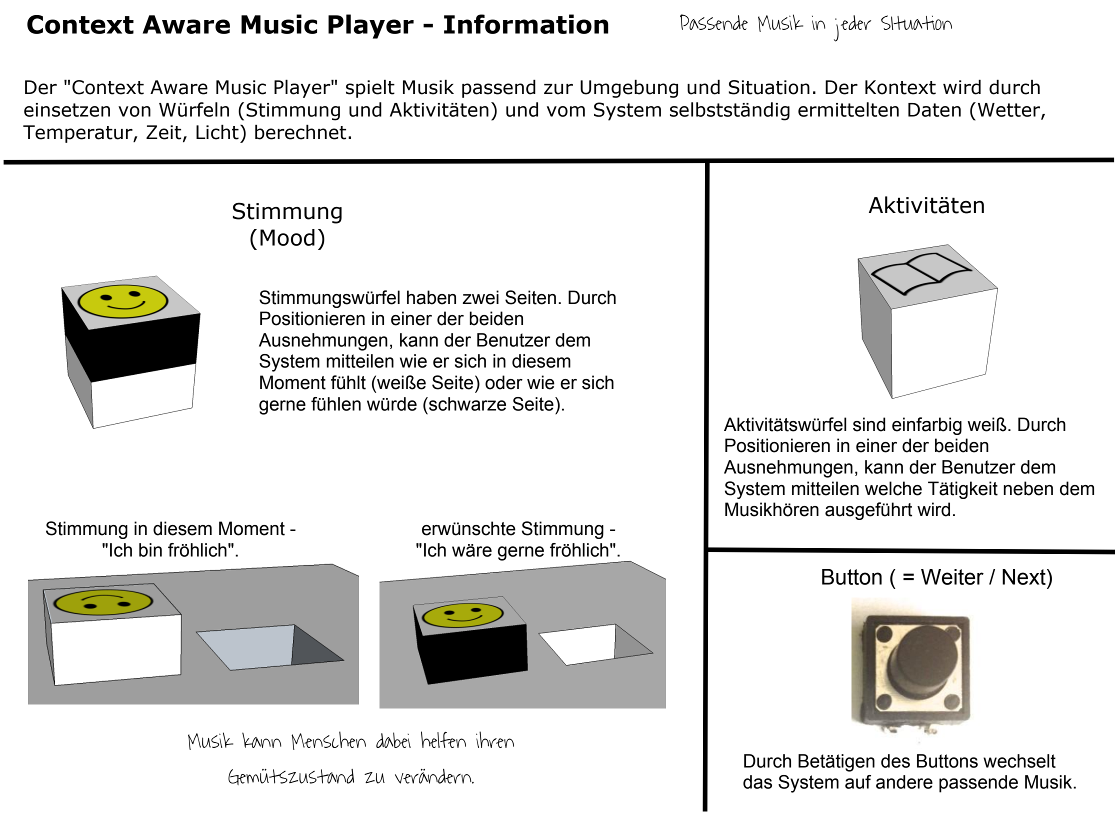

Figure 6.1: Information graphic provided to the test participants

Tasks: Predefined Situations: “Please try to express the following conditions.”

1. You are sad.
2. You are reading a book.
3. You are happy and eating dinner.
4. You want to feel happy.
5. You are tired and want to feel energetic.

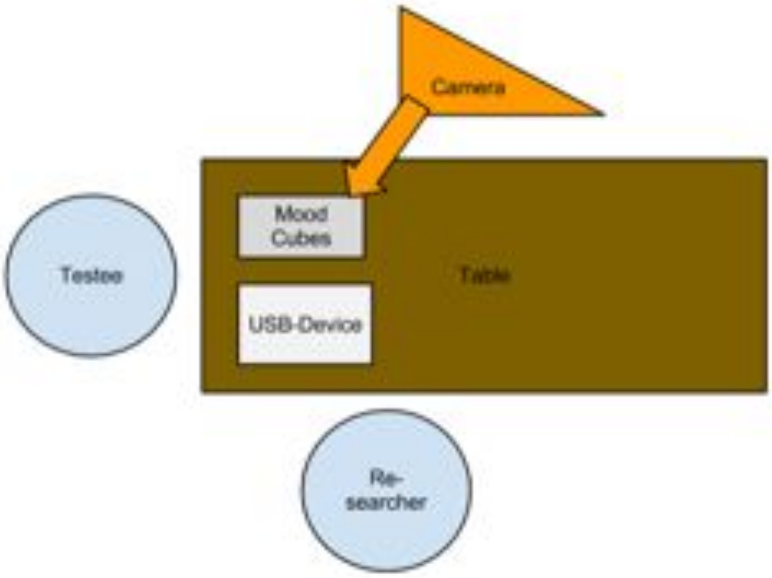

Figure 6.2: Setup of the first usability test

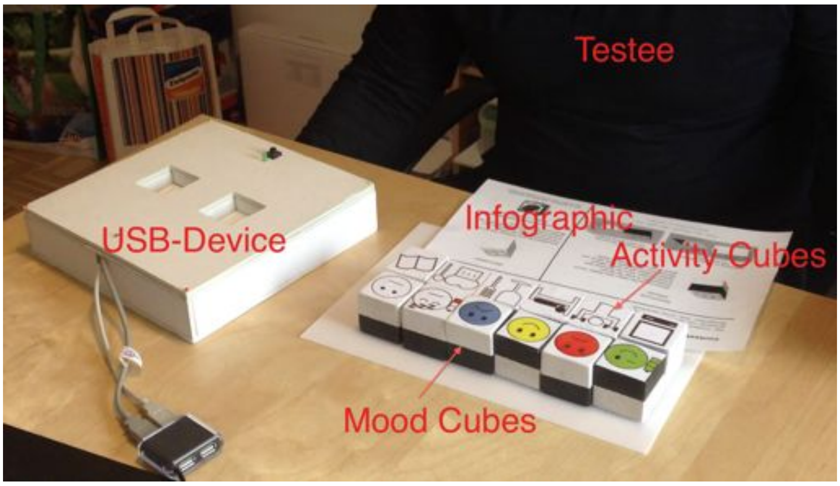

Figure 6.3: Photos of the first usability test setup

6. You are angry and want to calm down.
7. You relax and want to get tired.
8. You are working on your PC.
9. You are cooking.
10. You are working out.

A detailed description according to Rubin [Rubin and Chisnell, 2008, pp.79], also includes the parameters state, success criteria and benchmark. No benchmark was used for this test. A state and success definition can be written down in general for all ten tasks:

- Task-Description: See list above.
- State: The device is empty for the first task. Cubes and info-graphic are placed on the table (see Figure 6.3). The rest of the tasks, start with the setup of the success criteria of their predecessor.
- Success criteria: The right cubes are placed an the USB-Device. A definition of what is right can be found in Figure 5.7 and 5.8
- Benchmark: No benchmarks.

Real World Test (RW): Choose and accomplish one of three tasks while using the device (Music playback is simulated by the tester (Wizard of Oz method).

read a book: Read some pages of a book, while using the device.

relax: Sit on the sofa and try to relax, while you are using the device.

PC work: Check your E-Mails. Then find the answer to the question “Which were the first countries to join the European Union” online. Use the device at the same time.

eat Eat and drink something while using the device.

workout Do some sit-ups while using the device.

cooking Cut an onion or green pepper while using the device.

Person/Task	1	2	3	4	5	6	7	8	9	10	RW
1	✓	∼	X	✓	X	✓	✓	✓	✓	✓	✓
2	✓	∼	✓	✓	∼	✓	✓	✓	✓	✓	✓
3	X	✓	✓	✓	X	✓	✓	✓	✓	✓	✓

Table 6.1: Test outcome divided by task

✓: completed without errors

∼ : minor error while completing task

X : unable to complete task without help

Participant 1 TP1 left the sad-cube inside the device after completing the first task. First it was unclear whether this happened because of the imprecise wording of the task-description, or a lack of understanding how the interface works. The participant remarked that he was not sure, if he should remove the cube first, because the instruction did not explicitly say that. Setting the system back to its origin after every task, would have been a better option for the conduction of the test. In Task 3 he confused the black with the white side of the cube. After a short hint to look at the info-graphic, he corrected his mistake. In Task 5 the participant confused the symbols tired with the symbol for angry. After a hint that the angry-cube is incorrect he used the right symbol. For the real world test the participant chose PC-work. He used the next Button several times. He also used mood cubes, not only to describe his current mood, but to give feedback also. The participant asked if he needs to remove cubes when he wants to exit the program.

TP1: *"Wenn ich jetzt aussteig', muss ich das auch wegtun?"*

During the interview TP1 stated that he would like a smaller device that does require less space on his desk. He would also like a wireless device, because he does not like cables. He liked using the device and could imagine using one in the future. The info-graphic was sufficient for him. He used it a lot, but says that he would not need it, once he gets used to it. He listens to background music when: PC work, driving, breakfast. The black and white modes for current and desired mood works for him. He would like to have an activity cube for physical labor.

Participant 2 Like TP1, TP2 also left the sad-cube he placed in the first task on the table for the second task. When in Task 5, TP2 wanted to turn the black side of a cube to its white side, she needed to rotate a cube along two axis in order to have the face looking in the right direction. She confused calm with happy at first, but took the right cube after looking at it again. For the real world test she chose to read a book. Like TP1 she also used the mood cubes to give feedback and manipulate the system. When asked about this she explains that she wanted to give feedback to bad choices of the system.

I: *Mir ist aufgefallen, dass du beim Weiterschalten immer auch einen anderen Würfel reingegeben hast.*

TP2: *Ja.. Weil ich.. Das erste Lied was du aufgedreht hast hat überhaupt nicht gepasst. Oder so.. Zuerst wars neutral und ich wollt halt durch das Lesen und die Musik ein bisserl die Stimmung ändern. Und wenn ein Lied total unpassend ist für Lesen, dann ärgert mich das.. Und darum halt der sauere Smiley.*

I: *Deine Stimmung hat sich wirklich verändert, oder warst du nur kurzzeitig.. Hat sich dein Mood verändert, oder war es eine kurze Gefühlsregung in Bezug auf die Musik, die nicht passend war.*

TP2: *Kurze Gefühlsregung.*

In the interview she stated that she noticed the battery symbol on the energetic cube. It was easy for her to identify the symbols. She likes the way mood cubes work (with a black and a white side). Additional symbols for desired mood would confuse her. TP2 thinks that the device is fun to use. She wants one symbol to be turned by 180 degrees. In her opinion the cubes have exactly the right size. TP2 would not use a like or dislike button as a feedback mechanism. She listens to background music while socializing, reading, workout, having dinner, relaxing, PC work. All moods that she would use are covered by the existing ones.

Participant 3 In Task 1 TP3 used “I would like to be happy” instead of sad first. Then he confused the angry symbol with sad symbol. He also inserted an activity, because he thought that activities are mandatory. In Task 5 he used the activity “workout” instead of energetic and tired on the black side. When asked, he said that he would not like worded labels on the cubes. He would like to be able to distinguish between the two sides of mood cube by just looking at the top of it (without looking at the side). He would also prefer twelve cubes instead of six double sided cubes. As a real world task he read a book. TP3 used mood and activity cubes. He used the button to change music. Unlike TP1 and TP2 he did not use moods as a feedback mechanism. In the interview TP3 said he would like eating and drinking as separate activities. He said it was easy to identify activities, but he had problems identifying some of the symbols, especially the symbol for sad. He did not really read the info-graphic. He skimmed through the text and looked at the pictures. TP3 listens to background music while cooking, eating, reading, and sports/workout.

Problems observed at the first test: While most of the symbols were identified correctly, some moods can be confused with others. Even when a mood is interpreted the way it was meant by the designer, there is still some uncertainty in a few cases. After talking about situations, where users usually listen to music, it was clear that there are some activities that can not be expressed in the current system. Also users don’t know if what they are trying to express is what they actually expressed (lack of feedback [Norman, 2002]). The two sides (black and white) of mood cubes are hard to distinguish when you look down on them, because the symbols have the same background color on both sides. Because of the way people grab mood-cubes, symbols are oriented wrong after rotating a cube. The hand position can be seen in Figure 6.4.

Derived Design-Decisions: The problems found in the first usability test lead to the following Design-Decisions: Audio feedback after input should be implemented. After placing cubes the systems expresses the situation using audio samples like: “You relax and want to get tired.” One symbol on each mood-cubes should be rotated by 180 degrees, in order to support the natural hand position when cube-sides are switched.. In order to achieve better distinguishability black and white color of the symbol on the black side of mood cubes should be inverted. Implement Feedback mechanism: recall situations when radio-stations are skipped quickly. Additional Actions should be added physical labor (TP1), socialising (TP2, TP3). The system should also be customizable to support new actions. Also the recording of quickly skipped radio stations for providing better choice of music in the long run was planned and later scrapped because of issues explained in 5.4.

Findings that will not lead to design changes: Some of the findings did not lead to design changes for the system. In the second Task “You are reading a book” all users left the mood cube from Task 1 also inside the indentation. Users misunderstood the tasks as a progressing buildup. Later usability test instructions should be worded more distinct.

TP 1 would like a smaller device that does require less space on his desk. Since this was only desired by one user and usability and readability would suffer from a reduced size, no design change is planned.

TP 1 would also like a wireless device, because he does not like cables. A wireless version would go beyond scope. It would require additional effort and would not add much to the scientific discussion of the defined problem. The prototype will therefore not have a wireless feature.

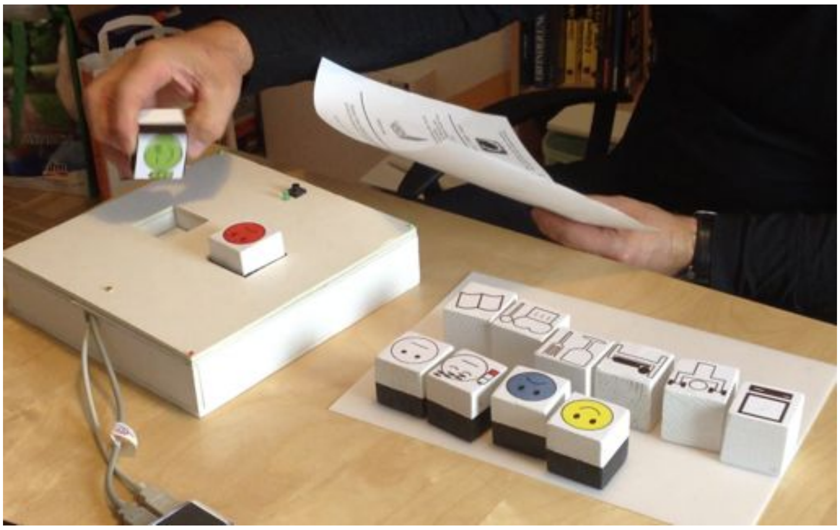

Figure 6.4: Hand position when a cube is turned

6.3 Second Usability Test

All persons listed in 6.1 participated at the second usability test. This more extensive test used a feature complete prototype of the context aware music player.

Test procedure: First users got some information about the project, as well as about the test procedure. One important thing was to make it clear that the aim is not to test their skills but to evaluate a prototype. The test started with a non-directed trial (about five minutes long), where users had a chance to play around with the system. I hoped to get information about how people who had never used the prototype, would approach this situation. The next step was to fulfill the tasks described below, followed by the real world test. Like in the first usability test, the participants had to answers some questions during an semi-structured interview. Topics of this interview were:

- Were the symbols easy to identify?
- Is the info graphic sufficient?
- Did the person like using the device?
- When does the person usually listen to background music (are there tasks missing)?
- What does the person think about interacting with cubes? (compared to mouse use or touch screens; in different situations)
- Is the device suitable for listening to music in the background? Is it in your way?
- Did the participant feel in control of the System?
- Which parameters are more relevant than others when choosing music? Are there any parameters missing?

Once again handwritten notes of observations during the test were taken. The test and the interview were video-recorded and later analyzed.

Aim: The purpose of this test was to see if subjects can identify the symbols, how the interaction works for them and to determine whether the device is easy to use while working on something else.

Metric: Relevant for evaluation were, like in the first usability test, statements during the test and interviews. Also mistakes they did in the predefined situations. Also the general interaction with the device was observed and analyzed. At first it was planned to measure the time a participant needs to complete a task. I found this irrelevant later when I reviewed the videos, because the time it took to complete a task very often neither had to do something with the level of understanding a user had about the system, nor how usable the prototype was. A lot of times I observed the opposite, users who understood how the system works took some time playing around with it and explored different capabilities. Other times, like in the task where users had to customize radio stations, some participants considered their choices more careful or listened to various radio-stations before they decided for one.

Test Setting: As can be seen in Figure 6.5 the test participant sat in front of a table where a notebook was connected to the USB-device.The researcher observed the test from the left side. Also the cubes and the info graphic was placed on the table (see Figure 6.6).

Tasks:

1. Comment a situation of your choice (by spaking out loud) , then input it to the system. (2 times)

   State: Preparation according to test setting. USB-Device is empty.

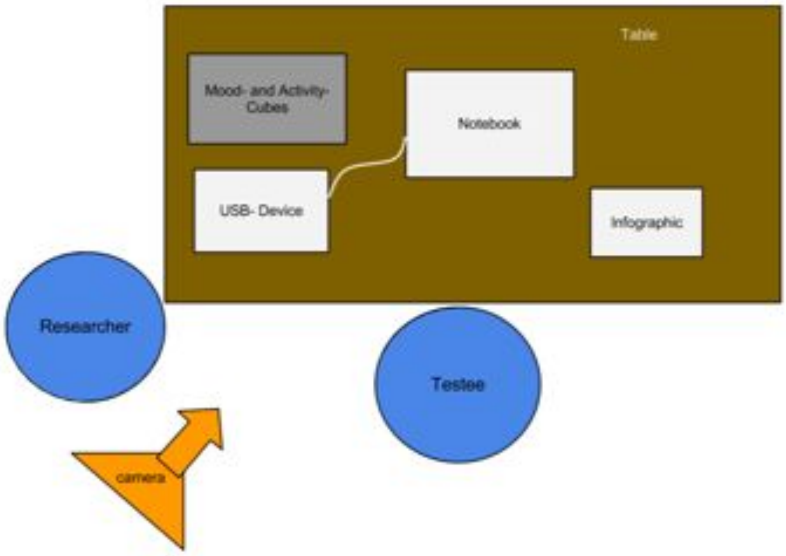

Figure 6.5: Setup of the second usability test

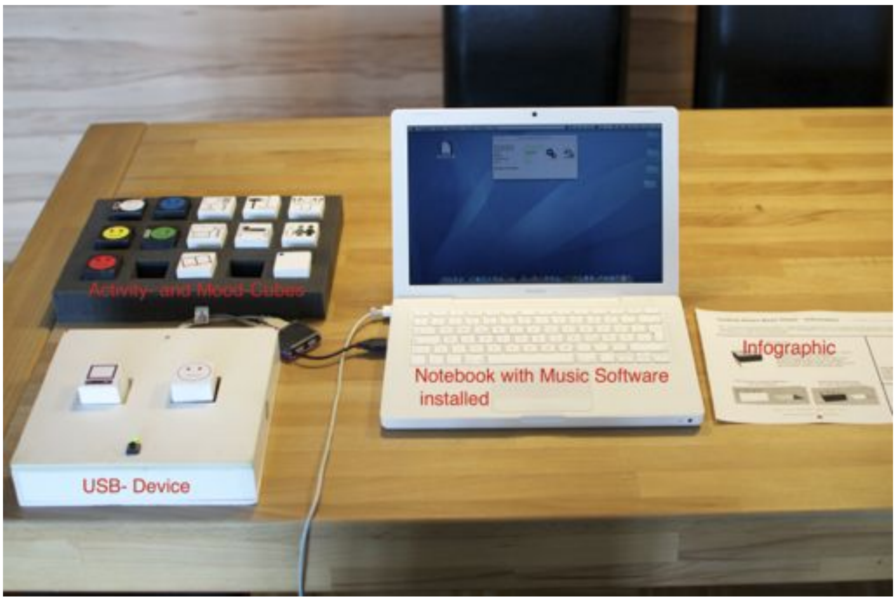

Figure 6.6: Photo of the second usability test setup

Success criteria: The right cubes for the commented situation are placed an the USB-Device. A definition of what is right can be found in Figure 5.7 and 5.8.

Benchmark: Note if user asks for help and comment what kind of help he got.

2. Change radio stations until you are satisfied with the result.

   State: Preparation according to test setting. Cubes from the previous task are still placed on the device.

   Success criteria: User skips at least one song and says that he is satisfied with the result.

   Benchmark: Note if user asks for help and comment what kind of help he got.

3. Change the weighting-value of weather to 4.

   State: Preparation according to test setting. The weighting of the weather value is not 4.

   Success criteria: Weighting value is changed to a value of 4.

   Benchmark: Note if user asks for help and comment what kind of help he got.

4. Customize three radio stations (by altering their tags).

   State: Preparation according to test setting.

   Success criteria: User has edited at least three radio stations. A radio station counts as changed when at least one tag has been changed and the settings have been saved.

   Benchmark: Note if user asks for help and comment what kind of help he got.

5. Add a new radio station. (You can find the information about the station on a text files on the desktop)

   State: Preparation according to test setting. A text file with name, genre and URI is on the desktop of the notebook.

   Success criteria: The new radio station is displayed in the list of radio stations. All values are correctly filled into the textfields.

   Benchmark: Note if user asks for help and comment what kind of help he got.

6. Delete the new radio station.

   State: Preparation according to test setting. A new radio-station has been added to the list.

   Success criteria: The new radio station is no longer displayed in the list.

   Benchmark: Note if user asks for help and comment what kind of help he got.

7. The system allows your to configure a custom activity. Is there an activity you would like the system to have? Add the new activity to radio stations that would fit to this activity.

   State: Preparation according to test setting. USB-Device is empty.

   Success criteria: The tag 'custom activity' is activated in at least one radio station and it has been saved.

   Benchmark: Note if user asks for help and comment what kind of help he got.

Real World Test: Choose and accomplish one of three tasks while using the device.

read a book: Read some pages of a book while using the device.

relax: Sit on the sofa, and try to relax while you are using the device.

PC work: Check you E-Mails. Then find the answer to the question “Which were the first countries to join the European Union” online. Use the device at the same time.

eat Eat and drink something while using the device.

workout Do some sit-ups while using the device.

cooking Cut an onion or green pepper while using the device.

- State: Materials for the chosen task are prepared. Clap detection is activated.
- Success criteria: The user places some cubes, performs one of the actions described above and skips songs like in Task 2.
- Benchmark: Note if user asks for help and comment what kind of help he got.

Person/Task	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**RW**
1	∼	✓	✓	✓	✓	∼	X	✓
2	✓	✓	✓	✓	✓	✓	X	✓
3	∼	✓	✓	✓	✓	✓	X	✓
4	✓	✓	✓	✓	✓	✓	∼	✓
5	✓	✓	✓	✓	∼	✓	✓	✓
6	✓	✓	✓	✓	✓	✓	✓	∼

Table 6.2: Test outcome divided by task

Participant 1 (TP1) During the non-directed trial TP1 tried to place some cubes, pushed the next button and opened both settings windows. One time the music started too early after the voice output, so TP1 asked what the system was saying. He also asked if there is a back-button that would allow him to listen to previously skipped radio stations. In Task 1 he said that he is tired, but puts the relaxation activity cube on the device. He listens to the voice output and nods. He said he is almost sleeping and adds the tired cube on the black side to it (“I want to be tired”). After a hint by the researcher he looked at the info-graphic and changed the black side to white. While completing Task 4 TP1 complained about the effort it takes when someone wants to customize all the radio stations. In Task 5 the participant tried to use a rightclick-menu for pasting the radio information, which was not supported. He also wanted to listen to the new radio station before saving it, which was also not supported. In Task 6 he accidentally pressed the “add new station” button, which can only be closed if all the information fields are completed. TP1 intuitively took the right cube in Task 7 and placed it on the USB-device. He expected new editing options from his action. He asked for help with this task. The custom activity of his choice was "online shopping". TP1 chose reading as real world task. He placed the reading cube on the device, sits down on the sofa and used clapping to switch radio stations.

During the interview TP1 said that he finds activities easier to identify than the mood-symbols. He would prefer a colored info-graphic. He does not know if he likes using the system and said that he would need to spend some more time with it. He did not feel in full control of the system, because he did not customize all of the radio stations. He also pointed out that one needs to know how the system derives a music choice from all it's parameters. Although he did not feel in control, he said that he could skip to a radio station he likes quickly. He does not need desired mood settings for angry and sad. He says that weather and temperature is unimportant for his choice of music and he also would like to reduce the tags for time to 'day' and 'night'. He did not feel in total control of the system, because the device was already preconfigured, but had no problem with getting to a radio station he was ok with (cf. interview excerpt below).

I: *Hast du das Gefühl gehabt, die Kontrolle über das System zu haben. Also hast du die Musik beeinflusst, oder hat das Gerät dir die Musik immer vorgegeben?*

TP2: *Naja, richtig beeinflusst hab's ich nicht weil ich's nicht programmiert hab, die Sender. Das hat schon einiges vorgegeben. Da muss ich erst wissen warum es eigentlich dort hingekommen ist, durch diese ganzen Stimmungsparameter und so weiter. Vielleicht kann man die auch noch erweitern, ich weiß es nicht.*

I: *War's dann aber leicht oder schwer, wie würdest du das einschätzen, einen Sender dann.. auf einen Sender zu kommen, der dann halbwegs passend war.*

TP2: *Ja eigentlich schon leicht.*

Participant 2 (TP2) During the non-directed trial TP2 tried out various cube combination and observed the output. In Task 1 she was unsure about the meaning of the custom cube, so she put it on the device and listened for the speech output. When she combined 'eating' and 'I am sad' the system played "The Cure - Lovesong" ,which instantly put a smile on her face. In Task 5 TP2 used the Command+C, Command+V shortcuts to copy and paste the radio station information. In Task seven, she could not think of any other activity than the existing in which she would listen to music. I had to suggest studying as an activity to perform this task. Like TP1 and TP3 she placed the custom cube on the table and searched on the screen for options. She also needed help to complete the task.

She chose relaxing as real world task. She placed the relaxing- and the desired mood 'happy'- cube on the device, sat down on the sofa. Although she was very satisfied with the played music she wanted to try the clapping-functionality. Clapping worked ok for her.

In the interview she said that she can not think of any symbol changes that would make moods or activities more recognizable. She said that interpreting the symbols is easy once you used the system for a while and added that one can simply put a cube on the device to get a voice prompt that will clarify the meaning of the symbol. She liked using the device and finds it pleasant to use. She called the interaction with cubes a gimmick that some will like while others will not and said that the space the device requires might be an issue. TP2 felt that she was in control of the system because of all preferences she could edit (see interview excerpt below).

I: *Würdest du sagen, das Gerät wählt für dich die Musik aus, oder du hast genug Eingriffsmöglichkeiten die Musik trotzdem so zu wählen wie du sie haben willst.*

TP2: *Ich hab genug Eingriffsmöglichkeiten, weil ich kann mich vorher hinsetzen, ich kann das gewichten, ich kann Radiosender auswählen, dazutun zu den Aktivitäten, zu den Stimmungen.. Dadurch hab ich definitiv genug Auswahl und dadurch hab ich die Kontrolle.*

Activities and moods are are most relevant for her music choice.

Participant 3 (TP3) During the non-directed trial TP3 intuitively placed an activity cube and a mood cube on the device. He also used the button to switch between radio stations.

In Task 1 he confused the black with the white side of the mood cube and did not react to the voice output, tough it was saying "I want to be happy" instead of "I am happy". Without correcting him, he used the two sides correctly at his second situation.

In Task 3 he said that he he assumes the settings get auto-saved when the window is closed. After he closed the window he opened it again to make sure it has been saved. In Task 5 TP3 used the Command+C, Command+V shortcuts to copy and paste the radio station information. In Task 7, the custom activity of his choice was "taking a bath". Like TP1 he hoped to get some configuration options when he placed the custom activity cube on the device. He was not able to complete the task without help.

TP3 chose reading as his real world task. Clapping did not work properly. Since the clapping has not been configured specifically for TP3, the software did not identify his clap-sounds. He noticed the different text-colors in the main interface, but had no clue what they mean.

During the interview TP3 said that he thinks that the symbols were easy to identify and states that he would just place a cube to get audio feedback if he was unsure about the meaning of a symbol. On the other hand he would like to have the option to disable speech output, because sometimes he does not want that the system reads out loud mood. He would like to have less text on the info-graphic, but thinks it is sufficient for using the system. TP3 liked using the system because of its customization options, like adding a new activity and the flexible use of placing either none, one or two cubes. He would like to even repurpose existing activities by assigning a new meaning to them. He would also like a more playful interaction approach like throwing cubes randomly in a bowl instead of placing them on the existing device. He prefers the interaction with cubes, compared to touch-screens or mouse. He thinks that the device is suitable for listening to music in the background. TP3 said that he did not feel in control of the music. He called it a more customizable radio, where one can tweak certain parameters, but the device chooses the music. TP3 said that although every parameter like weather or light influences his choice of music, he is only able to assign mood and activity to certain radio stations. He would like to have the option to tell the system that he had a stressful day.

Participant 4 (TP4) In the non-directed trial TP4 read the info-graphic first. Afterwards she was a little confused about desired and current mood, so she tried to place a cube on both sides and waited for the audio feedback in order to clarify it. She asked what would happen when someone places two activities and tried this also.

In Task 5 TP4 used the Command+C, Command+V shortcuts to copy and paste the radio station information. During Task 7 she stated that she likes the existing selection of cubes but would like to have a second sports cube for more relaxed sports like yoga. She was not sure if she had successfully completed the task when she clicked the ‘custom activity’ tag in the settings window of a radio station. She also tried to rename the tag, which was not implemented at the time. She chose cooking as real world task and placed the cooking-cube on the device. Clapping did only work after configuring the clap detection software specifically to her clapping sound. During the interview TP4 said that she like the clapping feature because she wouldn’t want to touch the device while cooking and finds it also handy in situations where she is not standing next to the device. The only symbols she was not sure about the meaning, was cooking and eating. She stated that this can be easily checked by trying to place one of those cubes and listening to the audio feedback and she could also read the text on the screen. Asked about the info-graphic TP4 said that she wouldn’t even need one, because most of it is self-explanatory. She enjoyed using the system, mostly because she liked using the cubes, which add a playful element to the experience. She also liked that she can customize the system the way she wants it to. The only downside she sees is the space a music device like this would require. She felt in control of the system, because of the possibility to configure it and because she can skip music she does not like (see interview excerpt below).

I: *Hast du das Gefühl gehabt, die Kontrolle über das System zu haben?*

TP2: *Ja. Ich mein, selbst wenn ein Sender kommt den ich nicht mag, ich kann ihn ja weiterschalten, und ich kann ihn auf meine Bedürfnisse auch anpassen.*

I: *Also jetzt im Vergleich eben dazu, weils ein automatisches System ist.. Ähm.. Hast du das Gefühl, dass die Musik stark fremdbestimmt ist, oder dass du da viel mitzureden hast?*

TP2: *Nein, ich kanns ja... ich kann ja mitbestimmen auch. Ich kanns ja weiterschalten, wenns mir nicht gfallt. Ich kann den Sender wenn er mir gar nicht gfallt rauslöschen und somit nur meine Favoriten drin haben, von daher, es zwingt mich ja nicht, dass ich das hör.*

She stated that weather, temperature and light don’t have much influence in the choice of her music, while time does a little. Mood and activity are the most important for her.

Participant 5 (TP5) During the non-directed trial TP5 tried various combinations of cubes and observed the output. He also used the button to switch radio stations. He also noticed that some parameters are marked green, but did not get the meaning of it. In Task 5 he tried to drag and drop the text file first and used copy, paste afterwards. The first thing he did in Task 7 was that he took the custom cube and put it on the device. He then opened the radio station configuration interface for some stations and added the custom activity to it. Then he tried to find a way to rename the activity, which he did not find, because it was not implemented in the prototype. He chose reading as his real world task. After sitting down on the sofa with the book the participant tried to skip songs by clapping. There were some minor clap-recognition problems, but it worked after a few tries. He stopped reading after a while to change the mood cubes. He said things he read can change his mood, but also the music playing can do so. In the interview he said that he was not sure what the symbol on the custom cube meant, so he simply tried to place it on the device and waited for feedback. TP4 said that he can imagine using moods on the black side that are usually delineated as negative, like 'I want to be sad'. He would like to have the system running independently from a computer. TP5 likes haptic interaction and would not want to change moods or activities on a touchscreen or with a mouse. He also said that he likes to hold a physical medium in his hands when he usually listens to music. He prefers listening to CDs rather than digital music and thinks that the cubes give him some of that haptic feeling. He likes the idea of using the system to listen to music in the background because he would not need to choose between CDs or create playlists first. He thinks that after one takes some time to configure all of the radio stations, there would be only a few skips necessary to control the system in a way that it plays suitable music. He said that he does not like the idea of skipping songs by clapping, because it would feel strange for him to walk around in his apartment and clap around. It reminds him of being in an expensive hotel room. On the other hand he can see the advantage of remote-controlling the music. He would like to merge temperature and weather. Time is not a relevant factor for his music choice. At the end of the interview he praised the system for its intuitive controls and said that one can have good results very quickly (see interview section below).

> **TP5:** *Es ist eigentlich ein ziemlich einfaches, einfach verständliches Programm.. mit dem man relativ schnell schon erste Erfolge erzielen kann, muss ich sagen. Also, weil eingestellt ist es schnell und wenn ich jetzt einmal so die Standard-Sachen wie Klassik, Rock, Pop, Jazz, Lounge und was weiß ich, 10 Sender einmal einstell, komm ich schon ziemlich weit damit. Und sehr intuitiv eigentlich.*

Participant 6 (TP6) In the non-directed trial TP5 tried to interpret different symbols on the cube and placed them on the device. By listening to the audio feedback, he learned that there is a difference between the black and white side of a cube.

In Task 1 he accidentally placed a cube with the wrong side on top, but he reacted instantly to the audio-feedback and turned it around. When he skipped radio stations while completing Task 2, he said that he would like have a back-button. In Task 4 he liked the preview feature and said that listening to the music makes it much easier to make configuration decisions. Unlike most of the other participants he had no problem configuring and using the custom activity cube. He chose reading as a real world task. Unfortunately the system could not recognize his clapping first. In the interview he said that he thought the symbol for computer work could be a TV at first. He said that a notebook symbol would be more recognizable for him. He also said that using the system was great fun for him. He liked to play around with the cubes, but also said that the space requirement might be a problem for him. One thing he liked about it was to interact with a physical device. He compared the experience with holding a paperback book in your hand instead of an e-reader. He also sees advantages for elderly users who might have problems using mouse and keyboard. He felt in control of the system, mainly because he had the possibility to skip music. Activities and moods are the most important categories for choosing music for him. TP6 would like to have a music player like this at home.

Findings By looking at the test outcome table 6.2 one can see that the task which caused the most problems was Task 7. This task was about configuring the custom activity. While TP5 and TP6 had no problems completing the task, TP1, TP2 and TP3 were unable to do so without help. TP4 completed the task, but was not aware that the configuration was already finished, which is also an issue. One thing to consider is that the problems with completing this task occurred in all three persona groups, which means that there is a general design problem. One problem most participants had, was that they did not know where to start. Four out of six participants tried to place the custom cube on the device and waited for some dialogue to open. Since this seems to be such a common approach, displaying some instructions when the cube is placed for the first time, seems to be a good idea for future improvements. Something that should be noted tough, is that everyone of those four instantly grabbed the right cube out of the possible activities in Figure 5.8. One minor problem, was that two participants wanted to rename the custom activity, which was not implemented at the time the usability test took place. This feature should also be accessible from the dialogue when the cube is used for the first time. It should also be accessible by right-clicking the custom activity tag (=selbstdefinierte Aktivität) in the radio station configuration interface(see Figure 5.14), since this was the first thing the two participants tried to do when they wanted to rename it. The system should also invite people to draw or print their own symbols for their custom activities. One time the music started too soon after a voice output. This should be fixed by fading the music in and out when the system voice is speaking.

A major issue is that most participants did not notice that some parameters on the screen are marked green. Nobody could get any meaningful information from it. This problem partly originated from the fact that, when a parameter gets marked green, people usually did not look on the screen, but the USB-device which they interacted with. The main problem with this is that this is one of the features that should visualize how the algorithm makes choices.

Users generally liked the idea of remote-controlling the music-player, however the third party software iClapper Pro [iClapper, 2013], which was used to detect clapping sounds in order to skip songs, did not perform well. First of all, the software needs to be configured every time a new person wants to use it, or when the room-acoustics change. A change in room-acoustics can happen when the device is used in another room, or even when windows are opened, in an already configured room. One time the clap-software was accidentally triggered by music coming from the player. After playing a live-recording the applauding audience must have triggered iClapper Pro. Despite these problems, the feature was still usable and the participants liked it. For future development of the prototype other clap-tracking applications should be evaluated, to see if they would perform better. Another possible solution would be the use of speech-recognition or the use of motion sensing technology, for a similar feature. TP3 had a problem with the audio-feedback. He said that he does not like that the system always vocalizes his moods. A mute button would solve this issue.

CHAPTER 7

Analysis and Conclusion

In the course of this thesis, an interaction concept for a context aware music player was developed and evaluated in two usability tests. The prototype, built for the purpose of analyzing the use of context aware music players, and evaluation of the proposed interaction concept, is a system that consists of an USB device, equipped with sensors that also functions as a tangible user interface and software that runs on a Mac, which uses the information provided from the USB-device, in order to determine appropriate music for the current situational conditions. The interaction concept proposed enables users to express information about their mood and activities in a subtle way, and lets them customize the system by mapping situation descriptions to music. Users describe their music choice for a given situation with sentences like: "On a rainy evening, I like to read a book while listening to classical music." or "House music gives me the energy to continue my workout." The evaluation of the configuration interaction showed that users have no problem expressing such natural language statements with pre-defined tags.

An interesting finding is that persons 4-6, who did not participate in the first usability test had less problems completing the tasks. There should be no coherence for better results in Task 7 though, because this feature was not tested in the first usability test. The fact that participants who did not attend the first test did not perform any worse in Task 1 and 2 (in fact they even had slightly better results), indicates that the general interaction with the device is already quite intuitive. All participants naturally understood that the cubes are used to place them on the USB-device. There were also no issues with where to put them exactly, since the cut cavities matched the cube's dimensions and limited the movement (cf. [Ullmer et al., 2005]). The metaphor created for this interaction resembles a shape sorter, a common toy for young children. Also the identification of symbols used for the cubes worked very well. One design change that was made after the first usability test, namely the audio-feedback improved the prototype a lot. Anytime users were unsure about the meaning, they simply placed the cube on the device and listened to the feedback that was commenting their action. Understanding the OS X text-to-speech voice that was used to create the feedback was not a problem for the participants. There was just one time TP1 was not able to understand the voice feedback. This was when the music started to early and overlapped with the voice output due to a bug. This should be fixed in future development of the prototype. The task that caused half of the tested users some trouble was the assignment of the custom activity. Some participants did not know how to start this task. Since most of the users thought that there will be an configuration dialogue once they place the custom activity cube on the device, this might be the clue where to start improvements. Since the custom cube is pretty much blank, the system should also invite people to draw or print their own symbols for their custom activities.

Another interesting thing was what participants thought about wanting to be in a mood that is considered negative, like "I want to be sad" . The system was initially designed to not restrict certain user inputs, but could be easily changed by removing the black side on some mood cubes. While some users said that they would never use negative moods as a "want to be" input, others liked the idea and said that there are times where they want to hold on to a negative emotion like sadness. The insight I got about this, is that restricting input for scenarios that seem unlikely may limit the user experience for those who think outside the box. Keeping those possibilities will not hurt users who don't want to use them.

Users liked using cubes for interaction with the system. TP5 and TP6 said that they prefer physical media when it comes to music or books, and liked that the cubes gave them some of the haptic experience they are used from books or CDs. This observation reflects the loss of physical qualities in digital music described by Gallardo and Jordá [Gallardo and Jordà, 2010]. One thing that I found strange is that some users said that they liked it, but also that a tangible interface might not be for everyone. The only reason participants would favor a touch-screen or mouse and keyboard was that cubes require more space that they might not have available for a music device in their homes. For future prototypes the size of the device and the cubes can be reduced, but this needs to be done carefully to ensure legibility of the symbols. Also the product should still have the right feel to it. Users generally liked the idea of remote-controlling the music-player, however the used third party software for clap-detection did not perform well. For future development, alternatives should be evaluated. Alternatives would be other clap-recognition software, speech recognition or motion sensing technology. One user addressed an issue that I did not think about when I designed the system. He did not like that the system always vocalizes his moods. This can indeed be a problem when you don't want to inform other people in the same room about your mood. Some people may also feel uncomfortable when a computer voice repeats their emotional state, especially when they are in a bad mood. Therefore a mute option should be implemented in the future.

One important research question, apart from designing an interaction concept, was the area of tension between an automated system that makes decisions for its users and user control. Mechanisms were designed to give back users some control over the system. A user should never be forced to listen to music that the system chooses (cf. Reddy and Mascia's thoughts about user feedback [Reddy and Mascia, 2006]. One way to give back some control was to implement a next-button that allows users to skip to the next best music on the priority list. The feeling of being in control of the system seems to be very important for the user experience, since participants who said that they felt in control of the system also expressed that they liked using it and would like to use it again in the future. One thing test participants said when they were asked why they felt in control was that they can configure the system to make decisions they would normally do. Customization options contributed to feeling in control of the system. For TP3 the customization did not go far enough. He would like to be able to repurpose every single activity-cube. Since there are some activities he would never use, he would like to overwrite them with new activities. This feature can be implemented by simply adding a new user interface where one can rename activities. Once again users should be encouraged to draw their own symbols for new activities. One crucial point about this is that users can configure the system more accurate when they have a more detailed insight into how the algorithm choses music. The problem with that is that it is the purpose of an automated system to hide complexity from the user. I approached this problem by trying to highlight matching context-tags green, so that users will know what factors were involved when the system picked the song that is currently playing. With this information users should be able to refine their configurations when the selected music was not suitable. Unfortunately most users did not even notice that some tags are highlighted and those who did, were unable to draw any meaningful conclusion from it. This problem partly originated from the fact that, when a parameter gets marked green, people usually did not look at the screen, but the USB-device, which they interacted with. Eggen and Mensvoort [Eggen and van Mensvoort, 2009] suggest that information should only be in the foreground when it is meaningful and appropriate. The transition from background into the foreground should be smooth. Drawing the user's attention to the screen every time matching characteristics get highlighted might not be a good idea, since most of the time a user just wants to listen to music and not being disturbed by information about why this specific music was chosen. It is therefore necessary to find a subtle way to display this information, which is still an open question.

Basically most of the problems, which occur in the use of a context aware music player result from two mismatches. The first originates from the gap between the mental model of users and the designer's model of how the system works. This is of course a problem that is not limited to context aware systems. In fact it can be found in any interactive object [Norman, 2002]. The second is an *awareness mismatch*, described by Schmidt [Schmidt, 2013], which results from the fact that the system perceives the world via sensors and interprets the information by using a model of the world, while users interpret the world using their memory and experience. Since the model of the world is shaped by a designer, there are some similarities to the mental model mismatch. Designers should try to minimize both of these gaps. Since one of the main reasons for the mismatch in mental models is the difference in knowledge about the system, designers can reduce this gap by communicating with users through the interface [Qian et al., 2011]. In the context aware music player presented in this thesis, this happens by using metaphors for the interaction with cubes and by visual and audio-feedback during the interaction. The lack of feedback in the first prototype of the context aware music player led to a big mismatch in mental models, and thus to a situation in which test participants used the prototype in a way it was not intended to by the designer. The second problem is much harder to tackle. Since it is impossible to create a system that perceives the world exactly the way a user does, the only option we have is to inform users about how such a system works. This way users benefit from the features of the system, without wondering about decisions made by the context aware device. With more knowledge about how the system works, they can customize it and thereby make it more useful for them. Based on my observations and interviews I conclude that the two most important influencing factors on user experience for context aware music players are customization options and making autonomous decisions transparent.

Future work: The next big step after correcting the problems described above, would be to transform the system from a USB-device to an independent system. This can be achieved by integrating a PC into the box. A Raspberry Pi, a credit card sized computer, developed by the Raspberry Pi Foundation [Raspberry-Pi-Foundation, 2013], would easily fit into the existing device and would also be capable of running the software, since it is written in Java. Text to speech and serial port detection is OS X specific in the current implementation. They need to be rewritten to run on Linux for the Raspberry Pi. Also speakers need to be integrated into the device. The major challenge for transforming the context aware music player from a USB device into an independent system, is the configuration interface. Since an independent player would not have access to a screen or input devices, the configuration interfaces in Figure 5.11, 5.13, 5.14 and 5.12 need to be accessed via another computer. One possible solution would be to run a web-server on the integrated computer (e.g,. a Raspberry Pi). The configuration interface could then be accessed on any device with a browser, such as a notebook, tablet, or smartphone. This would also add remote control capabilities from those devices. Although this thesis explored one possible way to implement a context aware music player, there are still some open questions. I hope that I will be able to further improve my prototype in the future and contribute to this interesting research field.

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