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Designing a Multi-Device Setting for a Museum Exhibition Integrating the Visitors' Own Devices

Diplomarbeit

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Abstract

This thesis addresses the challenges which arise when creating an interactive multi-device installation for a museum exhibition which incorporates the visitors' own devices into its device environment. As a part of literature research, it presents ways of designing multi-device environments as well as state-of-the-art interaction models and describes how to attract attention for an installation, communicate interactivity and how to motivate users to interact with the system. In the course of the research project MEETeUX at the St. Pölten University of Applied Sciences, such an installation, the "Weisskunig Quiz", has been created and deployed in the museum of the Klosterneuburg monastery, as a part of the annual exhibition on Emperor Maximilian I.

The Weisskunig Quiz, a multi-device and multi-user quiz in which museum visitors can participate with their own devices, was evaluated in several user tests. Based on the results of these tests, a new interaction model for interactive installations which incorporate users' own devices has been created and is discussed at the end of this tesis. This work also presents a set of guidelines on how to design an interactive multi-device installation for a museum.

Kurzfassung

Diese Diplomarbeit behandelt die Herausforderungen, die bei der Konzeption und Umsetzung von interaktiven Installationen entstehen, die aus mehreren Geräten bestehen (multi-device) und dabei die eigenen Geräte der Besucher und Besucherinnen einschließen. Als Teil der Literaturrecherche zeigt die Arbeit Möglichkeiten auf, Multi-Device Umgebungen zu gestalten, und präsentiert Interaktionsmodelle für öffentliche interaktive Installationen nach dem aktuellen Stand der Forschung. Sie fasst die wichtigsten Schritte (Aufmerksamkeit erregen, Interaktivität kommunizieren und motivieren) zusammen, die nötig sind, Besucher und Besucherinnen zur Interaktion mit einem solchen System zu bewegen. Im Rahmen des Forschungsprojektes MEETeUX an der FH St. Pölten wurde eine interaktive Multi-Device Installation, das „Weißkunig Quiz“, entwickelt, und als Teil der Jahresausstellung zu Kaiser Maximilian I. im Museum ausgestellt.

Das Weißkunig Quiz, bei dem Museumsbesucher und -besucherinnen mit ihren eigenen Geräten mitspielen können, wurde in mehreren Benutzertests evaluiert. Basierend auf den Ergebnissen dieser Tests wurde ein neues Interaktionsmodell für Installationen, die die Geräte der Benutzer miteinschließen, entwickelt. Dieses Interaktionsmodell wird neben einer Reihe an Guidelines für die Konzeption von von interaktiven Multi-Device Installationen am Ende dieser Arbeit diskutiert.

Table of Contents

1 Introduction

We are living in a world in which mobile devices are becoming more and more important, and the pace at which this importance is growing is only becoming greater. Less than 10 years ago, owning a smartphone was no certainty, whereas today, it is rather uncommon to meet someone who does not own one: A study from 2017 shows that 85% of Germans between 16 and 69 years had a smartphone at that time, while in fact less people - 83% - called a stationary PC or laptop their own (ÖWA, 2017). Authors of an Austrian study conducted only one year later even claim that 96% of all Austrians use a smartphone (Mindtake, 2018).

A lot of tasks are done on these devices that such a great part of the population owns. From simply making voice calls, sending messages or browsing social media to making financial transactions – if one looks through Google's and Apple's app stores, there is an app for almost everything amongst over two million of individual applications (Mindtake, 2018; Lifewire, 2019; Statista, 2019).

With technology rapidly taking over our daily routines, more and more institutions such as museums are trying to incorporate the possibilities offered by various interactive technologies into their exhibits. Museums with focus on STEM subjects (science, technology, engineering and mathematics) were the first ones to include interactive applications in their exhibitions to make them more interesting, but culture and historic museums quickly discovered their benefits as well. A lot of exhibitions from such museums feature objects which are, for example, historic artifacts displayed outside of their original context. They are static, non-touchable objects behind glass, and visitors can only see a glimpse of the information they offer. A back side of a piece of parchment, or other pages in a book are therefore completely hidden from the viewer. Using technology to build interactive exhibits can bridge the gap between the visitor and the exhibit and offer far richer engagement and learning possibilities for a better museum experience (Ho Chu, Clifton, Harley, Pavao, & Mazalek, 2015).

An example for such an interactive element that has been adopted by many museums is the multi-touch table. It enables multiple visitors to explore content at the same time while also discussing their opinions, views or findings in a collaborative way (Ho Chu et al., 2015).

When an interactive system does not only consist of one device, we talk about a “multi-device environment”, or MDE for short. Generally, this term refers to a setup which integrates a multitude of devices such as screens, surfaces, projectors, tracking systems, and others, which have their possibilities of interaction spread amongst them and thus form a unique, interactive environment (Seyed, Burns, Costa Sousa, & Maurer, 2013). It is worth noting that in a multi-device environment, like one would find in a museum, multiple devices complement each other and form the experience together while spatially not being far apart. This is important because when researching in the sector, the term “multi-device experience” itself is sometimes also used to e.g. describe the way a single website looks on a desktop computer, a tablet and a smartphone, not implying that all of the devices have to be at the same place or used at the same time (Levin, 2014, p. 5). This thesis will mainly focus on settings that follow the former definition.

1.1 Problem Statement

Nowadays, many museums feature interactive content – be it single touch displays or larger MDEs. However, they rarely take advantage of the fact described earlier: Most people own a smartphone, and most of them also carry it around wherever they go – this means that a large part of the museum visitors walk around with their personal interactive device in their pocket. Combining the stationary technology inside of the exhibition with the mobile, personal devices of the visitors into a multi-device environment can offer new possibilities to enhance the visitors’ museum experience by enabling them to interact with the exhibits in various ways, and at the same time, take content home after the visit (Blumenstein et al., 2017).

With multiple, both stationary and non-stationary devices combined in a public space, a few challenges arise when designing a multi-device environment for a museum. This thesis aims to cover these challenges and formulate a set of guidelines that can be followed in order to build a user-friendly multi-device environment in a museum that incorporates the visitors’ own devices (ODs).

1.2 Research Questions

To create guidelines on how to design a multi-device setting, the following research question will be answered in this thesis:

How does a multi-device setting have to be designed so that it offers the best user experience to visitors of a museum exhibition?

To answer this question, it was split into three sub questions, which are the following:

1) *Which kinds of multi-device concepts already exist, and what are the relationships between the individual devices used in those concepts?*
2) *What kind of challenges arise when designing a multi-device setting for a museum, and how can one overcome them?*
3) *How can a visitor's own device be incorporated into a multi-device setting in a museum?*

1.3 Method

To answer the research question, intensive literature research was carried out on the one side. On the other side, an interactive multi-device installation was designed and deployed in a real museum exhibition. It was evaluated in technical pretests, one user test consisting of observation, video documentation and interviews, and two tests consisting of observation and video documentation only. Additionally, the installation logged all interactions of each player. This quantitative data was evaluated as well.

1.4 Structure

The second chapter of this thesis outlines the challenges of multi-device environments as well as of public interactive installations in a state-of-the-art report. It also mentions the possibilities which arise when incorporating personal devices into interactive installations and shows examples which have been realized by various research teams. It also summarizes the options of evaluating public interactive installations.

The third chapter shows the design process of the interactive multi-device museum exhibit, the “Weisskunig Quiz”, located at the museum of the Klosterneuburg monastery.

The fourth chapter reports about the evaluations of the installation and the test results, while the fifth chapter discusses all of the findings and presents a new interaction model as well as a set of guidelines on how to design an interactive multi-device installation for a museum which incorporates the visitors’ own devices.

The sixth chapter summarizes the contents of this thesis and gives a final overview of the findings.

1.5 The MEETeUX Research Project

The contents of this thesis are part of the research project MEETeUX at the St. Pölten University of Applied Sciences, which was funded by the Austrian Research Promotion Agency (FFG). Although the designs and evaluations presented in this thesis were created and carried out by me, they were influenced by the valuable feedback and the results of discussions with advisors, co-workers and the curators of the museum of the Klosterneuburg monastery, in which the installation was deployed. This is why I have decided to use the pronoun “we” instead of “I”, whenever I describe something that also involved the work of others in this thesis.

2 Multi-Device Environments and Public Spaces

When it comes to designing a multi-device experience, the central thing to know is what kind of different devices the application will work on. Nagel and Fischer (2013, pp. 26ff) describe four central kinds of devices that are most commonly used in a multi-device environment: smartphones, tablets, PCs and laptops and TVs (or in general, large displays). However, that does not mean that a multi-device environment is limited to just these. With the Internet of Things and the Internet of Everything (IoT and IoE) becoming more and more real, anything can be part of a multi-device ecology – from smartwatches or other wearable gadgets to smart home components or even microchipped animals or humans (Levin, 2014, pp. 167ff). Which devices are incorporated in a specific setting, i.e. supported by the application, depends on the context: Who uses the application? What is their intention? How much time do they have? Which devices do they use when, how, where and why (Nagel & Fischer, 2013, pp. 54ff)?

Different devices are suited for different tasks and offer diverse technical possibilities. A PC or laptop, for example, has a higher processing power, whereas a smartphone has the advantage of being portable and offering a great number of sensors such as accelerometers or compasses. A larger screen can also contain more information, while one would have to prioritize onscreen elements on a smaller screen to prevent visual cluttering. Additionally, different devices are used in different contexts and places (Nagel & Fischer, 2013, pp. 28-29 & 115; Levin, 2014, p. 22).

This chapter first describes the different approaches on multi-device design. Then, the challenges of interactive installations in public spaces will be presented as well as possible solutions to them. Afterwards, additional challenges and possibilities of including the users' devices in a stationary multi-device system (BYOD – "Bring your Own Device") will be outlined, and examples of existing MDEs will be shown. Lastly, methods of evaluating public displays will be discussed.

2.1 When Multiple Devices Play Together

Designing an application that works on more than one device is a challenging task for both programming and design. With the rising number of technological devices, their usage becomes more fragmented. Users' attitudes towards them change, and they expect everything to work seamlessly no matter where they use an application (Nagel & Fischer, 2013, p. 15).

The 3Cs Framework for Multi-Device Experience Design

In order to design an application that incorporates multiple kinds of devices, one has to think about the relationships between these devices. Michal Levin (2014, pp. 21-129) as a pioneer of multi-device design proposes three approaches which she calls the 3Cs framework:

The Consistent Approach

Consistent design is the most basic multi-device approach and is, for example, found on most newer web pages. While Levin (2014, pp. 2ff) does include it in her 3Cs model, it is in conflict with the definition of multi-device environments as used in this thesis, since the different devices do not have the interaction possibilities spread amongst them. The Consistent Approach as described by Levin essentially means having one central application ported across devices, with its look and feel being adjusted to the device it is displayed on. The functions are the same on each device, but the method of interacting is different. For example, a web page with multiple columns on a desktop PC is usually organized in a single-column layout when viewed on a smartphone, and the navigation is usually hidden under a hamburger icon. Buttons are larger on devices with touch input to avoid the problem of less accuracy with a finger tap as opposed to a mouse click. Desktop features such as hovering the cursor over an element have to be replaced by a different interaction method on devices without a mouse. Depending on whether a user holds a portable device with one or two hands, the system's keyboard might appear as a whole on the bottom of the screen or be split and anchored to the corners of the screen, respectively.

To summarize, consistent design means that the entire experience of the system can be consumed in the same ways on any device. This design approach does not give much attention to the different use cases the system might be used – each device works completely on its own. Figure 1 shows a visual representation of the relationships between the individual devices in consistent design.

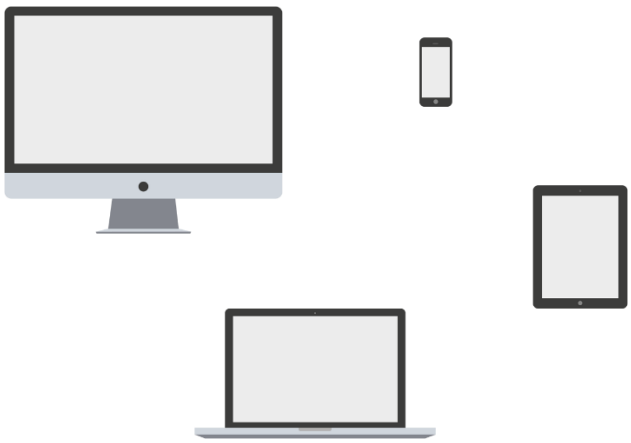

Figure 1. Consistent Approach – an application is independent from the device that it is being used on, like a responsive web page (Based on Levin, 2014, p. 129).

The Continuous Approach

This approach focuses more on context and flow by supporting the user in every step of the way through a longer task. This can be a single activity, or a sequence of different activities that are needed to reach an end goal.

For example, a user might start watching the new episode of their favorite show on their smartphone, while they are on the train back from work. When they have to get out, they interrupt the activity and resume it at home on their TV, exactly where they left off. The same applies to writing a document or reading a book at home, in a café or at the airport. Figure 2 visualizes this flow of tasks on the different devices.

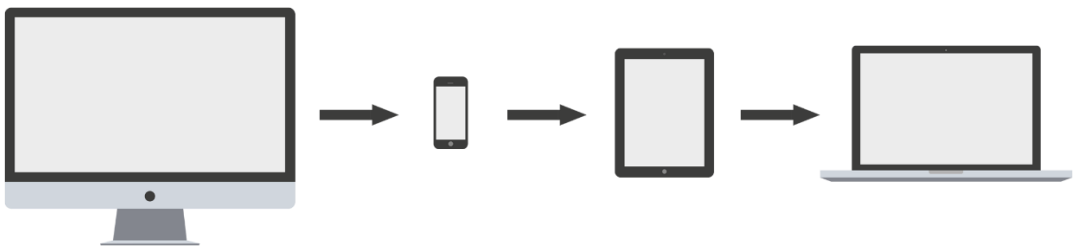

Figure 2. Continuous Approach – an application is designed in a way that one user goal can be achieved on multiple devices during a longer time span. An example is watching a video on a tablet, and then resume on a larger screen exactly where one left off (Based on Levin, 2014, p. 129).

An example for sequenced activities would be cooking: First, the user decides what to cook, then they will have to go shopping for groceries, and lastly, actually cook the meal. For that, they research recipes on their PC and save them. When they are at the store, they have the shopping list on their smartphone, and when they are in the kitchen, they use the tablet to see the cooking instructions.

Thinking even further, the refrigerator as a smart device could also be included in the task flow by automatically checking which of the ingredients are at home, and which have to be added to the shopping list.

Shifting contexts like this requires a lot of knowledge about the user, which ultimately leads to the need of some user profile and a login system. Michal Levin also points out that such a registration must be as easy as possible as well as beneficial for the user, otherwise they might refrain from using the application.

The Complementary Approach

This is the approach that is interesting for applications in places like museums. Instead of seeing "multi-device" just as "more than one device", the complementary approach focuses on actually using multiple devices at the same time and place, based on two types of relationships:

- There is the collaboration relationship, as visualized in Figure 3, where the different devices in the system work together as a connected group and create the full experience together. An example would be a tablet acting as a board game for playing Scrabble, while the smartphones of the players hold their tiles, or a large screen showing a target disc, with the arrows being "thrown" by giving the smartphone a quick shake.
- The second one is the control relationship, as depicted in Figure 4, in which one certain device offers the main experience, and other devices control aspects of it. A user's smartphone could, for example, act as a controller for a racing game played on a TV screen. This also brings additional personalization possibilities: For example, a user could join the game with their smartphone and be recognized by the system, thus automatically starting the race with their preferred vehicle or character.

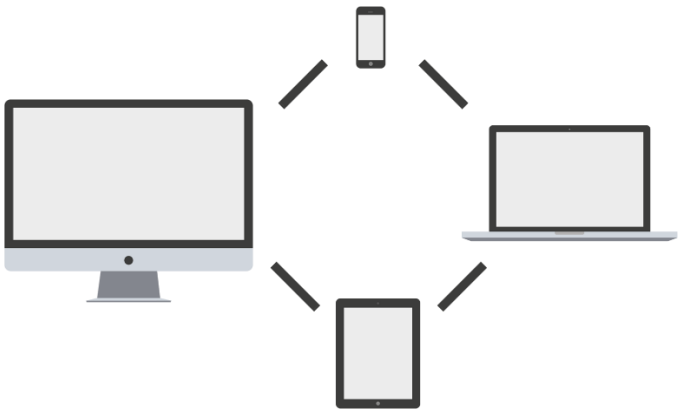

Figure 3. Collaboration Complementary Approach – the devices work together to create the full experience, like when a tablet is used as a board game, and the users' phones hold their cards (Based on Levin, 2014, p. 129).

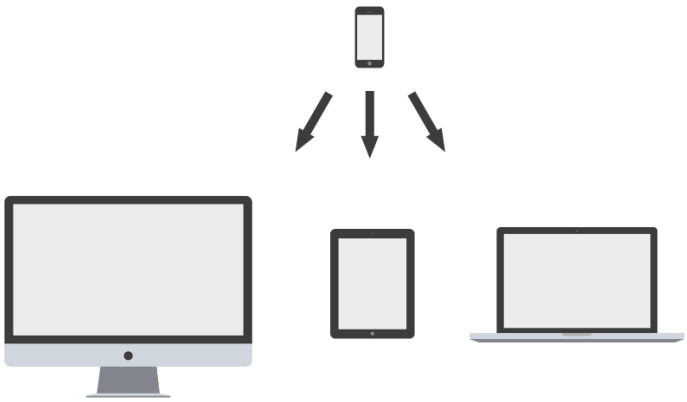

Figure 4. Control Complementary Approach – one device controls elements of another one. For example, a smartphone could be used as a controller for a racing game on a TV (Based on Levin, 2014, p. 129).

Control and collaboration relationships can also occur at the same time. It is not necessary for every player in a game getting the same experience – if each player has a different role in the game and their smartphone augments, for example, the main screen with different UI elements based on their role, all the players create the whole experience together.

Michal Levin (2014, pp. 132ff) suggests seeing the three Cs as building blocks for a multi-device experience, and describes another approach which she calls the "Integrated Design Approach": Mixing the 3Cs, rather than just using one of them, can address the users' needs in new ways. Video on Demand applications like Netflix and Amazon Prime Video, for instance, are good examples for using consistent and continuous approaches at the same time. The design and the interaction possibilities are consistent on all devices, while the user can also start watching content on one device, stop, and resume doing so on another.

2.2 Challenges of Public Spaces

The way of how a user interacts with a device or application greatly depends on the place where they are using it. There are three main environments in which a person might sojourn:

- In a **private environment**, there is hardly anyone who can influence the behavior of a user, but the user has the greatest influence on the devices around them. This includes places like the own house or apartment, or places where they have exclusive access to, like a hotel room. Houses of friends and family will most of the time also be regarded as a private environment (Nagel & Fischer, 2013, pp. 96-97).
- **Semi-public spaces** are accessible to a limited group of people. An example would be the own workplace or a meeting room. The available

devices are partly predetermined, but the situation can be influenced to some extent. Decorating the own workplace, for example, can also give the space a bit of a private feel (Nagel & Fischer, 2013, pp. 96-97).

- **Public spaces** are accessible to everyone, and the users have hardly any influence on the available devices or on the present people around them. A museum is such a space, and a public interactive installation raises the challenge of people possibly omitting any kind of interaction in order to maintain a social role and hence behave differently than in private (Nagel & Fischer, 2013, pp. 96-97 & Müller, Alt, Schmidt, & Michelis, 2010).

According to Brignull and Rogers (2003), the greatest problem standing in the way of people interacting with a public interactive installation is the fear of social embarrassment. Potential users may be wary of interacting with the installation if they do not know what exactly they are required to do and if it involves a risk of looking foolish in front of an audience – similar to the situation when a street performer invites a passer-by to help out with their show.

Brignull and Rogers (2003) conducted research on how to overcome this challenge, how people socialize around large public displays and how they change from being spectators to being participants and back. They designed an installation consisting of a laptop and a projector, which displayed a general question (like “What do you think of the food at the university?”) on a wall. People could add their own opinion on this question and personalize it with colors and a set of images by using the laptop. The researchers carried out two observational studies at parties as well as user questionings and discovered three types of “activity spaces” around the installation:

- **Peripheral awareness activities**: People in this space are focusing their attention on something else, like communicating with each other. They are aware of the installation in the room, but do not know much about it.
- **Focal awareness activities**: Here, people are engaging in social activities that are associated with the installation. They talk about it, gesture towards it and or watch other people using it. They give the installation more attention and learn about how it is used.
- **Direct interaction / participation activities**: In this space, people actually interact with the installation, either as an individual or as a group acting cooperatively.

Figure 5 shows the thresholds discovered by Brignull and Rogers (2003) of passing from one activity space to another. In order to move from the peripheral awareness to the focal awareness space, people need to first learn more about the installation they are watching from a distance:

- Is it interesting, enjoyable or worthy of attention?
- What is it? How is it used?
- What is its social standing? What do other people think of it and how do they behave towards it?
- What is the social system around it – what is the nature of the queue and what are the socializing activities going on in the near field?

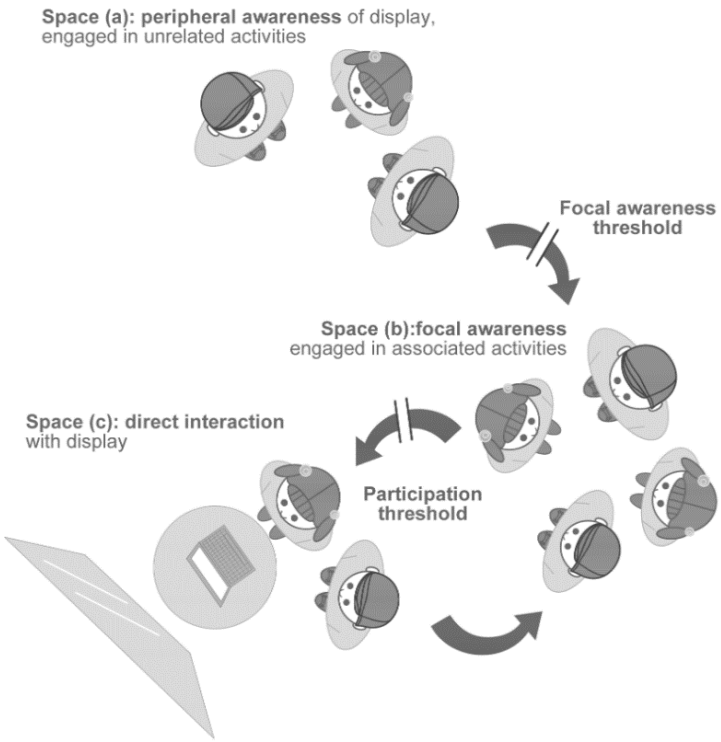

Figure 5. Types of Activity Spaces around a public display and the thresholds that need to be overcome until users engage with an installation (Brignull & Rogers, 2003).

Even though the interactive installation was placed at a spot where more people passed (e.g. near a buffet), Brignull and Rogers (2003) hit the expected barrier of social embarrassment right at the beginning of their observations, since nobody wanted to approach the installation and be the first one to add an opinion. To overcome this problem, the researchers sent out a “helper person” to interact with the system, which was later removed. Nevertheless, doing so led to a phenomenon they call the **“honey pot effect”**: Whenever a person used the installation, others standing nearby became interested and started socializing, making comments to their neighbors, referring to opinions on the screen and eventually using the system themselves, ultimately creating some sort of “buzz” around the installation. This effect is further described in chapter 2.2.1.

To cross the threshold from the focal awareness space to the participation space, the researchers suggest designing the installation in a way that users recognize

as fast as possible how long an interaction takes, what they will get out of it, what steps are involved, whether it will be a comfortable experience and – in case there is a need to "flee" – where they can walk away gracefully, without disturbing the ongoing public activity (Brignull & Rogers, 2003).

In interviews with participants, one particularly common feedback was that people noted to have felt pressured by the fact that the text written on the laptop was broadcasted in real-time. They compared it to the feeling of standing at the blackboard in front of a class and being afraid of spelling something wrong. One way of evading that problem would be to let people type in their opinions via their mobile phones, which, on the one hand, would reduce the potential of social awkwardness, but on the other hand, remove the beneficial honey-pot effect (Brignull & Rogers, 2003).

In contrast Brignull's & Rogers' (2003) findings, which rely on sole user observation, Streitz et al. (2003) approached the topic from another point of view. They built an installation which incorporates different interaction possibilities based on which of three defined interaction zones a user is standing in. These three zones, as also shown in Figure 6, are the following:

- In the **Ambient Zone**, where people are just passing by, the installation (a large wall consisting of 124 fist-sized LED cells) shows general information which does not depend on the presence of a particular person, e.g. how many people are still in the building. The information is abstract (the LED cells light up in different patterns) and also has a decorative purpose.
- When a person approaches the wall far enough to be recognized by its sensors, they enter the **Notification Zone**. Here, the light patterns change from a stand-by pattern to a notification pattern relevant to the people that are in the zone. To track and remember distinct users, the researchers built a mobile device, specifically designed to interact with the wall. This mobile device also shows each user information, like what the patterns on the wall mean when they enter the zone.
- The **Interaction Zone** is entered when a person is in immediate proximity of the wall. In this zone, they can use their mobile device to interact with the single LED cells to store and download information.

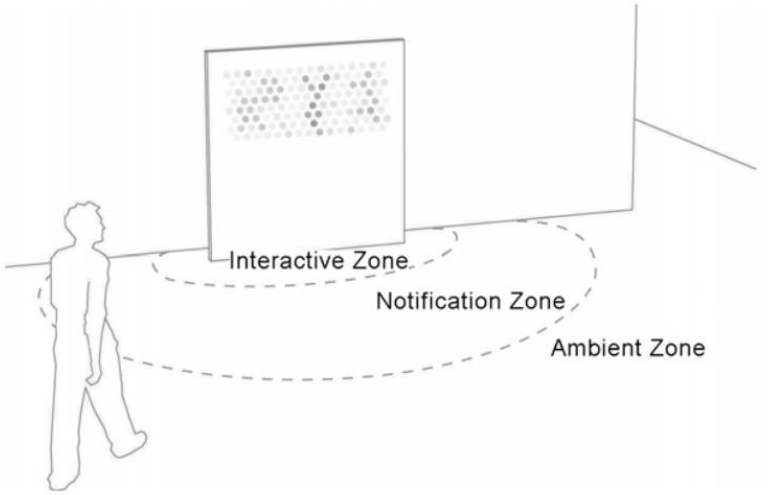

Figure 6. Interaction Zones as defined by Streitz et al. (2003). Their research prototype offered different interaction possibilities depending in which zone an individual passed.

Ott and Koch (2012) added a "Private Zone" to these models, since their setup consisted of different devices on which a collaborative application could be used. If an individual interacted with the application on a single-user device, they would not pass through any interaction phases, even though being in a public space. Their extension of the models is illustrated in Figure 7.

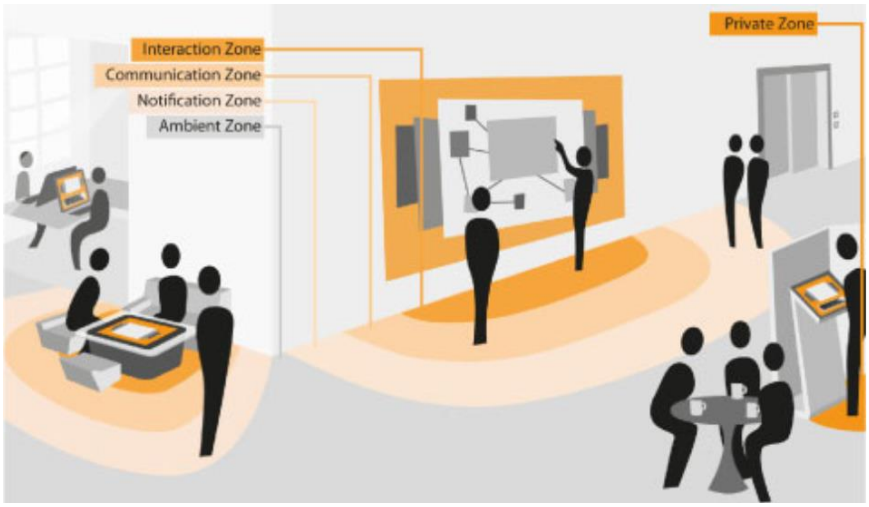

Figure 7. Ott's and Koch's (2012) approach on interactive zones shows how they occur around different devices. The model is largely based on the work of Brignull and Rogers (2003) and Streitz et al. (2003), but includes a "Private Zone" for single-user devices.

Vogel and Balakrishnan (2004) took up both Brignull's and Rogers' (2003) and Streitz' et al. (2003) findings and refined them to develop an interaction framework for public displays that allows a wider range of implicit (when just passing by) and explicit interaction techniques. Their starting point of research

was the vision of large displays in public and semi-public spaces, which allow accessing both general and personal information, without having to carry around a mobile device. Vogel and Balakrishnan (2004) defined four interaction phases which are also visualized in Figure 8:

- **Ambient Display Phase:** When the display is in this state, it shows general information that passers-by can easily see with a quick glance, like the weather, or, in an office environment, an event calendar and company-wide notices. It is the “starting phase” of each interaction.
- **Implicit Interaction Phase:** This phase starts when a user has shown interest in the display. In the prototype designed by the researchers, the system reacts to the body posture of a passing individual through camera tracking, showing an abstract representation of the user on screen to draw the user closer to the display and enter the next interaction phase.
- **Subtle Interaction Phase:** When the user has moved closer to the screen, willing to interact with it, the general displayed content is augmented with more details as well as with personal information. While people will only have interacted implicitly until this point, they can now interact explicitly with the screen by using simple hand gestures and open and close content while still standing out of reach.
- **Personal Interaction Phase:** As soon as a user selects or opens an item, they can move closer to the screen and enter the last phase. Standing directly in front of the screen, touch input is more suited for accurate, up-close interaction, but the hand gestures from the previous phase can be used as well. The content is the most personal here.

Vogel and Balakrishnan (2004) also describe that in their framework, the phases are seamless and the transitions occur smoothly – for example, taking a step closer to the screen already means a phase change, while a user can also turn around and walk away during any phase, ending the interaction.

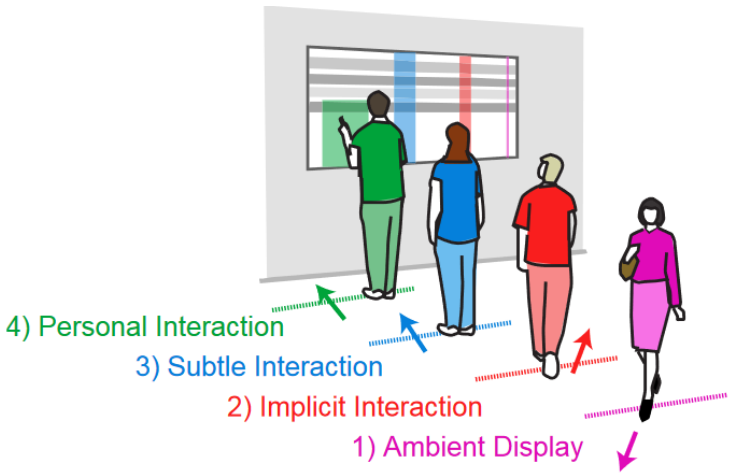

Figure 8. Interaction Phases as defined by Vogel and Balakrishnan (2004). The display shows different layers of information to users, depending on how close they are. The greater the proximity, the more personal the information becomes.

The greatest difference between private and public interactive applications is that users are always aware of their own devices, while public ones vanish in the clutter of things that compete for attention (Müller, Walter, Bailly, Nischt, & Alt, 2012). Ghare, Pafle, Wong, Wallace, and Scott (2018) differentiate between "display blindness" (people not noticing displays in public) and "interaction blindness" (people noticing the display, but failing to recognize that it is interactive).

Müller et al. (2012) describe the "Audience Funnel Model", which is depicted in Figure 9. It shows how a user approaches an interactive installation. Based on this model, the researchers formulate three challenges which have to be overcome until a user actually uses the public interactive installation:

1. A user first has to notice the installation itself.
2. Then they have to recognize that it is interactive.
3. Lastly, there has to be something that motivates the user to interact with it.

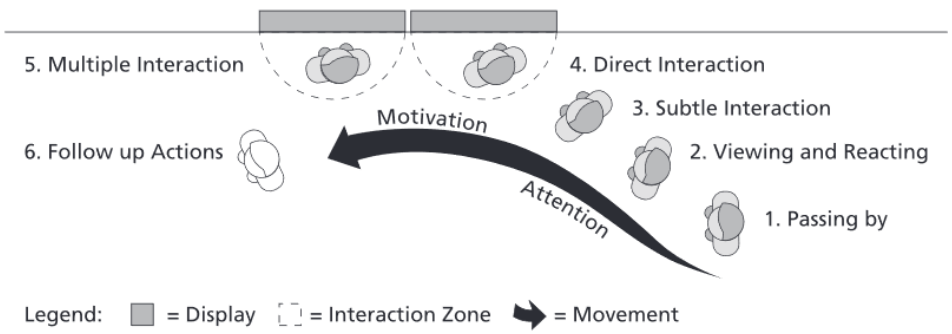

Figure 9. The Audience Funnel from attracting attention for an interactive installation to actual user interaction (Müller et al., 2010).

2.2.1 Attracting Attention for an Installation

With posters, shop windows, signs and noninteractive displays, which are not always interesting for everyone, the human brain is confronted with far more sensory input than it can process in detail. Hence, an individual will always focus their attention on a relatively small number of stimuli and process those in detail (Müller et al., 2010). An eye-tracking study by Dalton, Collins, and Marshall (2015) showed that when "scanning" the environment while walking through a public place (in their case, a shopping mall), people's gaze only dwelled at displays for about a third of a second (333 milliseconds), while 800 milliseconds are the threshold for processing information consciously. Thus, these displays have to use stimuli that catch passers-by's attention, so that they actively redirect their gaze back to it to pick up more information. Another fact shown in the study was that displays were often looked at from a distance, with the highest numbers of recorded gazes occurring at a distance of around five meters. Dalton et al. (2015) suggest that an interface of a public display should be designed in a way that the most important information can be seen from this distance (e.g. featuring an adequate font size).

Weiser and Brown (1997) emphasize that in a world of sensory overflow, it is important for computer systems to move into periphery and to not overburden passers-by. The researchers remark that when driving, a person's attention is centered on the road or the radio, but not on the noise of the engine, unless this noise becomes unusual. In this case, it is attended to immediately. They propose that public interactive installations should also be designed in a similar way and call this model "Calm Computing". However, as Weiser and Brown (1997) also point out, not every technology needs to be calm. Some installations are supposed to motivate people to participate in e.g. a game and do not make sense in the background. In these cases, stimuli like abrupt appearances of new objects, or certain types of luminance-contrast changes and movement can be used to attract attention (Müller et al., 2010).

Ghare et al. (2018) examined the effectivity of animation and proximity to attract passers-by attention. They designed an interactive installation showing a bookshelf on a large display and observed people passing it in a university hallway. In one version of the installation, the objects would start to move when a user walked by the display, while in the other version, the animations were played randomly. The researchers found that the version with random animations received twice as much attention than the version which only triggered the animations when someone passed by. This was because of a "tracking lag" in the second version – the animations only started when a person was almost past the display and too far away to notice them.

A study by Ju and Sirkin (2010) showed that when it comes to movement, physical moving objects are perceived even stronger than digital ones. In a field study, the researchers put up a 15-inch touch display on a speaker's desk. In one variant, an animatronic waving hand was placed next to the displays. In another, a digital projection of the same hand was shown. As a result, the display with the animatronic hand was interacted with almost twice as often as the one with the projected hand (Ju & Sirkin, 2010). This correlates with Dalton's et al. (2015) findings that people's gazes often followed along physical landmarks (e.g. architectural structures or displayed products) until they reached the display.

Another factor that attracts attention is the **honey pot effect**, as mentioned in chapter 2.2. When one person interacts with an installation, other people will start to pay attention, forming a crowd, which subsequently attracts attention of others (Müller et al., 2012).

Wouters et al. (2016) further examined the influence of the honey pot effect on interactive public systems. Based on the Audience Funnel Model of Müller et al. (2010, see Figure 9), they identified six user roles:

- **Passers-by**, who roam around the immediate vicinity of the system.
- **Bystanders**, who have seen the system from the distance but are still unaware of its features.
- **Audience members**, who are familiar with the interactivity and social norms around a system.
- **Participants**, who perform subtle forms of engagement with the system. They are still discovering interactive features and building a sense of comfort.
- **Actors**, who demonstrate a committed form of engagement, e.g. through interacting for an extended amount of time, through complex behaviors or by testing the system's capabilities.
- **Dropouts**, who have abandoned engagement with the system either by purposively not engaging with the system in the first place, or by quitting after having interacted for a while.

Wouters et al. (2016) also researched on how people move between these phases. From these trajectories, user roles, influences and triggers, they created the **"Honeypot Model"**, as illustrated in Figure 10. A particularly interesting part of the model is the so-called "Activation Loop", a self-reinforcing trajectory that reactivates interest and motivation to join the interaction: Audience members might tell bystanders what the installation is about. Through the social interaction, they learn about the system and might become motivated to try and participate themselves.

In Contrast to Brignull and Roger (2003) and Müller et al. (2012), who described the honey pot effect as unidirectional, Wouters et al. (2016) found that when a certain number of people around the interactive installation had been reached, people would rather move away than step closer. This is because of social and spatial constraints – interactive installations are not always able to accommodate a continuously increasing number of participants. At some point, the area around the installation will be too crowded, and users will also drop out after some time, with new ones moving up. The researchers call this balance of user motivation and ergonomic, social, hardware and software constraints the **"honeypot sweet spot"** and recommend that every public installation and its surroundings should be designed in a way that the optimal number of simultaneous users can be reached in a convenient way (Wouters et al., 2016).

In their Honeypot Model, Wouters et al. (2016) also describe the reasons for users dropping out of the interaction with an installation:

- **Unwillingness** occurs among *passers-by* who have not experienced the system yet. If they are not interested, or deterred by e.g. loudness, queueing etc., they might refrain from approaching.
- **Disappointment** happens when a *bystander's* personal expectations do not match the actual experience, and is often caused by usability issues.
- **Discomfort** is caused when *audience members* are not successful in overcoming social fears such as unfamiliarity or crowdedness. This is more likely to happen when an installation requires interactions such as excessive gestures which possibly feel awkward to perform.
- **Withdrawal** happens when a *participant* has spent some time in the interaction zone, but drops out before transitioning to the actor role either because they feel exhausted or because of spatial and social influences.
- **Completion** is the canonical reason for dropping out and occurs when an *actor* has the feeling that they have depleted all possible or interesting interaction possibilities.

The researchers emphasize that any system should allow for different degrees of commitment, which can, for example, be achieved by deploying triggers that relieve discomfort by demonstrating the interaction possibilities. These triggers can be placed at spots where dropouts pass when backing away, so that they eventually re-engage with the installation. Additionally, dropouts can also influence bystanders and audience members by either being overheard by them or telling them about their experience. Even when there is no direct social interaction, bystanders might form an opinion by interpreting a dropout's face (e.g. if they look happy or exhausted) (Wouters et al., 2016).

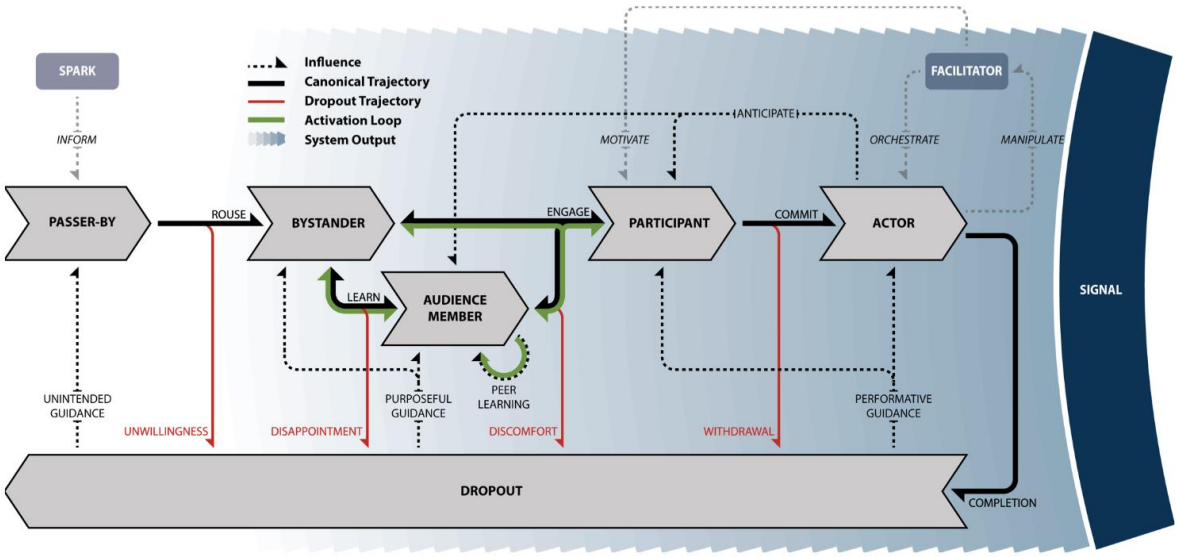

Figure 10. The Honeypot Model. The Graphic shows how, on the one hand, a user can pass from one user role to the next, and on the other hand, why they might drop out of the funnel at various points (Wouters et al., 2016).

2.2.2 Conveying Interactivity

When an installation has attracted the attention of a passer-by, the next important step is to make them notice that it is interactive. In a lot of cases, people will not expect that something in a public space has interactive capabilities and just walk by (Müller et al., 2012).

Müller et al. (2012) identified six techniques that can be used to communicate interactivity of interactive installations:

- **Call-To-Action:** The most common way of communicating interactivity is by using a simple text label on screen, such as “touch to begin”.
- **Attract Sequence:** A slideshow of images on the screen, which explain how the installation can be used. Through constant movement, they also attract attention. For example, in an idling state, machines at arcades sometimes use a looping video that explains the game by showing a person performing the interaction.
- **Analog Signage:** This technique can be posters or signs near the installation, which explain its purpose. It similar to the Call-To-Action method, but can also be more complex, like a printed manual. Another example would be putting markers on the floor to draw attention to the installation or to mark an interactive zone (Coenen, Claes, Vande Moere, 2017).
- **Honey Pot Effect:** As explained in chapter 2.2, audience members and bystanders can learn how to use the installation by watching participants. Wouters et al. (2016) call this the “Activation Loop”.

- **Persons inviting passers-by to interact:** Sometimes, users who have noticed the interactivity of an installation will try to motivate their friends or family to use it too. Researchers or instructors standing next to the device can invite users and explain the interaction as well.
- **Prior knowledge:** If a user passes the same device multiple times, they will already know how to use it. The same applies when an installation uses devices that are well known in general public (e.g. an iPad).

Depending on the type of installation, interactivity might also be recognized through signifiers in the surroundings. For example, smears on a screen would indicate that it is a touch screen. These properties of the environment are called "perceived affordances" (Müller et al., 2012). They can be used to design the environment around an interactive installation in a way that the decision whether a person wants to try and explore it comes at easy as possible: If a display, for example, does not provide any touch interactions, benches could be placed close to it. That way, users will be able to evaluate the interaction possibilities from a distance. Doing so can also make people more comfortable when approaching an interactive installation, since they tend to feel watched when others are nearby and refrain from exploring a system because of possible social embarrassment – a phenomenon called the "spotlight effect" (Gentile, Khamis, Sorce, & Alt, 2017).

While attract sequences and call-to-action methods are practical solutions to convey interactivity, Müller et al. (2012) describe another method: Since humans are very efficient at recognizing their own mirror images and human motion, they conducted a field study in which an interactive installation was placed in a shop window. By standing in front of the big display and moving the own body, users could "throw" digital footballs across the screen. The researchers tested three versions of the game – one showing no representation of the user, one showing their silhouette and one showing their mirror image as the "avatar" controlling the footballs. In addition, all three versions were also tested with a call-to-action message "Step close to play!" and a looping demo video. The results showed that the method with the most interactions was the one with the mirror image and without the call-to-action cue. This was because of a phenomenon the researchers call the **"landing effect"**: Often, people would pass by and see their mirror image for a brief moment, only realizing that the display is interactive when already having walked by. They would then turn around, walk back to the display and interact with it (Müller et al., 2012).

This way of implicit interaction has been used in various artistic installations, where digital clouds or flowers moved along with the passer-by. A lot of people discover the interactivity of such an installation "by accident" and then come back to explore it. When designing such an installation for public spaces, the authors

of the study recommend building it in a way that users have enough time to realize the interactivity when passing by (Müller et al., 2012).

Parker and Tomitsch (2017) describe three factors that influence the efficacy of an interactive installation. The factors overlap and influence each other and are referred to as the "interaction gulf" by the authors:

- **Position:** Before setting up an interactive installation, the researchers recommend observing the space at different times of the day and find out how it changes over time, to determine the best position for the system. If, for example, a display is to be put up outdoors, or indoors with large windows, there might be a time where the sunlight inconveniently reflects on the display. The installation could possibly also face towards the main source of people entering the space and be placed along the main paths people frequently use, so that it is recognized more often. However, the researchers also point out that placing the installation in a prominent place does also make users more prone to the fear of social embarrassment. Parra, Klerkx, and Duval (2014), who carried out a study with an interactive installation at a location with high traffic (i.e. a train station), note that in some cases, there is a trade-off between the social context of a place (how socially engaging it is) and the actual location (which might be highly exposed to passers-by flows).
- **Content:** People often prefer to use their smartphones to access local information – a trend that is likely to continue with increasing internet availability and general smartphone usage (ÖWA, 2017; Mindtake, 2018). Therefore, the interactive installation should not provide an experience that can easily be replicated with a smartphone, but one that is more unique to its location and purpose.
- **Function:** The functions of an interactive installation should be clear to the user from the very beginning. The time in which the application reacts to the user's interaction is also crucial, as a small lag can already lead users to thinking that the interaction is not working, making them leave (Marshall, Morris, Rogers, Kreitmayer, & Davies, 2011).

An important point raised by Müller et al. (2012) is that for some issues that might come up during the design of an interactive installation, one might have to find a compromise between the designers and the people responsible for the public space in which the installation will be put up in. For example, in their study with the interactive shop windows, the mirror image version of their game worked the best usability-wise. However, the shop owner liked the silhouette variant better, since it could feature the corporate colors.

2.2.3 Motivating Users to Interact

When users coincidentally come across an interactive installation in public space, they will need some kind of incentive to approach and use it. Generally, a person's motivation to use an application depends on whether they see it as a tool or a toy: A tool must be straightforward and easy to use, so the user can complete an external task. A toy, on the other hand, is used for its own sake and provides the user with a goal that they want to achieve (Müller et al., 2010).

In psychology, one distinguishes between extrinsic and intrinsic motivation. On the one hand, extrinsic motivation is based on getting a reward (such as money etc.) for completing a task. It also works through threats; however, no person will enjoy the task in this case. A problem with maintaining extrinsic motivation is that an individual has to be kept in a "reward loop" in order not to quit (Zichermann & Cunningham, 2011, pp. 16 & 26). On the other hand, intrinsic motivation originates from the task itself – the activity is its own reward (Michelis, 2009, p. 69f).

In his dissertation, Michelis (2009) identified five building blocks for motivating interaction in public spaces, based on intrinsic motivation: Challenge and Control, Curiosity and Exploration, Choice, Fantasy and Metaphor and Collaboration (Michelis, 2009, p. 84-111). These will be covered in the following.

Challenge and Control

This motivating factor is based on the notion that humans are motivated by mastering challenges (Müller et al., 2010). An activity becomes a challenge when its outcome is not clear from the beginning, but instead can be a success or a failure. The theory of "flow" has been picked up in game design theory and describes the individual's desire to progress. In any engaging task, a person experiences neurochemical rewards (the release of hormones like dopamine, serotonin etc.), but soon gets used to these feelings. Hence, the challenge has to become greater the more the user engages with the system. This is illustrated in Figure 11: If neither challenge and skill correspond to the user, they respond with apathy. If they have skill, they will first show interest. As soon as the challenge becomes more difficult, they will enter an aroused state until their skill starts to match the challenge and they enter a relaxed state. Ideally, the user stays in this flow – if either challenge or skill become too high, the user will experience anxiety or boredom, respectively (Sellers, 2017, pp. 153f).

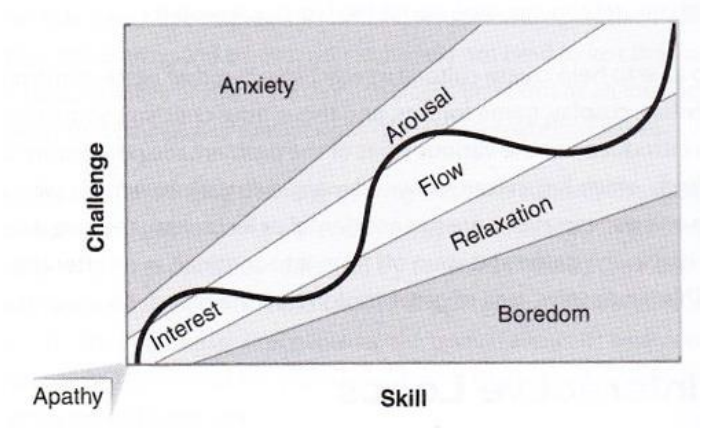

Figure 11. Interaction Flow – The higher the skill of a user is, the higher the challenge should become, so that the user stays in a constant flow between arousal and relaxation but never reaches boredom or anxiety (Sellers, 2017, p. 154).

Curiosity and Exploration

Curiosity is one of the most important foundations for intrinsic motivation. It is described as a precursor to explorative behavior, since humans strive to gain unavailable information about their environment whenever something is unclear or incomplete. When creating an application for public space, the interaction should be designed in a way that it is novel and surprising, but not incomprehensible – the desired user behavior can be activated by surprising elements and maintained through constructive elements (Müller et al., 2010). Michelis (2009, pp. 94ff) describes two kinds of curiosity: Elements that induce **sensory curiosity** are graphics, animations, music and sometimes also haptic stimuli. **Cognitive curiosity** originates from the described drive to complete cognitive frames, similar to when one wants to know how an interesting novel ends.

To create motivation through curiosity, an approach would be to convey a feeling of incompleteness or contradiction to the user, but offer to eliminate it through interaction (Michelis, 2009, p. 96).

Choice

Another motivating factor is when an individual is given the possibility to make active decisions concerning their behavior. Even when the presence of choice only exists in their imagination, the existence of a motivating effect was proven. The more choices are given to a user, the greater their perceived autonomy becomes, although a number of choices that is too great can also lead to a decrease in motivation (Müller et al., 2010). For example, common choices that are given to a user, but still enhance motivation, are personalization options such as choosing a name, avatar or theme (Michelis, 2009, p. 99).

Fantasy and Metaphor

Paras and Bizzocchi (2005, p. 5) describe the use of fantasy to enhance motivation in a game in the following way: “Fantasy has to do with the scene in which the activity is embedded; this should aim to intrigue the user, and provide an attractive setting.”

Fantasy is not only used to create a context that enables the user to immerse themselves in a game to fully participate – it can also help to create metaphors in an application which make it seem closer to “real life”. Whenever people feel unsure with the required interaction of a (public) system, they avoid using it. By incorporating elements which users are already familiar with into the design, this uncertainty can be overcome. An example for this is the metaphor of a personal computer having a “desktop”. Seen from a technical side, abstracting the classic command line interface to make it look like a desktop was more of a hassle. This metaphor, however, made it possible for people with non-technical background to understand and perform the interactions with the computer. Online shops use a similar technique: By calling it “shopping cart”, the feature does not need any more explanation, since users are already well familiar with the concept (Michelis, 2009, p. 102ff).

When using abstract metaphors, such as icons on a GUI (graphical user interface), Harley (2014) strongly recommends using text labels to clarify their meaning, since there are only few standardized icons. Otherwise, users might not interpret it in the right way and refrain from using parts of the system. Additionally, Harley (2014) notes that when designing an own icon for an application, the 5-second rule should be used: If it takes longer than 5 seconds to think of an appropriate icon for something, it is unlikely that it can effectively communicate the supposed meaning.

Collaboration

The last of Michelis’ (2009) five building blocks is based on the interaction with other people. As humans are social beings, seeing the effects of one’s own behavior as well as its influence on other peoples’ behavior has a motivating effect. This does not only apply to face-to-face situations, but also to social interaction over the Internet. In general, the collaboration aspect can be split in two parts: cooperation and competition, and the motivating effect of both greatly depends on each individual user, their preferences and their cultural background. For example, people who have a cooperative orientation also hold the preferences of others important. When creating an application in which cooperation plays a role, the correlation between each user’s interaction has to be shown in order to make use of the motivating factor. People who prefer competition seek to maximize their own preferences in relationship to the preferences of others, which is why in these cases it is especially important to

make an individual's efforts visible to other participants. If a user's success is recognized, they are motivated to repeat their behavior again.

Gamification

By far one of the most powerful motivators in existence are games. Being the combination of Michelis (2009) building blocks, games have shown to be able to get people to take actions that they would usually not take, without the use of force, and in a predictable way (Zichermann & Cunningham, 2011, p. 15). In 2016, the company Niantic released "Pokemon GO" and with it mobilized millions of people who collectively walked 8.7 billion kilometers, which is about the distance to the end of the solar system (Iqbal, 2019). The game "Where in the World Is Carmen Sandiego" was a blockbuster hit and motivated children to study geography – even though it was not designed as a learning game (Zichermann & Cunningham, 2011, pp. 3f).

Zichermann and Cunningham (2011) describe the most important gamification elements that can be used in an application to increase user motivation:

- **Points** show how much someone has progressed in a game. There are also redeemable points, which are more of a virtual currency – retail companies use a similar system in a form of "loyalty points", where collecting a certain number of stamps rewards a customer with a free item.
- **Levels** also indicate progress, and like with points, people will often compare levels, competing to beat each other.
- **Leaderboards** are based on the competitive factor of levels and points. A good leaderboard always displays a few players with a higher, and a few with a lower score, motivating a player to climb up the ladder.
- **Badges** as a sign of social promotion have been around for a very long time. For a lot of people, collecting them is a powerful drive, as an addition to the fact that they display what someone has achieved.
- The first moments of a user's experience with an application are crucial – a clever **onboarding** can make someone immediately recognize a system's purpose. Demanding a registration, for example, is a barrier for using an application, since a user cannot explore its purpose before giving away their data.
- **Quests** help users define goals in an application and add a meaning to the commitment towards a game.
- **Social Engagement Loops** are based on people re-engaging with a system as soon as someone else in their environment engages in the system as well.

- **Customization** is based on the power of choice (see chapter 2.2.3). While it might not be relevant to the game itself, personalizing even small parts, like a name, an avatar or colors, can already be very motivating to users.

2.3 Incorporating Personal Devices into Interactive Installations

When included in an otherwise static interactive installation, personal devices offer a whole new layer of interactivity. In a lot of cases, smartphones play the key role of a multi-device experience. Through their portable, personal nature, they constitute perfect control tools – for example, they can be used as a remote, or to augment content of a public display (Clinch, 2013; Levin, 2014, p. 146). Prior research has shown that they do not only have to function as input devices, though. Rukzio, Müller, and Hardy (2009) created an interactive installation for pedestrian navigation, where the personal phone served as an output device, vibrating as a haptic feedback whenever the desired direction was shown on a public display.

Clinch (2013) defines four roles a personal device can have in a multi-device context:

- **Personalization:** Information or interaction possibilities can be split between devices, with public parts being accessible to everyone and private parts being restricted to the user's device. As users can also be recognized through their smartphones, public displays can show personalized content when a user approaches. As described in chapter 2.1.1, an example would be a racing game where a large display is the main screen and the smartphones are the controllers. Each user could join the game and have their favorite car and racer set right from the start (Levin, 2014, p. 101).
- **Interaction:** As previously mentioned, smartphones can act as a device for interacting with the rest of the installation.
- **Co-Displays:** Through their private nature, smartphones form an excellent counterpart to public elements of an interactive installation. Depending on the purpose of the installation, the smartphone can augment the content of a large display and form an "individual view" that is uninterrupted by other people who might be moving around the installation. The display can also be used to share data from the smartphone or provide it with more display space.
- **Information Take-Away:** While an interactive installation will usually be stationary, a great feature of smartphones is the ability to take away

content from the installation, similar to traditional tear-off strips on analogue signs, but more powerful, as the content can be much more than a piece of paper.

Examples Personal Devices and MDEs

Müller, Otero, Alissandrakis, and Milrad (2014) created a multi-device setting with the aim of helping students to learn by encouraging reflections on the content. A large display showed videos and hosted quiz sessions where users could participate with their smartphones by downloading a mobile app. The videos were supposed to attract attention and encourage discussions between students, while the quizzes offered a fun way to foster the knowledge gained through the videos: A question was shown on the display, students could choose between answers that were displayed on their smartphones and the results were visualized back on the display.

The display was installed at two different schools; a general public middle school and a technical middle school. After registering in the app, the users were ready to join the interaction. One fact which the researchers noticed was that the registration proved to be a participation barrier especially in the technical school, where students reported to have had privacy concerns. Generally, the participation was higher in the general middle school. The researchers pointed out that one strong reason for this was one teacher who proactively advertised the installation.

Another detaining factor seemed to be that with the initial design, the students could not anticipate when new content was available for user interactions. The researchers tackled this problem in a subsequent study, where they added a timer animation to the public display, which showed when the next piece of content would be displayed. The feedback on the timer feature was very positive. Students reported finding it engaging, since they could plan the consumption of content without spending unnecessary waiting time at the display. Additionally, it caught passers-by attention and made them stop and wait for the upcoming content item (Müller, Alissandrakis, & Otero, 2016).

Schmidt, Seifert, Rukzio, and Gellersen (2012) experimented with different interaction possibilities between smartphones and interactive surfaces (such as multi-touch tables). They took the smartphones' technical capabilities into account and invented interaction techniques which involved handling data by touching the public display not only with the finger, but also with the smartphone itself. For example, the phone could act as a personal clipboard. By touching elements on the multi-touch table, the element was added to a list shown on the smartphone screen, and by selecting one of the elements on this list and touching the surface, the object reappeared. This could also be used in a way

that the user selected a person from the contacts on their phone and touched an address field on the multi-touch table, which was then filled out automatically.

Another interaction was to touch one point of the large screen with the smartphone and perform a drag gesture with the other hand. This formed a “bubble”, in which the underlying text was translated to the user’s preferred language.

Schmidt et al. (2012) also devised interaction possibilities for handling private data on public screens. One conceptual approach was placing the phone on the multi-touch surface, which created a little “private shadow” under the device with which the user could interact through regular touch gestures.

Lastly, they also included the smartphone’s rotation and tilt sensors to create an interaction technique which enabled users to adjust the value of sliders or rotary buttons by moving the phone accordingly. Figure 12 shows some examples of the usage of Schmidt’s et al. interaction techniques (2012).

Figure 12. Phone-Table Interactions by Schmidt et. al (2012). From left to right: A private touch area under the personal device, adjusting rotary buttons by tilting the device, forming a personal translation “bubble”, picking up elements from the table with the smartphone.

Examples of Personal Devices and MDEs in a Museum Context

Some of the earliest research on personal devices and MDEs in museums was carried out by Dini, Paternò, and Santoro (2007), who built a multi-device environment in a museum which incorporated PDAs as devices that could be carried around by users. Through infrared beacons, which had been installed at the entrances of each exhibition room, the system knew where which user currently resided, making the PDA a location-aware, personal museum guide. It was also possible to connect to local public displays to join riddles and guessing games with other visitors, and the PDA visualized which games had already been played and which were yet unexplored. Even though PDAs were not as ubiquitous at that time as smartphones are today, Dini’s et al. research still formed a good foundation for further work on the topic.

Haakvort (2013) emphasizes that one of today’s challenges of museum exhibitions which include technological elements is to make those elements as unobtrusive as possible. He identifies the smartphone as the first device which meets this expectation: It is carried around by the visitors and removed from the

exhibition when they leave. They have the same capabilities as traditional devices like audio guides etc. and therefore form a low-cost alternative for museums. Through the multitude of sensors they include, they also offer a whole range of new possible user experiences while preserving one important aspect: The users know their smartphones and are familiar with their usage (Hakvoort, 2013).

Kostoka et al. (2013) conducted a study about how museum visitors share their experience with others and how technology can help them take away content and memories from the exhibition. Through QR Codes and NFC tags, people could "bookmark" their favorite exhibits with their smartphone and later received an e-mail with the chosen content. They concluded that visitors like the idea of bringing home information about the exhibits they saw in the museum.

Hakvoort (2015, pp. 39ff & 67ff) describes a vision of an "Immersive Museum", where static exhibits (historical objects etc.), interactive exhibits (multi-touch tables and interactive displays) and the visitors with their smartphones form a network of interconnected systems. He conducted various studies in a "simulated museum" (It featured real exhibits, multi-touch tables and -walls like a museum, but was equipped with an adjacent observation room and tracking systems) to determine the social aspects of using a smartphone as a central part of an exhibition. The applications on the multi-touch devices could all be explored without a smartphone, but an additional mobile app allowed to connect with the interactive exhibits to experience them further. This way, both solitary and social experiences could be evaluated. Examples from the studies included "collecting" exhibits by scanning NFC tags with the smartphone and then connecting with the multi-touch table to digitally place the exhibits on the large display, which showed their point of origin on a map. Other visitors could also see which exhibits were placed on the table by which users.

The results of Hakvoort's (2015, pp. 61ff & 151ff) studies revealed that the spread interactions throughout the whole museum were well received as new museum experiences. Although the learning curve when first being confronted with the system was steep, participants quickly picked up the novel interaction modalities. Incorporating the users' devices into the exhibition allowed visitors to have both private and social interactions with the exhibits themselves and the multi-touch elements, respectively.

As a central finding of his thesis, Hakvoort (2015, pp. 60f) suggests that when using a smartphone for user interaction within a museum, the device should be treated as an integral element of the intended interaction. Using it for only part of an interaction results in the smartphone becoming an inconvenience which the user will try to resolve.

Jimenez & Lyons (2011) studied the usage of smartphones in museums more closely. They developed a game in which museum visitors could connect to a shared display via their smartphones and solve a puzzle together. There were different ways of how the puzzle pieces could be moved around, and the researchers studied which method was the best one for a collaborative museum game. The interaction methods were a simulated D-Pad (arrow buttons on the screen of the smartphone), touch gestures on the screen of the smartphone, and tilt movement. They found that the D-Pad was the easiest to learn, but the touch gestures were more enjoyable and useful. The tilt movement interaction was the most difficult to learn and use, although some of their participants ranked it as the most enjoyable. Jimenez & Lyons (2011) conclude that ease of use and ease of learning do not always come together. When designing the interactions for a shared-display interactive exhibit, one has to find a balance between these two factors, since the installation should be enjoyable on the one hand, but easy to understand on the other hand, to avoid visitors dropping out of the interaction early on.

Banerjee, Robert, and Horn (2018) built on Hakvoort's (2015) findings and experimented with replacing the smartphone in museum exhibits with a smartwatch (The concept of connecting the personal device to a stationary large display and saving interesting exhibits was the same). They carried out their study in a large natural history museum with over 45 interactive displays in the exhibition. The researchers remark that carrying a smartphone in an exhibition might lead to visitors spending more time looking on its screen instead of at the actual object. They propose that smartwatches are less distracting, only show information that can be consumed with a glance and direct the visitors' attention back to the exhibit. However, the author of this thesis finds that as of 2019, smartwatches are not prevalent enough to be used as a viable part of a museum exhibition – according to a survey (We Are Social & Hootsuite, 2018), only 6% of the people in Austria owned a wearable device in 2018, and renting them would again lead to problems which the smartphone as a ubiquitous device can overcome.

2.4 Evaluating Public Interactive Installations

While applications which are used in private environments can be tested fairly easily, public ones are heavily influenced by the environment they are put up in. They usually have a very broad target group, and foreseeing the behavior of the people is almost not possible due to the many different users at different times of the day. Additionally, the content which public installations provide has a great impact on how it is used, which is why the results of studies conducted on one

specific public installation will often not be valid for another (Alt, Schneegaß, Schmidt, Müller, & Memarovic, 2012).

Alt et al. (2012) describe three kinds of validity of user test results:

- **Internal validity** describes the amount of control which the test conductors had or have over confounding variables.
- **External validity** describes the generalizability of the results, i.e. if they also apply to other settings and situations than the one prevalent during the test.
- **Ecological validity** describes how close the results are to those that would have been achieved in a realistic situation.

These three kinds of validity cannot be achieved at the same time – the focus of a study can only lie in one of the three, and the two others will be partially sacrificed. This is especially true for public interactive installations which often show a large difference between the results of a test carried out in a lab setting and those that are achieved “in the wild” (Alt et al., 2012):

On the one hand, in a lab study, internal validity is very high. A controlled environment makes sure that sensitive equipment such as sensors and tracking devices functions correctly without any interferences, and it can be assured that the prerequisites for the test are the same for all participants (same prior knowledge, same test devices etc.). External influences such as other passers-by or general environmental conditions can be minimized.

Field studies, on the other hand, include exactly these external influences. This greatly reduces the internal validity, but increases the ecological validity by the same amount, because aspects such as effectiveness, social effects, audience behavior and privacy implications are almost impossible to measure in a controlled environment like a lab. When conducting multiple consecutive field studies, Alt et al. (2012) talk about “Deployment-Based Research”. In this special kind of field research, the results of one study are used to improve the application for the next study, where other research questions can be addressed. Through this method, the application is integrated into the intended use scenario in the most realistic way, and new insights can be gained during each evaluation iteration. Both field studies and deployment-based research require a lot of resources and are rather time consuming, but since public applications are in fact mostly influenced by factors that are only measurable on site, they are the most suitable options.

Alt et al. (2012) also outline five classical data collection methods that are suitable for evaluating public interactive installations:

- **Interviews**, often semi-structured, are a powerful method to assess the users' opinion on the installation and find out about concerns and problems. Semi-structured means that the study conductor follows pre-defined guidelines for the interview, but can deviate from them if they discover interesting findings that they would like the users to elaborate on.
- **Questionnaires** are a good method for quantitative evaluation. They can be standardized and used to judge usability, or be customized to find out about users' opinions on certain aspects or the performance of the installation. A well-known questionnaire is the System Usability Scale (SUS) (see Brooke, 2013).
- **Focus groups** usually consist of five to eight people. A session lasts about one to two hours and includes a demonstration of the prototype of the application. The researcher leads a discussion based on certain guidelines and tries to answer the research questions. The advantage of this is that feedback can be obtained early in development, but depending on the group constellation, some people might not have the courage to state their honest opinion.
- **Observations** are the most powerful tool for evaluating public interactive installations since they allow assessing audience behavior, effectiveness and social impact both ad-hoc (e.g. by taking notes on site) and post-hoc (by analyzing video footage). Usually, the observers or the cameras are hidden from the users, so that they behave in a more natural way than they would do during any study where a researcher is visibly present. This ensures the highest ecological validity. The drawback of observations is that it is often not clear why users acted in a certain way, hence why they are often combined with subsequent interviews.
- **Logging** (e.g. the number of clicks, time spent on a certain screen etc.) can be used if the installation is tested over a long period of time, since a lot of data can be collected with low effort. A disadvantage is that some logging may concern personal data, which might be an issue in a public setting.

Summary

The term "multi-device" is used for multiple scenarios: Sometimes, the term might be used when an application works consistently on different kinds of devices, even when these devices are not connected in any way or belong to the same user. However, the definition of a "multi-device environment" used in this thesis requires the devices to have the interaction possibilities spread among the devices and ideally form a unique interactive experience. Levin (2014, p. 21-129) describes the "3Cs framework" which describes three approaches for multi-device application design: The "Consistent Approach" (when the devices are not

connected in any way, as described before), the “Continuous Approach” (when an application is designed in a way that a goal can be achieved by using multiple devices one after another), and the “Complementary Approach”, which corresponds to the definition used in this thesis in the best way. In this approach, the different devices form the interactive experience together, at the same place and time. MDEs can also be a mix of more than one of the 3C approaches.

When designing an interactive installation, one of the greatest challenges is the users’ fear of social embarrassment – people will almost always try to maintain a social role and hence behave differently in public spaces than they would do in private. This issue has been addressed by various researchers, who created different interaction models for public interactive installations and described the thresholds between the interaction phases, the challenges of overcoming them and the phenomena which commonly occur (such as the “honeypot effect” – the effect where people curiously approach crowds – and the “landing effect” – where people realize the interactivity of an installation by accident and then come back to investigate it further). In general, there are three steps an installation has to take before a user interacts with it, which are 1) attracting attention, 2) conveying interactivity and 3) motivating the user to interact. These steps will also be important for the success of the interactive installation developed in the course of this thesis. However, our concept does not only include stationary devices, but also personal, portable devices, which become a part of the MDE. Since the personal devices play a distinct role in MDEs (they can be used for personalization, interaction, information take-away or as co-displays), the thresholds within our interactive installation are likely to shift (e.g. a visitor will not have to stand directly in front of the large shared display in order to interact), and the interaction models found in scientific literature will not fully apply.

This chapter also described evaluation methods for public interactive installations. Because of the fact that people behave different in private than they do in public, lab studies are not suited for evaluations of public interactive installations. Eligible evaluation methods include on-site interviews and observations, questionnaires, focus groups, and software-sided logging.

The next chapter covers the design process of the interactive installation which was developed in the course of this thesis.

3 Designing an MDE for a Museum

In the course of writing this thesis, an interactive multi-device environment was created and deployed in the monastery museum in Klosterneuburg. It was part of the annual exhibition “The Emperor’s New Saint”, which was open from March 9th to November 17th, 2019. As a memorial for the 500th anniversary of the death of Emperor Maximilian I, it thematized him and Margrave Leopold III at a time of media in transition. We worked together with the curators of the exhibition to create interactive content which, on the one hand, served research purposes, and on the other hand, could impart knowledge to the visitors in a pleasant way.

This chapter summarizes the design and concept process behind the installation and describes its functions.

3.1 Concept and Setup

The exhibition in the monastery museum followed a story: When the user downloaded and opened the exhibition app (which was also developed as a part of the MEETeUX project) on their personal device, they were greeted by Emperor Maximilian, who told them that they were not yet worthy of sitting on his throne, since they did not have their own coat of arms. As the visitor advanced through the exhibition and interacted with different exhibits, they would unlock parts for their own coat of arms, which they could assemble inside the app.

As an interactive exhibit, the installation which was created as a part of this thesis had to fit in this story. Theme-wise, it was to present one of Maximilian’s biographies, the “Weisskunig”, a book containing 251 woodcut illustrations about the life of Maximilian and his deeds. In a brainstorming workshop with the curators, the following idea of a game came to be: Emperor Maximilian grants an audience only to people who know enough about his life and who have a certain social status, i.e. belong to bourgeoisie or nobility. The visitor starts with the status of a beggar, but can work their way up the social ladder by answering questions about the emperor correctly. Maximilian (as the character who leads the visitor through the exhibition) shows the visitor pictures from the Weisskunig as well as a matching question with four possible answers. The Weisskunig images and the questions were provided by the curators. The game was simply named the “Weisskunig Quiz”.

We came up with a setup consisting of three stationary devices and the own devices (e.g. smartphones and tablets) of the visitors, which are also visible in Figure 13:

- The images from the Weisskunig, questions, answers, a timer and the visualization of the given answers were shown on a large, wall-mounted, 65-inch screen with a resolution of 3840 x 2160 pixels. It was the central element of the multi-device environment, prominently facing towards the “entrance” of the space where the installation would be set up. The initial idea was to use a projector instead of the screen, but the black wall at the destination space and the clear difference in financial costs led to the decision of going for a screen.
- A 42-inch monitor served as the “guest list” of the emperor’s audience – a sort of leaderboard which showed the usernames of the visitors who had managed to earn enough points to become part of the bourgeoisie or the nobility. It was mounted on the right wall of the installation space in portrait orientation.
- In case visitors did not have a suitable device to join the game or had not downloaded the necessary app for any reason, we decided to install an iPad as a stationary device to play. The first plan was to put the tablet on a kind of speaker’s desk in front of the large main screen, to make it clearly visible and emphasize that it is supposed to be interacted with. However, this was changed by the curation team who believed that it would not fit into the exhibition’s design. Instead, the tablet was put in a metal frame and chained to the left wall of the space as an anti-theft measure. A little stool was provided so that visitors could hold the heavier tablet on their lap while playing.
- The last element of the installation were the own devices (ODs) of the visitors. If the visitors had downloaded the app, they could join the game by simply pressing a “Join Game”-Button. Then, the question and the answers as well as the timer were displayed on the ODs and the visitors could select their guesses.

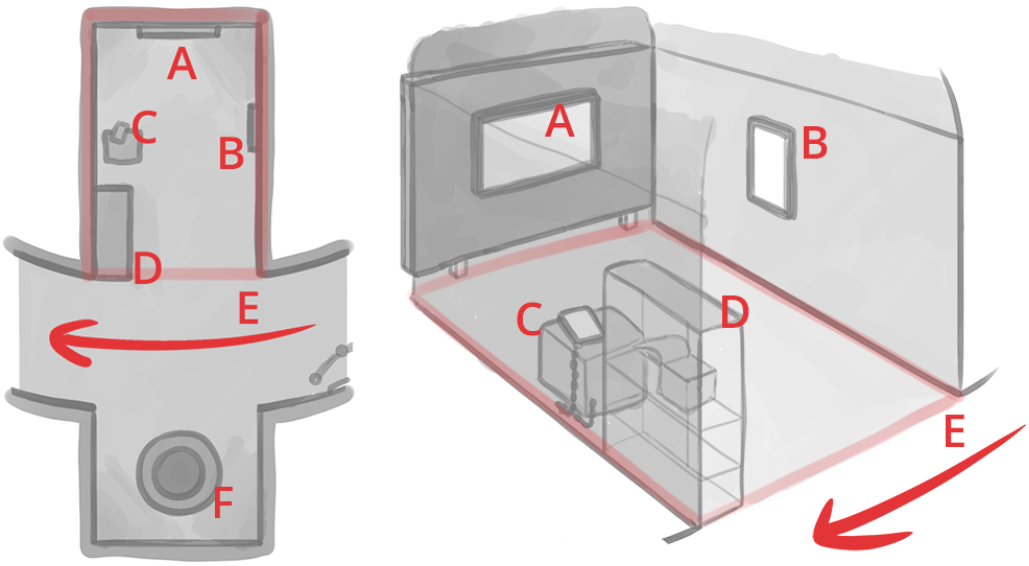

Figure 13. The setup of the multi-device environment. On the left sketch, the niche and its surroundings can be seen from above. The right sketch is a 3D representation of the niche only. (A) The large main screen. (B) The smaller screen for the guest list. (C) The stool and the stationary tablet, chained to the wall. (D) A vitrine with a book showing emperor Maximilian on his throne. (E) Intended path through the exhibition. (F) Immovable baptismal font, unrelated to the installation.

3.2 Design Iterations

The screens of the game underwent multiple design iterations until the look was fixed. Feedback from the MEETeUX team concerning possible usability issues and technical feasibility as well as requests from the curators of the exhibition influenced the design process.

3.2.1 Large Main Screen

The main screen should show the Weisskunig image, the question and the answers, and visualize the results of each round. Figure 14 shows one of the first mockups, which used a bar chart to visualize the answer distribution.

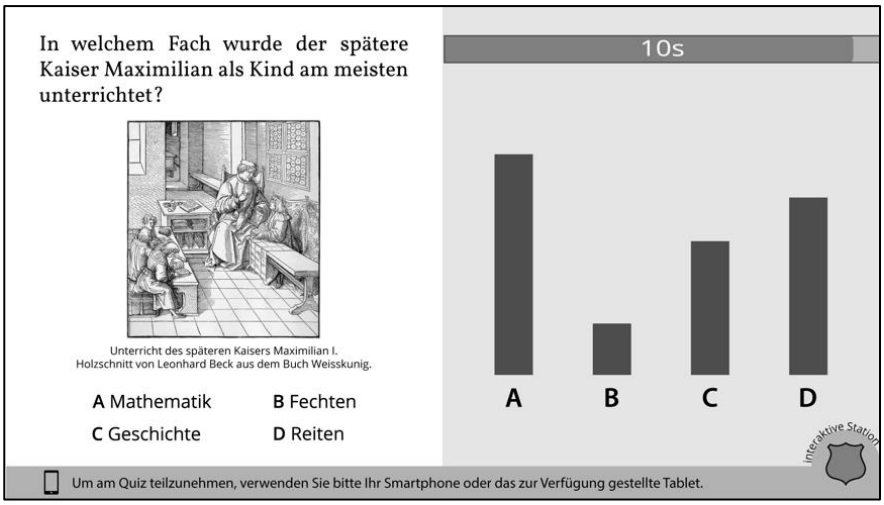

Figure 14. One of the first mockups for the Weisskunig Quiz. The left side shows question, image and answers, while the timer and the answer distribution in the form of bar charts are shown on the right side. At the bottom, an icon and a text indicate that a visitor can join the quiz.

Since the large screen was also the central element of the game and the first object that visitors would see when they passed the niche in which the installation was set up, it needed to be the eye-catcher in the setup and also immediately show the visitors what they should expect from it.

As described in chapter 2.2, an interactive installation first needs to attract attention, then communicate its interactivity and lastly, motivate the users to interact.

To attract attention, the screen was mounted facing towards the entrance to the niche. In addition, the large image from the Weisskunig should catch the viewer's eye. The timer, apart from telling the user how much time they had for choosing an answer, served two causes: On the one hand, since humans tend to respond well to movement, its animation contributes to the attention-raising factors. On the other hand, it is a well-known element and tells the viewer that they can anticipate new content and how long a possible interaction will take, which can motivate them to watch longer and eventually join.

To include additional animations and make the interaction flow more interesting, we decided that each time a user selects an answer on their OD, this action should be visualized on the large screen as well. Each given answer should be represented by a "bubble" that would fly onto the screen as soon as an answer button was tapped on a participant's OD – a design approach inspired by Huron, Vuillemot, & Fekete (2013), who used a similar technique to visualize incoming Tweets during a live TV show. The different design approaches are shown in Figures 15 to 18. Figure 15 shows the first version of the "answer bubble" design.

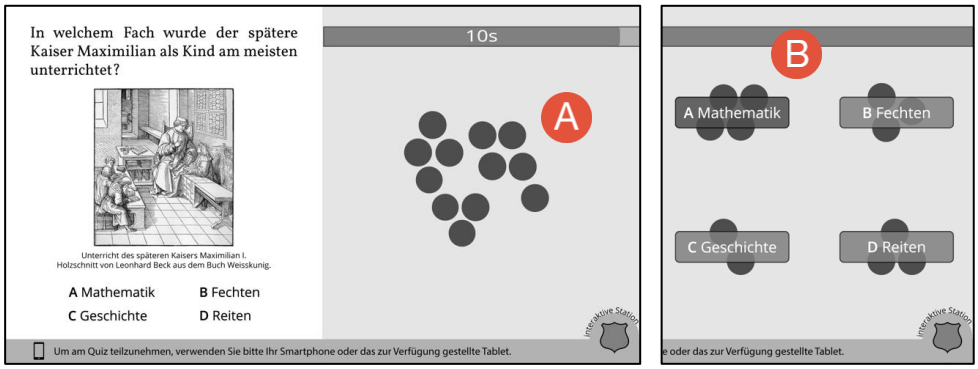

Figure 15. Left: The first idea of the "answer bubbles". The left side of the screen once again shows the question, the image and the answers. As soon as a user taps on an answer on their device, a bubble flies in and lands on the right side of the screen (A). Right: When the timer reaches zero, boxes with the answers are displayed, the bubbles move to their respective boxes and the correct answer is highlighted (B). This way, it is visualized how many people answered the question in this round in total, and how many chose which answer.

In a meeting with the curators, it was brought up that the design in Figure 15 looked too sterile and did not have much to do with the theme or design of the exhibition. Figure 16 shows an attempt of using wine drops and medieval goblets as a metaphor for the answer distribution. The text in the timer, which initially indicated how many seconds exactly were left, was cut out due to a contrast and readability problem that would occur as soon as the timer bar passed the text.

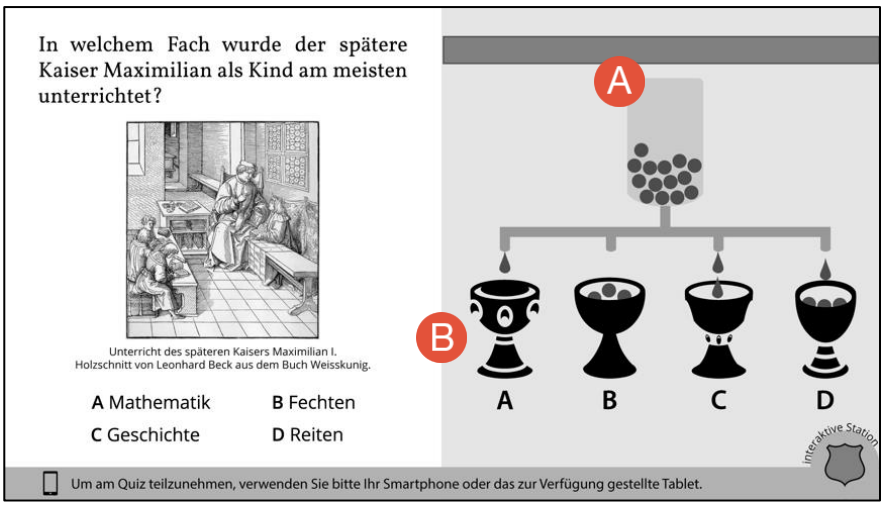

Figure 16. A more stylized attempt on visualizing the answer distribution. The answer bubbles still fly in from offscreen and land in a vessel on the top right (A). When the timer reaches zero, the bubbles become "liquid" and run through the funnels to land in the goblets that correspond to the answers (B).

We, however, found that the goblet approach looked too crammed and left little possibilities for adding text like additional information or the number of answers.

The form of the goblets took away a lot of space so that not many bubbles could fit into them. The animation of the bubbles flowing into their respective bubbles did also not feel as clear as in the previous design.

The next approach was the “hourglass” approach, which is shown in Figure 17. Up to this point, the procedure was always as follows: Users would choose an answer, and the answer bubbles would assemble at a certain point on the screen. Only when the timer reached zero, the bubbles would move to their respective answers, revealing which of them was chosen how many times. In the hourglass approach, the bubbles would fly to the upper part of their respective hourglass (each hourglass represented one answer) right after the user made their choice. Combining the goblet and the bar chart approaches solved the screen space problem and added another information layer: When the timer reached zero, the bubbles would fall down into the lower part of the hourglass, and bars would rise from the bottom, indicating how often the answers were chosen in the past exhibition days. We liked this reintroduction of the bar charts from the first draft because they are easily readable and well-known among the people who visit the museum (Black, 2009, p. 28).

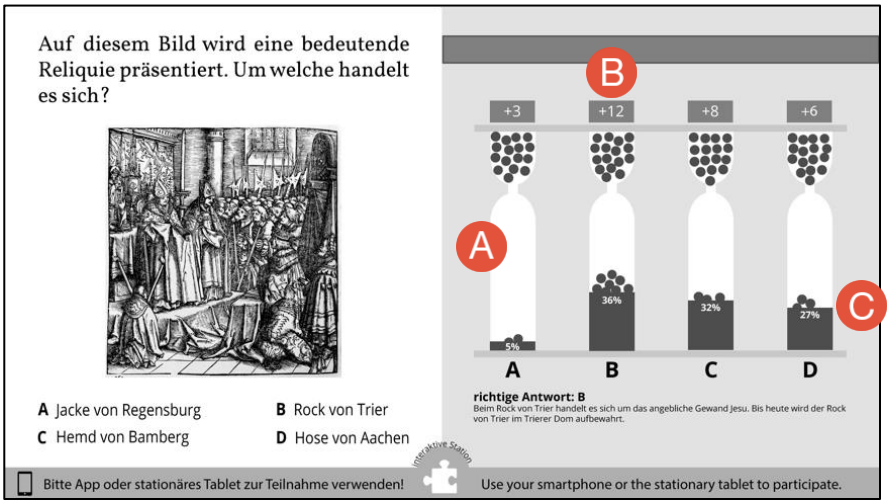

Figure 17. The hourglass approach. In this abstract bar chart visualization, the answer bubbles assemble in their hourglasses. While the timer is running, the lower parts of the hourglasses are empty. Only when it reaches zero, the bubbles fall down and merge with the bars that rise from the bottom (A). Above the hourglasses, a little box shows how many times the answer was chosen in this round (B). In the bars, one can see how often the answers were chosen in total (C). This is shown in percent.

However, there were still a few flaws we noticed in the hourglass approach: First, our mechanic of “collecting” the bubbles in the upper part of the hourglass was in contradiction with the function and mental image of a real hourglass, where the sand continuously flows and can’t be started or stopped at will. Additionally, hourglasses are usually connected with temporal data, which we did not have in

the Weisskunig Quiz. Therefore, we changed the hourglasses to “pillars”, which also work better as a metarphor for the bar chart visualization. The boxes which showed how many times an answer was given in a round were moved to the middle of the pillars, because showing the percentages inside of the bar would have led to problems if the bar was very small or nonexistent. The animation sequence itself stayed the same, as shown in Figure 18.

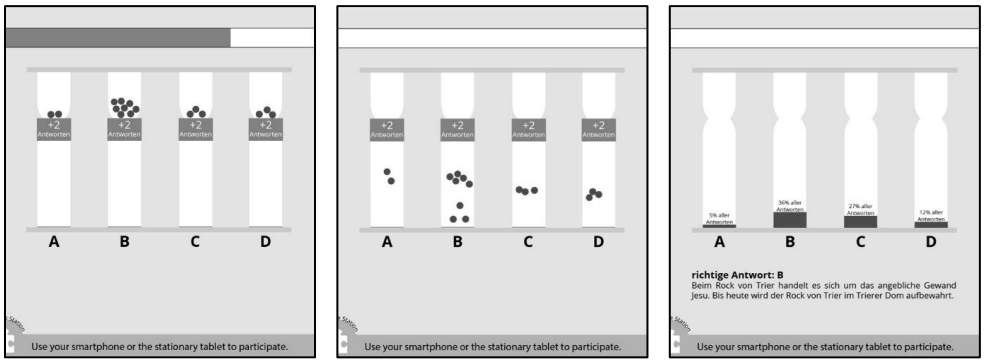

Figure 18. The pillar approach. First image: While the visitors are choosing their answers, the bubbles assemble in the top parts of the pillars. The boxes show how many times an option has been chosen so far. Second image: When the timer reaches zero, the bubbles fall down the pillars and vanish when they hit the bottom. Third image: At the same time, the bars of the bar chart start rising. A text above them shows the answer distribution in percent. Under the pillars, a text with more information about the correct answer is displayed.

The first pillar design in Figure 18 still had one problem: One could not see where the theoretical “top” of the bar charts was (i.e. where the 100% mark was – was it the top of the pillar, the narrow part, or somewhere in the bottom part?). For the final design, this was solved by adding a line near the middle of the pillar to better visualize this “border”. The percentages of the answer distribution were also moved above this line, since otherwise, they would lead to a similar contrast problem as the text in the timer bar had. Additionally, since one could never know how far a bar would rise, the text could either not have enough space within the bar (if the bar was very small) or above the bar (if it rose to a high value like over 60%). By simply showing the text outside of the bar chart, this problem was avoided. This is shown more closely in Figure 30 in chapter 3.3.

Inside the exhibition app, the sections of the exhibition were color coded – to keep the colors consistent and avoid possible confusion, we chose the same colors as those of the corresponding section for all screens of the game. We also assumed that when a non-German-speaker would look at the screen, they might miss the smartphone icon which was located only at the “German side” of the message at the bottom of the screen, which is why the icon was changed from the puzzle part to a tablet-and-smartphone icon, and the single smartphone icon at the left was removed to make the text more symmetrical. Minor design

adjustments such as the font size were also made in the final design, which can be seen in Figure 19.

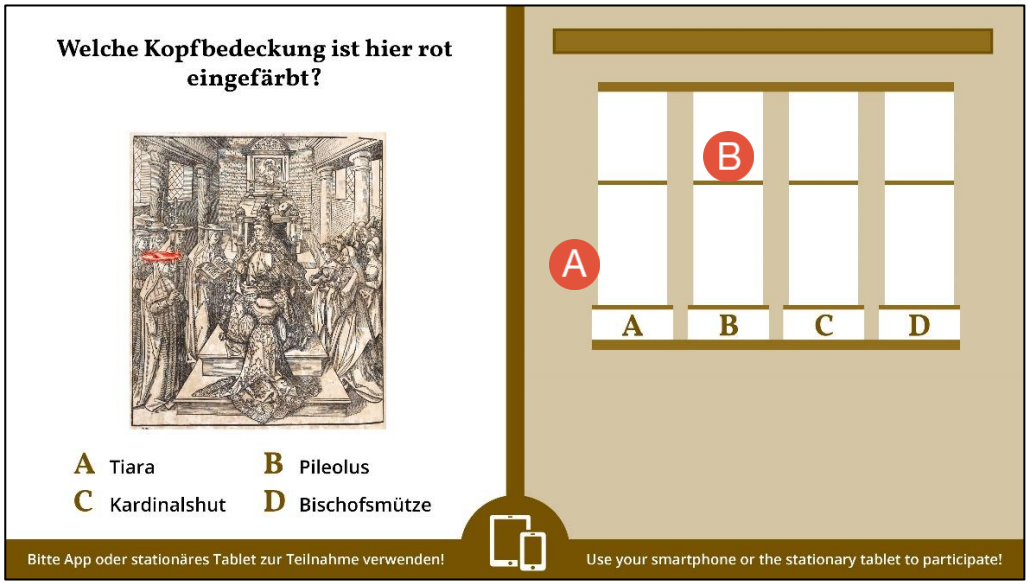

Figure 19. The final design for the large screen. The pillars (A) look more like pillars, and lines (B) were added to mark where, on the one hand, the 100%-mark of the bar chart was, and on the other hand, where the bubbles assembled and later fell down from.

3.2.2 Mobile Application

The own device of the visitors served as the input devices for the game. They had to display the buttons for the answers and also the question – this was because the ODs also served as personal language channels. While the large screen was German only (except for the message at the bottom, which was displayed in both German and English), the ODs' interfaces were always in the language that the visitors had chosen when they downloaded the exhibition app. As mentioned in 3.1, the mobile part of the Weisskunig Quiz was only accessible through a "Join Game" button in the exhibition app (or via the stationary tablet). Figure 20 shows a very early mockup of the mobile part of the game.

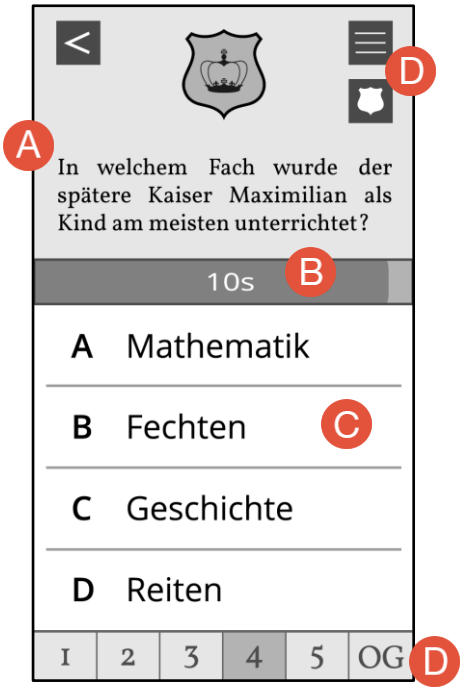

Figure 20. The first design approach on the mobile screens. It shows the question (A), the timer (B), the answer buttons (C), and also many elements that were soon removed as the concept of the overall mobile app advanced (D).

This screen in Figure 20 still shows the navigation bar, the hamburger menu and the coat of arms button (located under the menu button) that had little to nothing to do with the Weisskunig Quiz. This was because at the point of this design, the concept of the whole app was not finished, and it was unclear how the "sub games" would later be integrated. Eventually, it was decided to open the sub games as an overlay that could be closed with a simple button.

Figure 21 shows three variations of the second design draft of the mobile screens, which already include the "leveling system" that was part of the story of the game. Again, the text that indicated the number of seconds left to answer was later removed because of contrast problems.

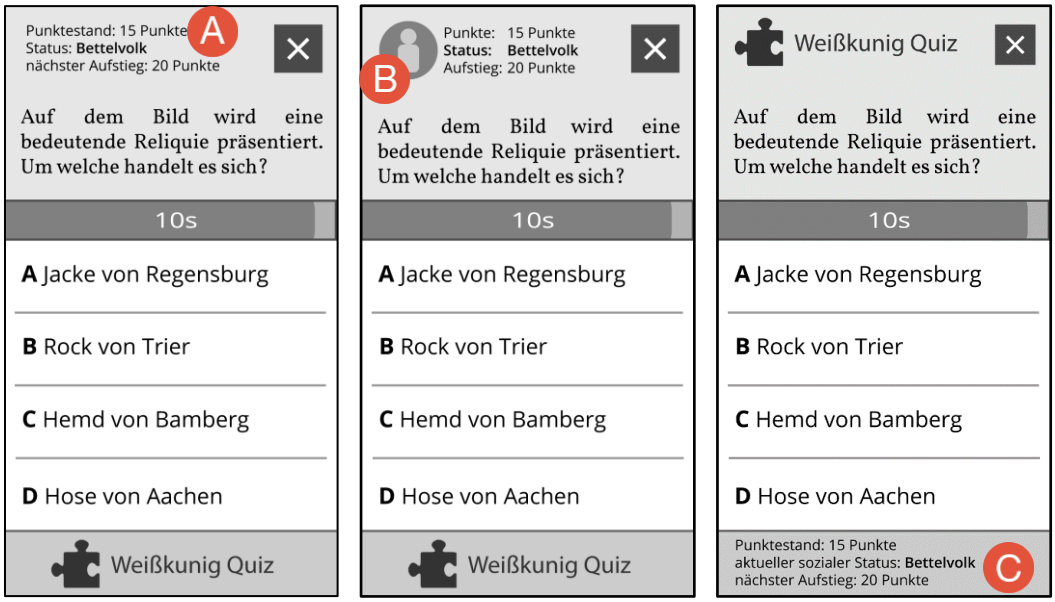

Figure 21. Three variations of the second draft, which experimented with where to display the information about the game progress (i.e. the visitor's social status and the points needed for a "level up"): In the top left corner (A), with an icon (B) or at the bottom (C).

In concept evaluation meetings, we settled on the version which showed the points information at the bottom of the screen. Since it was just a block of text at that point, which was very likely to be overseen when skimming the screen, it was refined in the next design iteration, which can be seen in Figure 22. A progress bar and a text label, which showed exactly how many points were still needed for a level up, were added. The progress bar also acts as an additional motivational element. In the bottom left corner, an icon with a describing text label indicated the current social status. The heading "Weisskunig Quiz" was also removed since it was not necessary and left more space for longer questions.

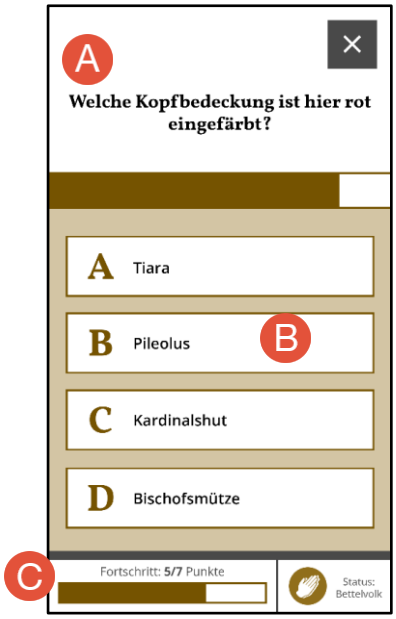

Figure 22. The final design of the mobile part of the Weisskunig Quiz. At the top, the question is displayed (A). The answer buttons (B) were refined, and the font size changed so that longer text would fit into the space. The level information – a progress bar, an icon and corresponding text labels (C) – are located at the bottom of the screen.

3.2.3 Guest List

The guest list itself was not interactive. As a leaderboard, it should simply display the names of the people who have reached a certain amount of points, to acknowledge their efforts. Additionally, as described in chapter 2.2.3, leaderboards are an element commonly used in gamification to motivate users to further devote themselves to a task. Figure 23 shows the first draft of the guest list, which shows the top five players ordered by their earned points. The three best players are displayed under the “nobility” heading, the two follow-ups under “bourgeoisie”. When two players had the same amount of points, it was planned to order them alphabetically. Whenever someone new would climb the leaderboard, the oldest entry would be replaced by their name.

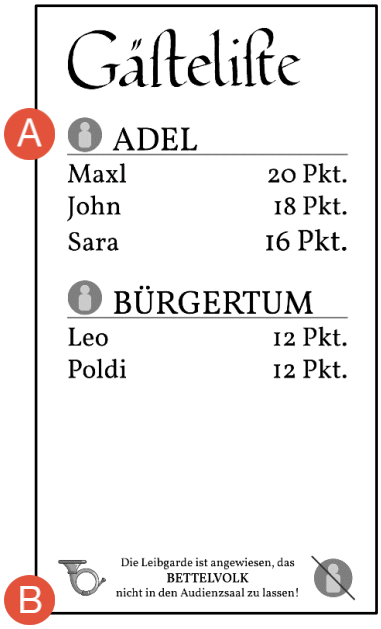

Figure 23. The first draft of the guest list. It shows the top five players ordered by social status (nobility and bourgeoisie) and earned points (A). At the bottom, a message tells visitors that "beggars" (lowest social status) are not allowed at Maximilian's audience (B). At the time of the creation of this mockup, it was yet unclear how many questions would be in the game and how many points would be needed to "level up".

After a meetup with the curators and the content delivery, it was clear that the game would consist of 16 questions with four answers each. We decided on the following system for earning points: The 16 questions would infinitely loop, and visitors could join at any point of the game. This was important because a longer waiting time would keep visitors from exploring the interactive installation when there was a whole exhibition to see. Every question that was answered correctly would award a player with one point. At seven points, they would ascend to the bourgeoisie status, and at 13 points to the nobility status.

With only 13 points necessary to reach the top of the guest list, we removed the point display and decided to order the names on the leaderboard by time (the newest entry first). This also left the guest list with more space, which is why the final design, which is shown in Figure 24, shows 14 entries instead of five. The icons of the social statuses were matched with the icons in the mobile application to make the recognition easier, especially for visitors who would use the app in English. For them, the icons provided an additional mental "link" and made it clear that the headings on the German-only guest list referred to the social statuses in the game.

The message at the bottom that tells visitors that beggars are not allowed in the audience was, just like the join prompt on the main screen, the only bilingual

message on the guest list, since it was important in order to understand the story of the game.

Figure 24. The final design of the guest list. The point display was removed, and 14 players are shown instead of five. The names are ordered by time only, with the newest one being the first in each category. The message at the bottom is shown in both German and English, and the icons are matched with those in the app.

3.2.4 Stationary Tablet

One fact which we foresaw in advance was that it would be difficult to convince all of the visitors to use the exhibition app in the museum. This was, on the one hand, because a good part of the visitors were older people with little knowledge or interest in new technology, and on the other hand, because people might just want to avoid any unnecessary bother of downloading and learning a new app. In either case, not having the necessary device or app would automatically have excluded any visitor who wanted to participate in the interactive installation, so it was imperative to devise a method which would allow anyone to join the game even without having an own device.

The resulting idea was to provide a tablet running only the part of the exhibition app that was required to join the Weisskunig Quiz. Figure 25 shows the first and the final screen designs of the stationary tablet. The only thing which differentiated the tablet from any own device is the “starting screen” where visitors were able to either pick a name or use an auto-generated one. A heading and a short text explained that the tablet was intended to be used to join the game, and a button at the bottom of the screen could be used to easily change between German and English language. In the final version, a flag icon was used instead of the “DE/EN”-label, because it is an eye-catching, universal symbol for

selecting a language and doesn't vary between the languages themselves (i.e. "DE" would be "GER" in English, whereas the flag doesn't change). The game screens of the tablet were identical to those on the own devices of the visitors, albeit optimized for the larger screen.

Initially, the stationary tablet was to be mounted on a speaker's desk in front of the large screen, but the exhibition curators felt that this would not fit into the aesthetic of the exhibition, which is why the tablet was put in a metal frame and chained to the right wall of the installation space.

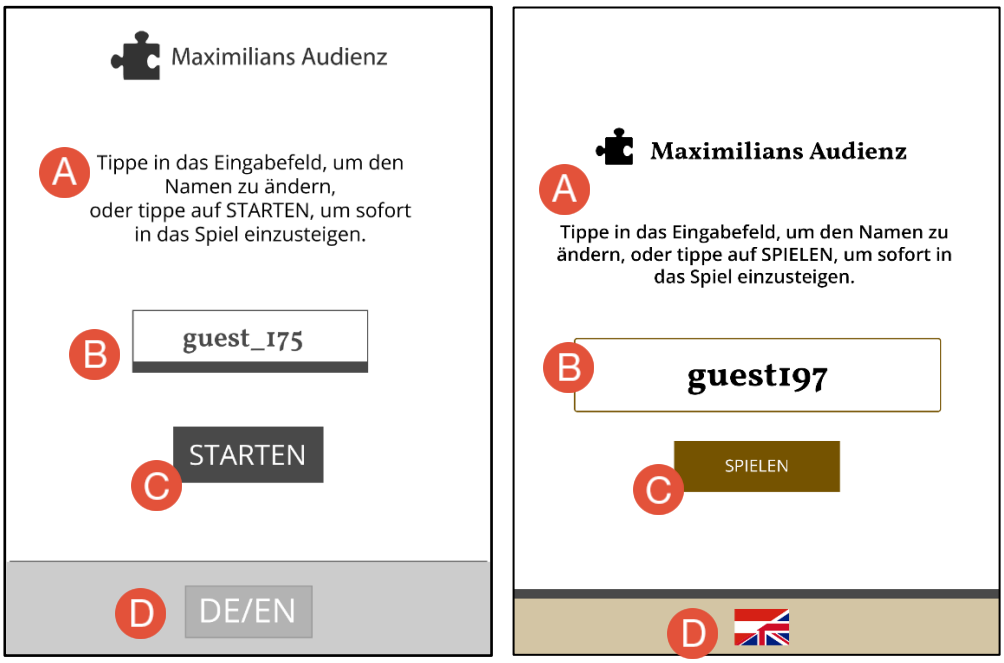

Figure 25. First (left) and final (right) design of the starting screen of the stationary tablet. It shows a heading and a quick caption which tells the visitor how to join (A). In a text box, a visitor could type in a name that would show up on the guest list if they answered enough questions correctly (B), and by tapping the "Play" ("Spielen") button (C), they could join the game. A language button at the bottom of the screen enabled the visitors to change the language (D).

3.3 Finished Game

In the following, the game flow of the Weisskunig Quiz is presented.

On the ODs of the visitors, the game can be started by standing near the installation and tapping the "Join" ("Mitspielen") button. The username required for the guest list is the username that the visitor chose at the first start of the exhibition app. If starting the game on the tablet, they can type a name into a text field and join through the corresponding button. The start screens of OD and tablet can be seen in Figure 26.

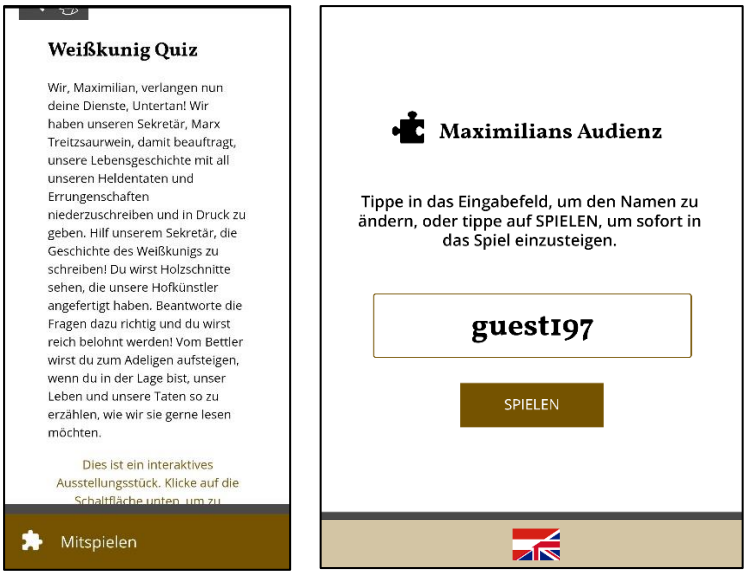

Figure 26. Joining through the exhibition app (left) and through the stationary tablet (right).

In the most likely case, the user will join the game in the middle of a question. They are then presented with a screen that shows the timer and a prompt to wait for the next question, as seen in Figure 27. This is to avoid any unfairness or confusion due to not having the full time to answer the question.

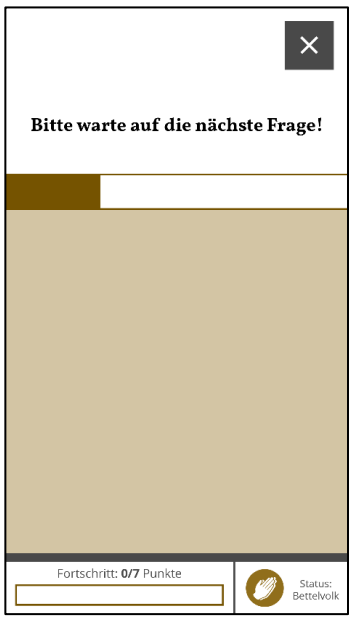

Figure 27. If a user joins in the middle of a question, they are prompted to wait for the next question.

When the user has joined the game, the question, the timer, the corresponding answers and the progress bar at the bottom are displayed on the screen of the OD and the stationary tablet. As soon as the user has chosen an answer, the buttons disappear. Instead, the devices show which answer the user has

selected, and prompt them to wait until the timer runs out and the results are revealed. Both the answer selection and the waiting screen can be seen in Figure 28. In case the user did not choose an answer in time, the text shows “Your answer: No answer” instead, and the answer is automatically counted as incorrect.

Figure 28. The mobile device while answering a question. On the left, the answer choices are still shown, while on the right, the user has already chosen an answer and waits for the question to be resolved.

On the large screen, the question and the corresponding image and answers are shown. Because the images of some questions are very detailed (in fact, a lot of woodcuts from the Weisskunig are) and need to be shown in a certain size to recognize those details, they are not displayed on the mobile devices. We found that this was no problem, since the questions which require a close look at the images explicitly refer to them, and all images are universal in all languages.

While the timer is running, the chosen answers of all participants (the “answer bubbles”) are collected in the upper parts the columns on the large screen. The darker text fields below the incoming bubbles, as seen in Figure 29, show how many times each answer has been given so far.

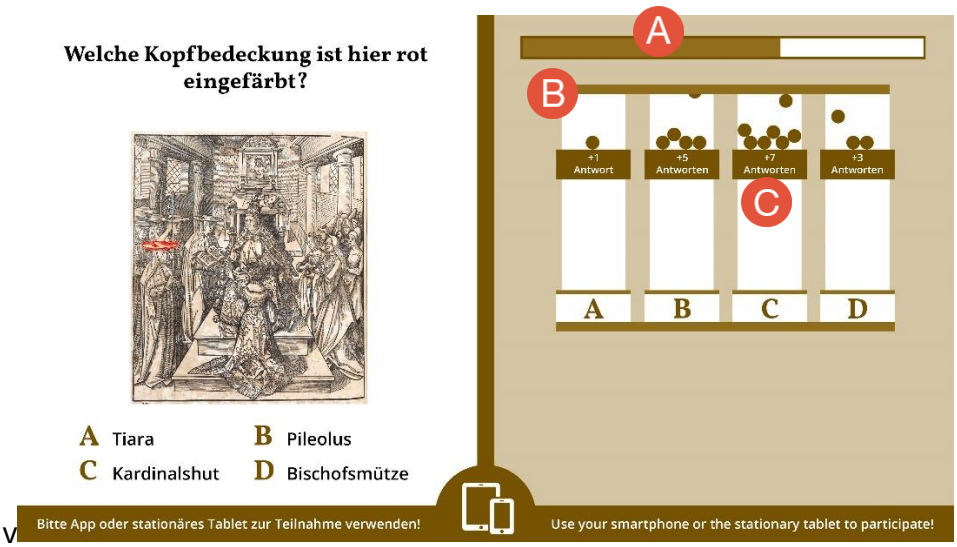

Figure 29. The large screen in the middle of a question. The timer is running (A), and the answer bubbles assemble in their columns (B). The text labels below them show the amount of times the answer has been chosen in this round (C).

When the timer reaches zero, the dark text labels disappear, and the answer bubbles fall down. As soon as they touch the “ground”, the bar chart rises, and a text which shows the overall answer distribution appears in the upper part of the columns. Since the game also provides elaborations of the correct answers when a question is resolved, it was necessary to leave some time for the users to read them. To visualize the waiting time and make it once again possible for visitors to anticipate the next question, another timer, as seen in Figure 30, was implemented. The timer during a question is 25 seconds long, the one during the resolving lasts for 15 seconds (In the first version of the game, both timers were 30 seconds long. This was changed after tests and user feedback (see chapter 4). The elaboration text and the second timer are also displayed on the mobile devices, as shown in Figure 31.

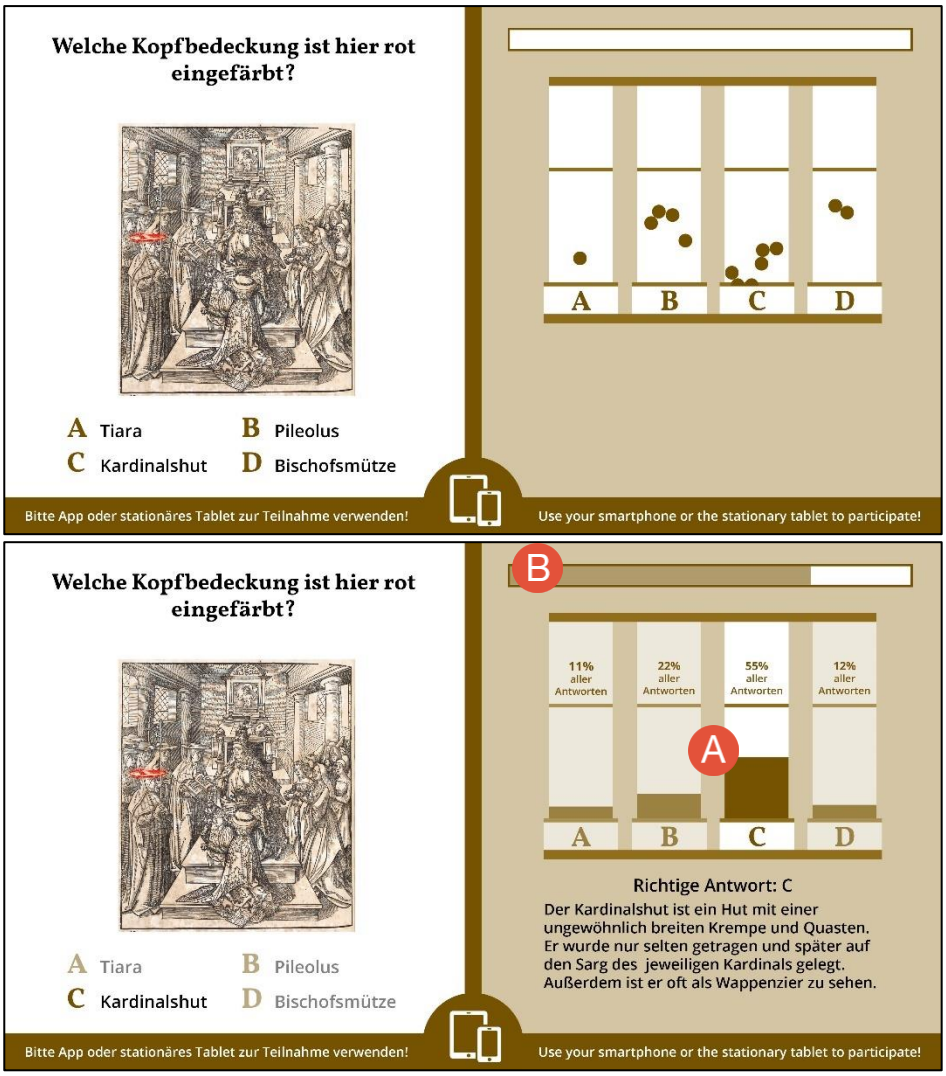

Figure 30. The large screen during the resolving of a question. Top image: The answer bubbles fall down. Bottom image: The bar chart rises to display the overall answer distribution (A). A second timer with a slightly lighter color starts counting down to visualize the waiting time until the next question (B).

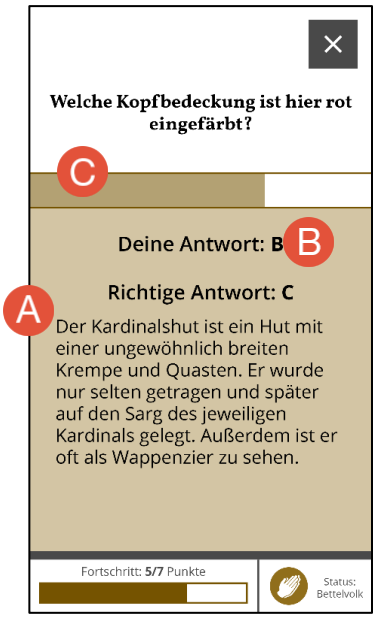

Figure 31. The screen of the mobile devices during the resolving of a question. The text which explains the correct answer (A) is displayed under the line which shows the user's given answer (B), and the second timer is seen above (C).

If a user has answered a question correctly, a point is added to the progress bar at the bottom. When they reach seven and thirteen points, they advance to the social status of bourgeoisie and nobility, respectively, and their name shows up on the guest list.

When the visitor wants to quit the game, they can do so by tapping the "Close" button in the top right corner of the screen. To prevent unintentional quits, the mobile device shows a popup which asks them if they really want to quit. If they have not yet collected enough points to be on the guest list, an additional text is displayed which explains that "people with the social status of Beggars cannot attend the audience". Through two buttons, the user can decide whether they want to stay or indeed quit the game. The exit screens are shown in Figure 32.

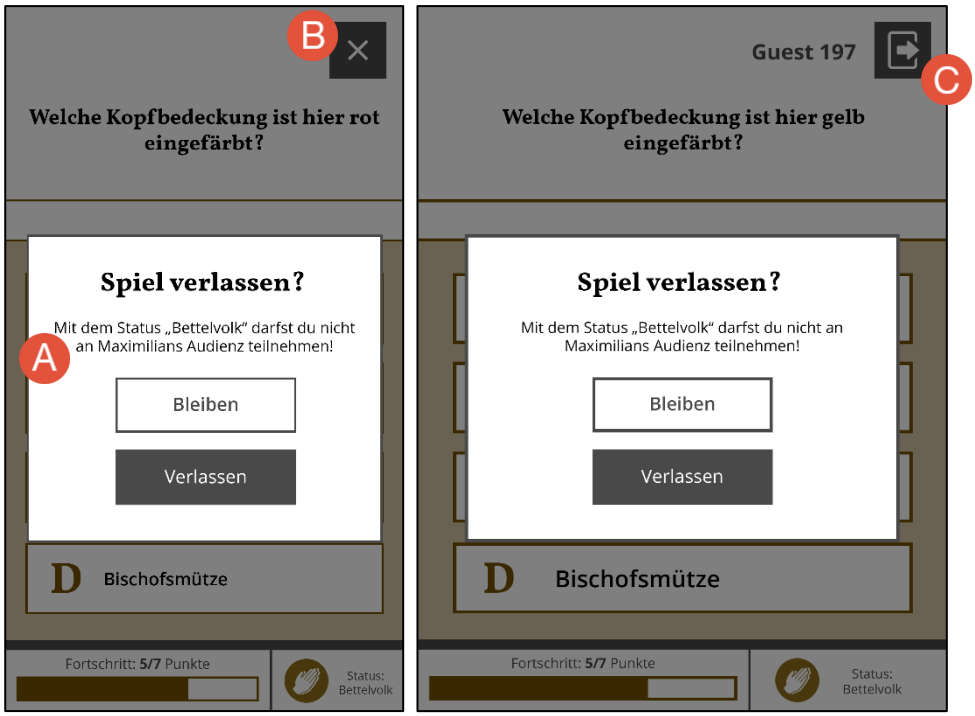

Figure 32. The logout popup on the mobile devices (left: own device; right: stationary tablet). If the user has not yet reached a higher social status, the game explains that they will not be on the guest list (A). Because quitting the game leads to a complete logout on the stationary tablet (as opposed to the ODs, where quitting takes the user back to the main screen of the app), the “X” on the close button (B) was replaced through a classical logout symbol (C).

For the stationary tablet, an additional logout dialogue was implemented: With their own devices, the visitors would be connected to the game until they explicitly quitted. On the tablet, though, it was possible for a visitor just to lay away the device and leave, and the next user would simply pick it up and continue the session as the same logged-in user. To prevent this, an auto-logout was implemented. After two minutes of inactivity, a similar popup appears on the tablet and explains that the user will be logged out in 45 seconds (the number of seconds is displayed dynamically, i.e. the text always shows the number of seconds left until the system performs a logout automatically). The user then has the option to tap the “Stay” or the “Logout” button, as seen in Figure 33. If no action is taken, the tablet goes back to the start screen when the time runs out.

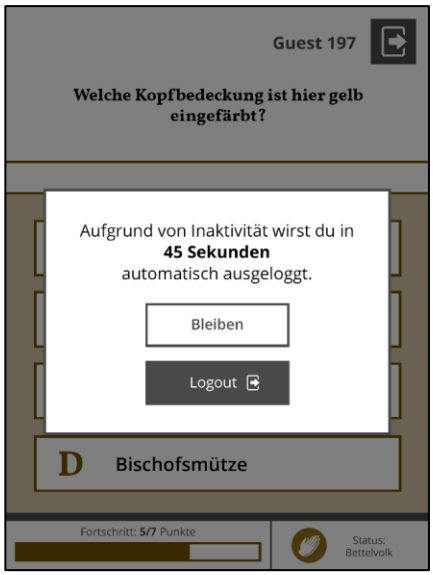

Figure 33. When the stationary tablet does not detect any input for two minutes, it shows an auto-logout dialogue. If the user is still there, they can simply dismiss it by tapping the "Stay" button. If they are not, the tablet counts 45 seconds and then goes back to the start screen.

Figure 34 shows a photo of the deployed installation at its final space in the museum as well as some visitors interacting with it through their own devices. The large screen is in the front, the guest list can be seen on the right wall and the stationary tablet lies on the red stool on the left, behind the glass vitrine.

Figure 34. Three people interacting with the Weisskunig Quiz installation through their own devices. The stationary tablet lies on the stool on the left, in the middle, the large screen can be seen, and the guest list is visible on the right.

Summary

The Weisskunig Quiz went through several concept and design iterations, and this chapter documented the reasons behind the decisions and changes of each draft. We started with a classical "Who Wants to Be a Millionaire"-approach, but

realized that we had to design something more eye-catching in order to fulfill the first step of a good interactive installation, which is attracting the visitors' attention (Müller et al., 2012). Thus, the idea of a live-visualization of the chosen answers was born, and we included "answer bubbles" in the design, that would fly in on the screen during the answering phase, and move to the field with the corresponding answer when the question is resolved. However, when we found that the design looked to sterile and unrelated to the exhibition theme this way, we kept the answer bubbles, but tried a more stylized approach where they would fall into their respective "answer goblets" during the resolving, like wine drops. In the end, to make the visualization easier to understand, we changed the goblets and fused the answer bubble idea with the bar chart from the first draft: The bubbles would now assemble in a column corresponding to their answer, and fall down into a rising barchart when the question is resolved.

The other elements of the multi-device installation (stationary tablet, guest list and own devices) were designed in a similar way, although the challenge with them laid in conveying the social status, i.e. the "level progress". In the end, we went for a progress bar with labels and icons on the OD and tablet, and a list ordered by time (which also incorporated said icons) on the guest list. Additionally, the stationary tablet got an auto-logout to deal with the assumption that visitors might just put it away without logging out. To determine the effectivity of the game design, the installation had to be evaluated, which will be covered in the next chapter.

4 Evaluation

Besides having been developed under constant feedback from the curators of the museum and usability experts from the MEETeUX team itself, the Weisskunig Quiz underwent several technical pretests and three user tests. The first one was an observation test, followed by a semi-structured interview, while the second and third tests were observation only. Both tests were conducted on site, i.e. in the museum exhibition with real visitors. In addition, the application itself collected a great amount of detailed data about the usage of the game by logging usage time, right and wrong answers and answer time. The tests, the data analysis and their results will be presented in detail in this chapter.

Overall, the different evaluations of the Weisskunig Quiz aimed at answering the following questions to determine the user-friendliness of the installation:

- How do visitors behave around the interactive multi-device environment? Do the behavior patterns found in the literature research apply in the museum as well, or are there deviations?
- What makes the visitors approach and join the Weisskunig Quiz? What are the reasons for not joining?
- Are there any factors that lead visitors to quit after a short amount of time?

4.1 Technical Pretests

During the development of the Weisskunig Quiz, the game was tested in two small technical pretests, one in January and one in February 2019, both at the St. Pölten University of Applied Sciences. In these tests, the Weisskunig Quiz was moved from the development screen onto the same screen which would later be mounted in the museum, to see how the game would look like on the final target device. Members of the MEETeUX team and some of their co-workers from neighbor offices met in the developer's and my office, where the screen was located, to test various technical and graphical matters.

In the first pretest, only three members of the MEETeUX team tested the game using one development smartphone. The main issue we found was the susceptibility of the screen design to changes in the font size. While the design

worked well with short, one-word answers (with which we had designed the game at first), the data which was provided by the curators of the exhibition also included longer answers which broke the design in its current state. For example, the answer “Steinbock” (“Capricorn”) worked well, but “Wappen von Niederösterreich” (“Coat of Arms of Lower Austria”) demanded for a smaller font size in order to fit in one line. As a countermeasure, we tried to dynamically change the font size, depending on the length of the answers, but the inconsistent sizes did not look good on the screen. Furthermore, it sometimes led to the answers becoming so small that they were not well readable even from a rather short distance. We eventually solved the issue by moving the image from the Weisskunig up, closer to the question, and making space for the answers to take up up to two lines and keeping their original size.

In the second pretest, five MEETeUX members and three of their co-workers took turns in playing the game with two development smartphones. We recognized one inconvenience regarding the timers: In the beginning, both the timer during a question and the timer during the resolving of a question were 30 seconds long. With the three co-workers, who were still unbiased and not used to the game, we decided that this was indeed too much waiting time. We eventually reduced both timers to 25 seconds, knowing that we would have to observe how actual museum visitors would deal with the given time as soon as the game would be set up in the museum.

4.2 Observation and Semi-Structured Interview Test

The first evaluation was conducted on Saturday, May 18th, 2019, at the Klosterneuburg monastery during regular opening hours (8 AM to 4 PM). The date was chosen because a medieval fair took place on the same weekend on the plaza in front of the monastery, and because the exhibition curators assumed that it would attract more visitors who would seize the chance and visit the museum as well.

Test Setting

The test took place inside of the exhibition halls of the museum, right where the Weisskunig Quiz had been placed. The author and one other member of the MEETeUX team stationed themselves in a niche opposite to the installation space, behind a large baptismal font, but also roamed around in order to not give visitors the impression of being watched. Figure 35 shows a detailed plan of the testing environment. Whenever a visitor approached the installation, we observed them without interrupting, making notes whenever something interesting happened. In addition, a hidden GoPro camera positioned on the glass vitrine

captured everything that happened in the installation space. When the visitors left, we approached them and asked them whether they were open for an interview. The interview was semi-structured and consisted of a short gathering of general data such as demographics, followed by questions about the Weisskunig Quiz and ended with a final SUS questionnaire (The full questionnaire can be found in the Appendix A). The questions required either free answers or ratings on a Likert Scale from 1 (negative/unlikely) to 7 (positive/likely). The reason why we decided to use an odd number for the range is that for the tests, it was not necessary to push the participants towards a negative or positive opinion, but neutral opinions were accepted as well.

Apart from the SUS questionnaire, which the participants filled out by themselves, the answers to the questions were written down by one of the test conductors. One interview typically lasted around 15 to 20 minutes (including filling out the SUS questionnaire). After each interview, we thanked the participant and allowed them to pick some thank-you-gifts from a set of goodies. Among them were chocolate cubes, post-its, notepads and pens.

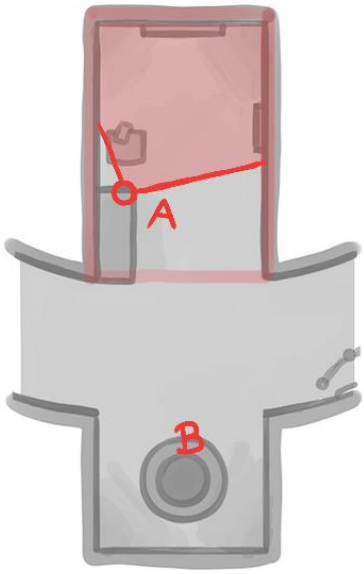

Figure 35. The installation space in which the test was carried out seen from above. (A) is the camera, which captured everything that happened in the space, and (B) is the baptismal font, where we hid during the observation.

Participants

During the day, eight visitors (3 male, 5 female) aged from 9 to 69 (M = 44.9, SD = 22.5) years agreed to participate in the interview. Four people (three female, one male) interacted with the installation, but refused to take part in the interview. Two other museum visitors (both male) were observed glancing at the installation but not approaching it. Apart from one person, everyone used the stationary tablet when interacting with the game. Table 1 shows a detailed listing of the participants' data: Their gender, age, how long they use their smartphones per

day, how experienced they rated themselves with digital devices, how much they stated to like quiz games and -shows as well as how long they had interacted with the game (measured by observers) and which device (stationary tablet or own device) they had used during the observation.

Table 1. Demographic data of the participants of March 18th, 2019.

ID	Gender	Age	Minutes of Smartphone Usage per Day	Digital Experience (1-7)	Quiz Affinity (1-7)	Time Interacted (mm:ss)	Device Used
P1	w	68	15-30 min	2	6	01:24	Tablet
P2	m	69	does not own one	3	6	00:41	Tablet
P3	w	58	does not own one	3	5	09:17	Tablet
P4	m	55	10-15 min	6	3	09:17	Tablet
P5	w	51	30-60 min	5	6	06:29	OD
P6	m	24	30-60 min	7	4	05:50	Tablet
P7	m	25	30-60 min	7	5	05:50	Tablet
P8	m	9	15-30 min	5	7	05:05	Tablet

We had prepared the interview and questionnaires in both English and German, however, all participants were either from Germany or Austria and therefore answered in German only. The mean time the participants spent at the installation was 05:29 minutes (SD = 03:09 min). On average, they rated their experience with digital devices with 4.8 (SD = 1.7) and their affinity with quizzes with 5.3 (SD = 1.2). Two participants reported not to own a smartphone, one claimed to use theirs for 10 to 15 minutes a day, two people for 15 to 30 minutes and three for 30 to 60 minutes.

It is worth noting that P1 and P2 were a married couple as well as P3 and P4. P6 and P7 were a pair of friends who visited the exhibition together.

Questionnaire Results

Table 2 shows the given answers to the questions with ranged answers and Figure 36 shows a visualization of the values. The questions were phrased as follows:

- How easy to use did you find the game?
- How did the simultaneous usage of two screens feel to you? (Tablet/Phone and big screen)
- How understandable was the visualization of right and wrong answers?
- How much did you like the graphical design of the game?

- How likely is it that you would use a smartphone in an exhibition? (This was the last question of the whole interview)

Table 2. Answers to the ranged questions given by the participants. The values ranged from 1 (negative/unlikely) to 7 (positive/likely).

ID	How easy to use?	Simultaneous Usage?	Visualization right/wrong?	Graphical Design?	Smartphone in Exhibition?
P1	7	5	7	6	7
P2	7	5	7	6	1
P3	4	4	4	5	1
P4	6	5	5	6	1
P5	7	7	7	7	6
P6	7	7	7	6	4
P7	7	7	7	7	4
P8	7	7	7	7	6
MEAN	6.5	5.9	6.4	6.3	3.8
SD	1	1.2	1.1	0.7	2.3

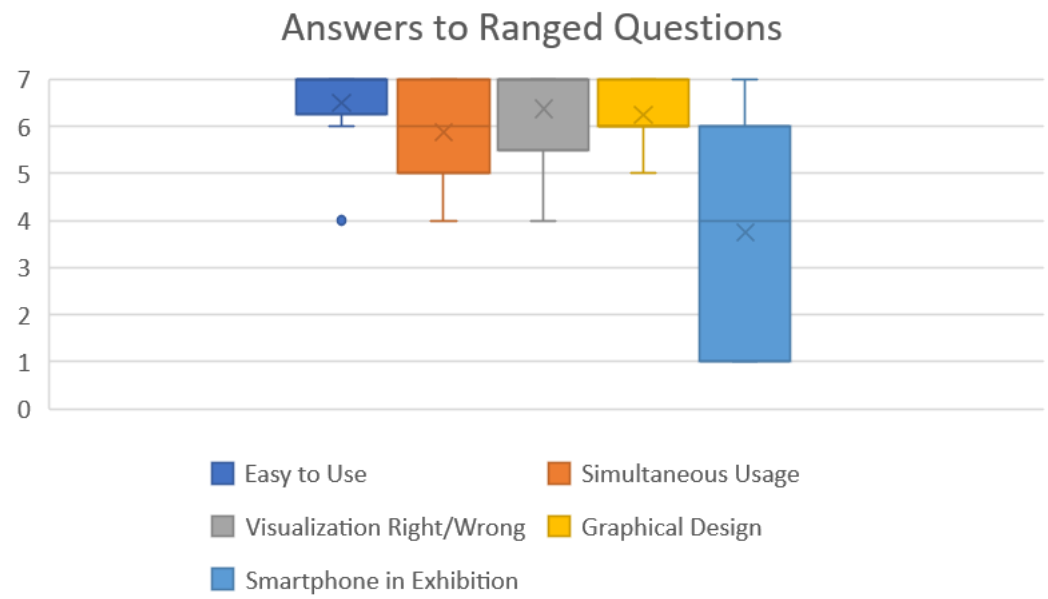

Figure 36. Visualization of the given answers listed in Table 2.

The other questions of the interview required free answers of which we took notes:

- Please describe to us what you saw – how the application looked like, what you noticed…
- Why did you approach the installation?
- When did you notice that the little balls on the big screen represent the given answers?
- How do you feel about the time you had to answer a question? (Three options: it was too short, just right or too long)
- Did you notice the guest list on the right screen? Do you have an idea what role it could play in the game?
- Do you have any suggestions on how we could improve the game?

Table 3 shows the central aspects of the participants' answers.

Table 3. Participants' answers to the free answer questions (continued on next page).

ID	Describe what you saw	Why approached?	Noticed answer balls?	Time to answer?	Noticed guest list?	Improvements?
P1	Big picture on screen and answers	Curiosity. The picture stood out and the timer moved	Did not notice	Just right	Did recognize but purpose not clear	It's a question-answer game, what are you supposed to improve?
P2	American test system	My wife went there	Did not notice	Just right	Did recognize but purpose not clear	Nothing to improve, it's just a game about knowledge
P3	-	Another museum visitor recommended	Did not notice	Too short	Did recognize but purpose not clear	Don't like beige-brown. 2nd timer could be shorter. Image and font should be bigger or cable of tablet longer.

P4	Screen, tablet and score list	Another museum visitor recommended	Clear from the start.	Too short	It shows who got how far	Image should be bigger, hard to see from afar, second timer could be shorter
P5	Main screen looks like a book	I was just interested what it is	When I gave first answer.	Just right	Noticed, and purpose also clear	Second timer could be shorter
P6	Questions and answers, like Kahoot	Wanted to know what it is	When friend took over tablet and I looked more at the screen	Just right	Noticed, but why are there no points?	Second timer could be shorter, image is hard to see from afar
P7	Like Kahoot	See what it is and if you can participate	Clear from the start.	Too long	I guess when you do well, you get on there	No
P8	Big screen with questions and answers	Wanted to know if I could play	Noticed them, but wrongly assumed their purpose	Too long	Did recognize but purpose not clear	No

Regarding additional remarks the participants gave, a few of them reported that they would not immediately download an exhibition app if there is one available. P1 said she would have loved to have used the app if she had known about it, because she had seen a similar one in a museum in Berlin, which had impressed her. P2 said that if he had a smartphone, he would only use it for exhibition apps. P3 claimed to “hate it” when smartphones are used in an exhibition. P5, P6 and P7 pointed out that their decision to download an app greatly depended on the app and its contents. P8 said that if an app is well integrated into the exhibition, he would download and use it.

P4 remarked that the auto-generated usernames (Guest123 etc.) on the stationary tablet diminished the value of the guest list, because they make it difficult to guess who is who.

The last part of the interview was a SUS questionnaire (see Brooke, 2013). Overall, the participants rated the Weisskunig Quiz very positively, with a SUS score of 88.1, which indicates an above average usability. The results of the SUS can be seen in Table 4. One person rated the game notably worse than the other participants. This could be due to the fact that he claimed to not really be a fan of quiz games and that he was not as motivated to participate in the test as the others (he had only followed his wife, who seemed very interested in the application, while he looked more like he wanted to carry on with seeing the exhibition).

Table 4. The results of the SUS questionnaire and the corresponding grades.

ID	SUS Score (X / 100)	Grade
P1	95	A
P2	95	A
P3	76.6	B
P4	61.6	C
P5	93.3	A
P6	91.6	A
P7	93.3	A
P8	98.3	A
Total SUS Score	**88,1**	**A**

Observation Results

In general, all participants were pleased with the Weisskunig Quiz. One fact which is clearly visible from the given answers is that the installation succeeded in making people curious and drawing them nearer, as reported by 5 out of 8 participants. The part of the installation which grabbed most of the attention was clearly the large main screen, since it had all of the attention-catching elements as described in chapter 2.2.1: A large image, prominently displayed questions and answers and an animated timer. Additionally, it was placed in a way so it would be the first object which visitors would see when walking by the installation space. Another interesting fact was that one person took the guided tour (which does not pass by the Weisskunig Quiz) through the museum after having participated in the test. There, they recommended a married couple to go see the installation after the tour, who also agreed on participating in the test.

A commonly observed behavior was that visitors would often walk through the exhibition as pairs and also approached the installation as such. Since only one stationary tablet was provided, one of them occupied the tablet, while the other one positioned themselves in front of the large screen to look at the pictures more closely. In case of one married couple, both of them discussed about each question for such a long time that they never noticed that the timer had already run out. The other two pairs took turns in handling the tablet and changed roles after a couple of questions. To tackle this issue, one could provide a second stationary tablet, however, it is uncertain whether pairs would then indeed split up or keep using one tablet together.

While the time provided to answer a question seemed to be just right (out of 8 participants, 4 said it was just right, 2 found it too short and 2 too long), 4 out of 8 people pointed out that the second timer (i.e. the duration of the resolving of a question) was too long. This was solved by reducing the time from 25 seconds to 15, making the final timers 25 and 15 seconds long.

The graphical design and the visualization of the answers was praised by the participants, except for one, who did not like the beige and browns and would have preferred more colors. A positive element which was mentioned a few times was the explaining text which was displayed during the resolving of a question. The participants appreciated the additional information instead of just having to accept that an answer was right or wrong.

When playing alone, participants felt very restricted by the stationary tablet's chain. While the font size was large enough for all but one participant, the image seemed to be too small, especially for questions that specifically addressed one element in the picture (e.g. "Which writing tools is Maximilian using here?"). A solution to this problem would be to provide a longer chain. Increasing the size of the images themselves is not an option because other elements such as the font would have to be reduced in size.

Another problem with the stationary tablet was its position behind the vitrine. Nearly all of the participants only recognized the tablet at the second glance, after they had looked at the large screen and actively examined the environment. A pair of older ladies, who refused to participate in the interview, approached the main screen, discussed about the questions and pointed towards the screen. After one question, one of them lost her interest and turned around while remarking "Nobody participates there anyway". The other lady disagreed and started explaining what was happening on the screen, but then followed her friend. On the way back, she saw the tablet in the corner, stopped and said "Oh, wait, I think you can join the game with this!", visibly curious. Only when the other lady said "No, we're not going to do that now", she abandoned the tablet and left.

This speaks for the initial plan to put the tablet on a speaker's desk in front of the screen, which the exhibition designers refused to do.

Another fact that would call for a more prominent placement of the stationary tablet is that one of the participants first thought that the large screen would respond to touch input. This surprised us, because we had mounted it at a height where average-sized people could not reach the upper part of the screen (The four answers, though, were reachable, which might have contributed to the misunderstanding). Before the visitors saw the tablet and started interacting with it, the visitors would tap an answer on the large screen and be confused due to the lack of feedback. As described in chapter 2.2.2, a possible solution would be to put up benches near the screen, which would, on the one hand, indicate that it is not meant to be touched, and on the other hand, encourage visitors to sit down and spend some time at the installation. An additional poster prompting visitors to join through their smartphones or the stationary tablet could be helpful as well.

The simultaneous handling of multiple devices was no problem for the participants, however, some features of the game were not properly recognized: Three participants, for example, did not realize the "answer bubbles" at all, and one person only recognized them when they gave the tablet to their friend and had a closer look at the screen. and one (P8) recognized them, but wrongly assumed their purpose. This problem could also be related to the fact that during the whole test, there was never more than one person playing (i.e. more than one active device), hence why P8 assumed that the answer column which had the bubble in it was merely the one that he had selected. It is likely that more people would have understood the answer bubbles if they had seen others flying in towards different columns, since when they looked at the tablet to pick an answer, they never saw the animation of their own. An improvement that could be made nevertheless is to display a bubble on the tablet or OD when the user picks an answer, which then flies off the mobile device's screen to land on the large main screen.

The guest list was the element that proved to bear most of the difficulties. While all participants noticed it, only three of them understood its purpose. This might be because only one of the participants played long enough to reach the bourgeoisie status (i.e. answer 7 questions correctly). This person also correctly recognized the guest list as a score board, along with two others who had not reached any higher social status, though. The others only guessed the guest list's meaning when they were prompted to take a closer look at the tablet's screen, where the progress bar was. A possible solution would be to add captions on the guest list, such as "Answer 7 questions correctly to become a part of the bourgeoisie".

Overall, the usability of the game was very good, which the positive SUS scores show (the SUS score is a combination of the participants' answers on 10 standardized questions on the usability of an application; see Brooke, 2013). Apart from the issues described above, the game seems to be well understandable and intuitive for the users.

One particularly notable insight which we gained through the test was that hardly any visitors downloaded the necessary app on their own devices. This was because of the inconvenient path the visitors took through the museum: In the entrance hall, which did not give any information about the available app, the people waited for a tour guide to pick them up. They then went to the upper floor of the museum, where the other part of the exhibition was. When the tour was over, the group was dismissed in the middle of the exhibition in the lower floor, whereas the only posters advertising the app were located at the entrance to the lower floor exhibition.

Since this was a problem which broke the purpose of both the Weisskunig Quiz and the app itself, the MEETeUX team reached out to the museum staff, emphasizing the need of thorough advertisement and/or information.

4.3 Plain Observation Tests

To evaluate the Weisskunig Quiz, two additional tests were carried out. In these tests, visitors of the museum were observed to see how they behaved around the installation, how they interacted with it and why they approached or abandoned it. Contrary to the test described in chapter 4.2, the observation was not followed by any questionnaires or interviews.

4.3.1 Observation: School Class

The first observation test took place on June 7th, 2019, once again during regular opening hours of the museum. We picked a date where a school class visited the exhibition, because this meant that a relatively large number of people would explore the museum at the same time, whereas on regular days, only occasional visitors would go through the museum without the guided tour, which did not go through the lower floor exhibition where the Weisskunig Quiz was. The school class explored the exhibition for two hours (from 11:00 to 13:00).

Test Setting

The children of the school class were asked to download the exhibition app on their smartphones in advance, which means they knew about the app, but were not told anything about the interactive installations in the exhibitions. In contrast to the previous test, where the observations were followed by interviews, this test

was observation only. A GoPro camera mounted left above the big screen (see Figure 37) in about 3 meters height captured the whole installation space. The children first took the guided tour and were then left to freely explore the exhibition in the lower floor. Members of the MEETeUX team roamed through the halls to provide technical support for the children if it was needed. The video material from the camera was reviewed afterwards.

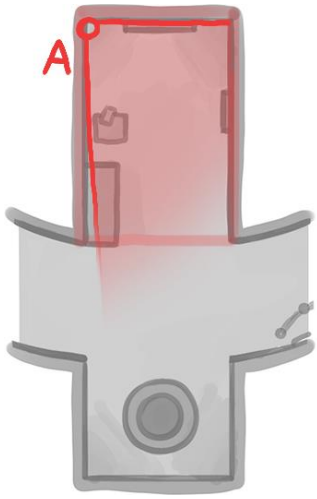

Figure 37. The installation space from above. (A) marks the location of the camera, which captured everything that happened.

Participants

The school class came from a gymnasium (middle school) in Vienna and consisted of 20 children between 10 and 12 years (8 boys, 12 girls) and two teachers. Except for two girls, everyone had their own smartphone which they used in the exhibition. There were 15 other regular visitors in the exhibition too, whose behavior was also observed and recorded.

Results

Occasionally, individual adult visitors passed the installation, observed it and discussed about the questions from a distance, but never directly joined, probably because they felt that the space was too occupied by the children. This was observed with four visitors, who turned away after around half a minute and inspected the vitrine next to the installation instead. Four additional adults passed the installation without looking at it and went straight to the vitrine. Others seemed to avoid the crowded space but looked from a distance while they were passing, while three approached the game despite the crowdedness and watched the game for a short time (under two minutes).

Overall, the children quickly understood how the game worked. The only issue which commonly occurred was that some of them thought that the large screen

was a touch screen, as one participant in the previous test had also done. Two girls, for example, approached the screen together when one of them reached out to the large display, asking “Oh, can you play there?”. Before she could touch the screen, however, the other girl grabbed her hand, pulled it away from the monitor and pointed to the message on the bottom: “No, look, it says you have to play with your smartphone!”. Two others also touched the screen for a couple of times, before they realized that the only way to play was with another device. One boy played the game with his smartphone for a few minutes, before he approached the monitor and tried whether it would respond to touch as well.

The Honeypot Effect (see chapter 2.2.1) was very well visible during the test. For example, three boys were sitting on the stool playing the game. One girl approached and asked the boys how she could join. She then went to get two of her friends, who also joined the quiz. After a while, three boys came to investigate the crowd. One of them asked “Can I play this too?”, and joined. At this point, eleven people were in the exhibition space, eight of which were playing the game. The crowd dissolved when one of the teachers came to tell the children about another interactive installation they had overlooked before.

The Weisskunig Quiz encouraged a lot of social interaction. For example, four kids were playing at the same time, all using their own smartphones, but still playing in pairs and discussing about the questions. When one of them looked at the screen and saw the other answer bubbles flying in, he surprisedly turned around to one of the MEETeUX team members and asked “There are others playing too?”. On other occasions, children started jumping and dancing or striked victory poses when they had guessed a correct answer. Lively discussions emerged frequently, such as “This question is easy! – What, really? Please tell me the answer, please!” or “Haha, who the heck selected bishop’s cap? – That was me!”.

The visualization was well received by the children, who often gestured towards the barcharts, giving comments such as “Look, most of the people answered like you!”.

Because in this test, all the kids used the app on their phones and not only the stationary tablet, the motivating effect of gamification elements as described in chapter 2.2.3 was very visible: On the one hand, the children eagerly tried to climb up the “social status ladder” of the game, regularily announced their levels and searched for their names on the guest list: “I’m still a beggar”, “I have 5 of 7 points and I’m still a beggar”, “I am already in the bourgeoisie!” were sentences they frequently exclaimed. On the other hand, the exhibition app itself had a feature where visitors could collect parts to create their own coat of arms by solving tasks in the exhibition, which proved to be a very motivating factor. It was possible to earn three parts for the coat of arms through the Weisskunig Quiz,

one for reaching the bourgeoisie, one for reaching the nobility status and one for simply participating. The children regularily remarked how many parts they had and showed each other their creations. While playing the Weisskunig Quiz, one child said to another: “We have to answer a lot of questions here, so you get more parts for your coat of arms!”.

Most of the children approached and played the game in little groups of two to three, but they each used their own smartphone. The times the groups interacted were 6, 18 and 12 minutes. Another group played for three minutes when their teacher asked them something and they followed her, quitting the game. One girl played for three minutes, then made a break to customize her coat of arms and show it to her classmates, and then went on playing for another 14 minutes.

One issue which appeared in both tests is that people who were logged in with a guest accound or had not changed the auto-generated name on the tablet had difficulties finding their name on the guest list, even though the auto-generated name was displayed on both the phones and the tablet.

Interpretation

The fact that the message at the bottom of the screen was not enough to convey that the large main screen was not a touch screen calls for placing benches or stools around it, as Gentile et al. (2017) suggest (see chapter 2.2.2). This could possibly also extend the time visitors are willing to stay, since they could just comfortably sit down. A few kids from the school class demonstrated this very well when they just sat down on the floor after having already played for a while or sharing the tablet stool between three.

Regarding the issue of the auto-generated names on the guest list, I assume that this was probably because the names were neither easy to remember (Guest1234, Guest2398 etc.) nor easily findable among the lot of other guest names on the guest list. Seeing how many visitors use the tablet or prefer using a guest account in the app (presumably because of data protection concerns, even though only an e-mail address was required for a full registration), forcing people to choose a name is not an option. A possible solution might be to use guest names which are randomly put together from a set of words and numbers (e.g. SilentEmperor1, ProudKnight12, ClumsySquire5 etc.).

In this test, the children did not seem to have any problem with the simultaneous handling of multiple devices. On the contrary, they understood the answer bubbles right when they saw them (one child was surprised that others were playing too when seeing the bubbles fly in). The author believes that this was due to the difference in the number of players in both tests. While in the first test, all participants played with one device only and did not see the answer bubbles (or thought they just marked the selected answer), there were always more than two

people playing in the second test, which enabled everyone to see answer bubbles flying in before or after they had chosen their answer.

4.3.2 Observation: Advisory Board

The second observation test was carried out within the scope of an advisory board meeting on June 24th, 2019. The observation test lasted from 10:00 to 13:00, during regular opening hours, and other random visitors were present as well.

Test Setting

Similar to the observation test with the school class, the participants were asked to download the app in advance. They were only told which kinds of interactive installations existed in the museum, but they were neither told any details, nor how the interactions with them worked. On the same day of our advisory board meeting, the curator team of the museum had a meeting with external advisors as well, who also walked through the exhibition and played the Weisskunig Quiz once. The GoPro camera was mounted on the same spot as in the school class test and its video material was reviewed afterwards.

Participants

Six people (five men, one woman), who were experts in various sectors (e.g. usability, digital wayfinding in museums, or accessibility for visually impaired people) explored the exhibition in the course of our meeting. The group of the curator team also consisted of six people, but only two of them were unfamiliar with the game. There were seven other random museum visitors who played the Weisskunig Quiz as well.

Results

The curators gave their external visitors a tour through the museum, showing them the app on their smartphones. When they arrived at the Weisskunig Quiz, they gave a three-minute demonstration of the whole installation. Even though the people unfamiliar with the game did not explore it themselves, they remarked that they really liked the idea of the game. One of them praised the stationary tablet, since it would “accommodate the wishes of somebody like me [who does not have a smartphone]”.

From our own advisory board, five of six people participated in the game. One blind person did not play because a lot of questions referred to the images on the large screen. Three of the participants played for 14 to 15 minutes, until they reached the bourgeoisie status. One person played for 8 minutes, and one played with his smartphone for one minute, then experienced connection problems, and changed to the stationary tablet, where he played for another 4

minutes. A lot of social interaction was once again visible during the time of play, and the players would regularily tell each other how far they had already progressed in the game, check if they found their name on the guest list, and talk about the questions together. When they reached their desired status, they made victory gestures, laughed, and talked to the other players.

In the course of the observation, two random visitors walked by the niche and looked at the screens, but did not stop or approach the installation. One had a look at the vitrine with the book, but did not pay any attention to the game.

One older lady, who walked through the exhibition using the app on her smartphone, approached the installation and joined the game. She pushed the stationary tablet to the edge of the stool to sit down, and played for 11 minutes. For some questions, she stood up to have a closer look at the images, but then went back to the stool.

One particularly interesting pair of players was an older couple: They approached the screen and talked about the questions for two minutes ("It's for the kids, to see if they paid attention."), until the woman asked, "What happens when I touch it?", and touched the large screen. Meanwhile, the man had turned around and found the stationary tablet, which he picked up, remarking "This thing weighs so much that nobody takes it". The tablet in his hand, he asked his wife "Well, did you touch it?" When she said yes, he put the tablet down and went back to the large screen (the tablet reached the auto-logout after a while). The couple then "played" for 11 minutes, happily discussing about the images and the questions, but each time touching the answers on the screen. After some questions, they realized the visualization on the right side of the screen and recognized the right and wrong answers ("Look, we had that one wrong."). Only after 6 minutes, they started wondering about the missing feedback when they touched the screen ("Nothing happens, but I did touch it!"). They then saw the timer and concluded "Ah, look, you have to tap if before this is over, or else it [the resolving] happens automatically." During one question, which required counting certain elements on the image, they spent a lot of time studying the image. When the man realized that the timer was almost over, he quickly hit the screen with a finger, hoping to still answer "on time". They left after having seen all 16 questions.

Interpretation

Overall, the results of this observation test were similar to those of the preceding tests. One issue which was more visible than before were the connection problems, which sometimes occured because the Weisskunig Quiz was located at the edges of two Wi-Fi radii. We approached the technical team of the monastery to re-position the routers in some way.

The issue of people believing that the large screen could be touched was very present in this observation. As mentioned before, this could be changed by placing more stools or benches around the screen or putting up additional posters.

4.4 Analysis of Collected Data

The Weisskunig Quiz logged several kinds of data during play sessions, which will be presented in the following: The ID of the user (as a sequence of hexadecimal numbers, which could not be used to trace a person or get any information on their identity), the date, how long they played the game, whether an answer was correct, wrong or skipped, and how much time was needed to answer a question. The only thing which we could tell from the user ID was whether the user came from the stationary tablet or an own device. Although the game was installed for a longer time, the data for this analysis is only from the time period between the 26th of March, 2019 (official opening of the exhibition, when we stopped making changes to the game), and the 22th of July, 2019 (approximately four months later). Table 5 shows the numbers of tablet and OD users and the average play session times.

Table 5. Numbers of players who played with the stationary tablet and own devices. The average session times (how long someone played the game) are shown as well. The unusually high standard deviation of the tablet session times is due to the fact that visitors would sometimes give the tablet from one visitor to the other, without logging out inbetween, while the OD sessions were always ended explicitly.

Device	Total users	Average Session Time (mm:ss)	SD Session Time (mm:ss)
Stationary Tablet	234	05:42	14:37
Own Device	220	03:33	04:19

The usage of the tablet and the own devices is very balanced, which proves that many people played the game without an own device and that the provision of the stationary tablet was indeed a good choice. While the average session times of OD users are certainly acurrate, we observed that visitors would sometimes share sessions “by accident”: There were situations where more people were around the Weisskunig Quiz, and one visitor played with the tablet and put it down without explicitly logging out. The next visitor then took over the tablet before the auto-logout could happen, extending the logged in user’s session. On one day, this led to a session of 71 minutes, a value which distorts the average times of the tablet session times.

Interpretation

Most of the quantitative data on the quiz answers can be explained easily – for example, question 10 (which asked for the name of a certain type of medieval helmet) got a lot of incorrect answers, presumably because this is a kind of knowledge not many people have. Question 16, which asked where Maximilian's father was buried, had the most incorrect answers, probably because people are tempted to choose Klosterneuburg, while the correct answer is St. Stephen's Cathedral. The same explanation applies to question 11 ("Who was Maximilian's first wife?"), which got the most correct answers, because Mary of Burgundy was mentioned in the exhibition (and in various other media commemorating the 500th anniversary of Maximilian's death) quite a few times. Question 4 ("Which ritual can be seen here?") was answered the fastest, because the ritual on the image is very easily recognizeable as a baptism. Question 13 ("On this picture, a truly important relic is shown. What is it?") was answered the slowest, because it takes some time to find the relic in question on the image.

Question 5, however ("Maximilian is adorned with a laurel wreath. How many times can he be seen on the picture?"), is the one that was skipped the most, i.e. most visitors did not answer before the timer ran out. The question required players to count elements in the (very detailed) image. The difficulties with this question could be seen in all previous tests as well, where people would always approach the image until their noses almost touched the screen, try to count, and then realize that the timer had already run out. A possible solution for this would be to introduce variable timers which depend on the current question, a measure which would, however, require more extensive user testing.

The complete list of all 16 questions in the Weisskunig Quiz can be found in Appendix B. Appendix C shows a detailed list of the quantitative data collected on the visitors' answers to these questions.

5 Discussion

The evaluation of the Weisskunig Quiz showed some minor problems, which can all be resolved fairly easily. For example, visitors who used a guest account often had problems finding their names on the guest list, since the auto-generated names were very prevalent, and through the sole combination of “Guest” and a number, very confusable. This could be solved by generating guest names from a set of words (e.g. SilentEmperor, ProudKnight etc.), and, if necessary, a short number. The answer bubbles posed a problem for users who were playing alone, since they always missed the animation of the bubble flying in. Adding an animation on the tablet and OD, which shows the answer bubble flying out of the screen before it arrives on the large screen, could be a solution for that. A possible way to convey the “level system” better would be to show a message when a player answers their first question correctly (e.g. “This was correct! Answer 6 more questions correctly to advance to the Bourgeoisie!”). Regarding the different times visitors need to answer different questions, a variable timer could be introduced, which is shorter for easy questions, but leaves more times for questions which require players to take a closer look at the image. This would, however, require more user testing.

After observing a lot of visitors around the Weisskunig Quiz, I can conclude that the game indeed encouraged social interaction. People discussed about questions or the game in general, and compared their results and progress. They often striked victory poses or (especially the children from the school class) started dancing when they got a question right. Since the game included both questions which could be answered with knowledge, and questions which one could only guess, it was suited for both children and adults. However, as the Weisskunig Quiz was designed as a social game from the start, it is not certain that the integration of smartphones in multi-device installations leads to more social interactions in all scenarios.

While evaluating the Weisskunig Quiz, I recognized a few significant issues which also translate to similar interactive installations: The data which the game collected automatically show that about half of the people who played the Quiz had done so by using the stationary tablet – if we hadn’t installed it, we could have lost over 200 potential players. This is because of two factors: First, people tend to be critical when it comes to new applications they have to download on their ODs, either because of security concerns, or simply because they are not

sure if the application is actually worth downloading. They like exploring the game first to get an idea of what it is, which they can perfectly do on the stationary tablet. The same applies to people who just pass the installation and become curious. With the tablet, they can just join the game without having to spend additional time downloading an app on site. Second, the inconvenient path which guided tours took through the museum resulted in visitors being dismissed in the middle of the lower floor exhibition, whereas the only posters advertising the app were in the entrance hall. Often, visitors would pass the installation without knowing that there was an app to download, or how to download it. For these people (and also for those who did not have a smartphone in the first place), the stationary tablet was essentially the only way to play the game. Depending on how many visitors one expects for an interactive installation, one could consider adding a second or even more stationary tablets, to enable pairs to compete against each other, or to simply provide more possibilities to join, in case one tablet is already occupied. For the Weisskunig Quiz, however, providing more than one tablet would have been too expensive compared to the number of visitors who played the game.

We reached out to the curation team of the exhibition to put up information posters with instructions inside the exhibition, but were told that the exhibition designers would not allow it for aesthetical reasons – another drawback we had to accept, since our request to put the stationary tablet on a speaker's desk was also denied for the same reason. Instead, it was put in a metal frame and chained to the wall, which led to a number of problems. To anyone who intends to design a similar interactive installation or mobile app for a museum, I would strongly recommend discussing with the people responsible for the exhibition and emphasize that there has to be some kind of compromise between the aesthetics of an analogue exhibition and the usability of the digital parts. The more parts of the digital elements of the exhibition have to suffer from design restrictions from the analogue side, the less visitors will use them, and the less meaningful they become as a part of the exhibition. This again poses the question why one wants to have digital elements in the exhibition in the first place.

Especially the fact that the stationary tablet was chained to the wall instead of positioned in front of the large screen affected the installation. Firstly, the metal frame was very bulky and heavy, and the rather short chain made it impossible to approach the screen with the tablet, which led to visitors creating odd workarounds where they would walk back and forth between the tablet on the stool and the large screen. Secondly, visitors often oversaw the tablet and consequently assumed that the large screen was a touch screen. This problem was very present in the Weisskunig Quiz, probably because most people these days are used to touch input – after all, it is used on cash and ticket machines, food order terminals, multi-touch tables in other museum exhibitions, and more.

While there was a message on the bottom of the screen which prompted users to use their smartphone or the tablet, most people did not see it or just ignored it. This shows that the installation has to be set up in a way that the it does not create any affordances to touch the large screen from the start. An example would be, as proposed previously, to place benches or stools around the large screen, which show that visitors are supposed to sit around the monitor instead of approaching it directly. In addition to being another eye-catching element, they would offer the possibility for visitors to sit down and comfortably spend a bit more time at the exhibit than they would do while standing all the time. The stationary tablet(s) could then either be connected to the stools or placed on speaker's desks between or on low tables in front of them. An example of two such setups is shown in Figure 38.

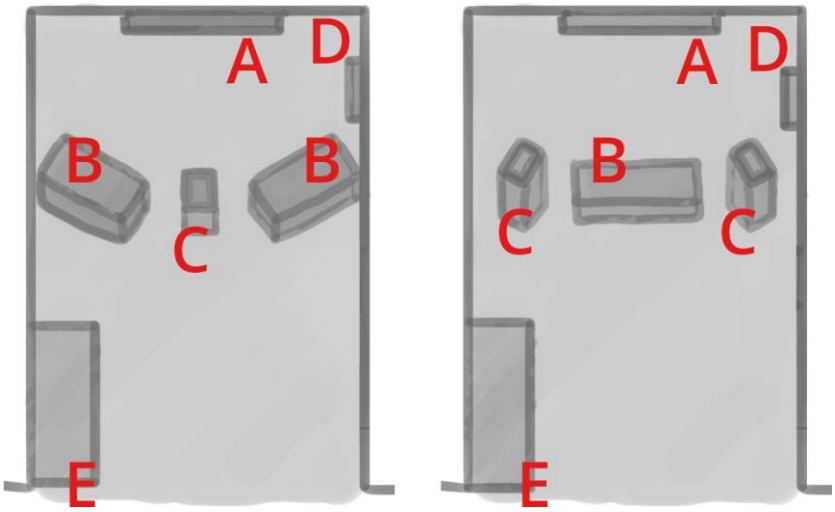

Figure 38. Two possible improvements of the Weisskunig Quiz setup, one with a single stationary tablet (left) and one with two (right). (A) is the large screen. (B) are benches where visitors can comfortably sit down. (C) are stationary tablets. (D) is the guest list. (E) is a vitrine with a medieval book, which is not related to the installation.

5.1 The Weisskunig Model

The problem that a lot of people mistake the large screen for a touch screen leads me to one important conclusion: Most of the interaction models for public interactive installations, as presented in chapter 2, only address installations which involve direct (mostly touch) interaction with the main element (mostly a large screen or projection), and thus only apply to the Weisskunig Quiz to some extent. Therefore, I propose an interaction model for interactive museum installations which incorporate the users' own devices and afford interaction from a distance. It is based on both my literature research and the insights gained

from the evaluation of the Weisskunig Quiz. The model, which I will refer to as the “Weisskunig Model”, consists of three zones, which Figure 39 illustrates.

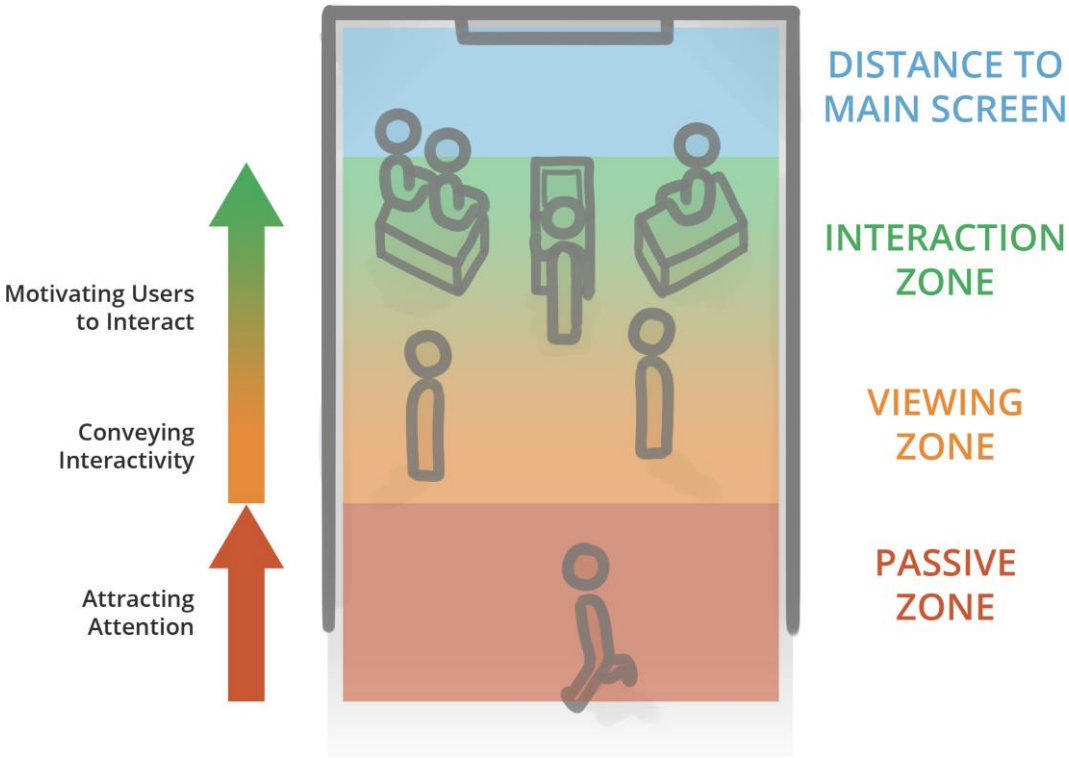

Figure 39. The “Weisskunig Model”. It shows the three zones and the challenges which have to be overcome to make a visitor pass from one zone to the next. While the border between the Passive and the Viewing Zone is hard, the one between Viewing and Interaction Zone is more of a gradient, because with the smartphones as interaction device, people do not have to stand in a specific place. Unlike in other interaction models, there is a distance to the main screen, i.e. a “zone” in which no user should stand for a long time.

The Passive Zone

The Passive Zone is the zone where people walk by the installation. In case of the Weisskunig Quiz, it is located at the entrance of the niche and around it. It is basically all the space around the niche from which visitors can technically see the installation. To pass from the Passive Zone to the Viewing Zone, the visitors’ attention must be attracted in some way. The best method for this is to use some kind of movement, which humans generally respond well to – this can be physical, animatronic movement or on-screen animations of all sorts. The animation and/or the most important information should be visible from a distance of around five meters.

The Viewing Zone

The Viewing Zone is where people whose attention has been attracted gather to see what is going on around the installation. It is probably the most important zone, since the decision whether a visitor will join the game or not is made here. Inside of the Viewing Zone, people must make up their mind by answering the following questions for themselves: What is this? Is it interesting for me? Can I join, and how? How do others behave towards it? Even if people already know about the installation from flyers or brochures they have read before their visit, informational elements such as posters (or even helper persons) should be installed in this zone, so that people can easily answer the mentioned questions. The Viewing Zone is also where peer learning happens – people who have played or are playing the game might start talking to the viewers, or viewers will share their perception of the installation among them. In the Weisskunig Quiz, the Guest List is located in the Viewing Zone, since it is an information element on the one hand, and on the other hand, players can look for their names on it when they have finished playing and attempt to leave.

The Interaction Zone

The Interaction Zone is the place where people actually devote themselves to the installation. In contrast to other interaction models, the border between the Viewing Zone and the Interaction Zone in the Weisskunig Model is not hard, but more of a diffuse gradient, since installations which afford interaction through the smartphone do not require the user standing in a specific place. This also reduces the possibility of the "spotlight effect" happening, where people avoid interaction in order not to embarrass themselves. With the smartphone as the interaction instrument, the interaction is more anonymous, and a person just has to be in a radius where they can still see the images on the large screen. When interacting with a stationary tablet, there is a bit less anonymity. However, the screen of the tablet is still rather private and only visible to the person standing in front or very close to it. To pass from the Viewing Zone to the Interaction Zone, visitors have to be motivated to join. Depending on the installation, different techniques among the following might work: Providing a challenge, raising people's curiosity, creating a story around the installation, giving users freedom of choice, or enabling collaboration. The Weisskunig Quiz naturally plays with the curiosity of viewers, since humans usually want to complete incomplete information (like wanting to know the answer to a question). Gamification elements (such as Leaderboards, Badges/Collectibles, Quests, Customization etc.) can also be used to motivate visitors to interact.

Distance to the Main Screen

Unlike in other interaction models, the Weisskunig Model includes a distance to the main screen of the installation. People should and will usually not cross the

border between the Interaction Zone and the main screen, since they will occlude the view of other people playing the game. The distance between the Interaction Zone and the main display depends on the size of the screen, how big the elements on it are, and on the height at which the display is mounted.

Another difference of the Weisskunig Model is that in most of the models described in chapter 2, the corresponding installations were located in places such as public halls at a conference, university halls, or offices, where people usually spend more time in the near field of the installation than they would do in a museum. In a buffet hall, for example, people eat and socialize longer and often have the possibility to check out an installation “later”, which gives the installation more time to “convince” visitors to explore it. In the museum in Klosterneuburg, visitors usually start their tour through the lower floor exhibition at (or near) the entrance and follow a certain, rather one-directional path through the museum. If they pass the Weisskunig Quiz without playing it, chances are low that they will come back later. It has to be convincing enough to visitors, so they spontaneously decide to join the game.

5.2 Design Guidelines

As a result of my research on interactive installations and the evaluation of the Weisskunig Quiz, I also propose a list of guidelines for designing an interactive installation for a museum which offers the best user experience to the visitors:

Make Joining as Easy as Possible

In general, people seem to be very sceptical when it comes to downloading an app on their devices. This poses a problem for installations which incorporate the users’ smartphones. Designers of an interactive installation should consider providing one or more rental or stationary devices to avoid losing users due to this reluctancy, or because they do not have a smartphone at all. Depending on the features of the installation, it might also be possible to provide a web interface which users can just access with their browsers.

Provide Clear Explanations

Since people from all age groups with different technical affinity visit museums, it is important to explain every part of the application very clearly, either through an onboarding system or through little (unobstrusive) messages on the screen. A help system can be beneficial as well. Since visitors only spend a relatively low amount of time at the installation, they are likely not to take their time to learn all the features of the app.

Give Obvious Feedback

Users should immediately see that their interactions on the ODs affect the rest of the installation. Depending on the installation or application, this might call for extensive feedback in different forms (in case of the Weisskunig Quiz, textual messages and additional animations on the users' devices would have been needed while with other installations which use tilt and rotating functions, other kinds of feedback might be appropriate). The ODs have to be an integral part of the installation, otherwise users will try to find workarounds to resolve this inconvenience.

Agree on Features and Requirements Beforehand

When creating an interactive installation for a museum, it is especially important to specify expectations and requirements with the people responsible for the exhibition, lest the installation suffers from limitations such as integral elements being moved somewhere else, or the Wi-Fi not reaching certain areas.

Be Aware of the "Interaction Zones" around the Installation

Designers of an interactive installation in a museum have to be aware of the "interaction zones" which naturally form around the space. In chapter 5.1, I proposed the "Weisskunig Model", which shows the interaction zones around an interactive installation which incorporates users' devices and explains how users "transfer" through the different zones. The nature of the different zones can be used in the physical design of the installation, e.g. by putting furniture into the interaction zone and information posters and/or screens into the viewing zone.

Consider the Steps of the "Audience Funnel"

In general, one should keep in mind that an interactive installation should do the following: **Attract visitors' attention** in the Passive Zone through eye-catching elements and/or animations on screen. **Communicate interactivity** and how to join/interact in the Viewing Zone (From the experiences I got from the Weisskunig Quiz, I can say that there can almost never be enough information sources, from simple posters to informational screensavers). Lastly, **motivate users to join**, either through providing a challenge, making them curious, enabling collaboration, inventing a pleasing story around the installation, giving users freedom of choice, or use other gamification elements such as leaderboards or badge collection options.

Limitations of the Weisskunig Quiz

Both the Weisskunig Quiz and the Weisskunig Model have some limitations. For example, in its current state, the game itself is not accessible to people with visual impairments. The main reason for this is that most of the questions refer to

the displayed images. While it would be technically possible to add a describing audio track, it would either give away the answer, or not help at all (e.g. with the question which requires counting elements in the image). By changing the affected questions, the game could be made more accessible. However, it is probable that letting a screenreader read the text aloud takes more time than reading them, which is why a visually impaired person would need a longer answer time, whereas a seeing person might become bored.

A limitation of the Weisskunig Interaction Model is the fact that the corresponding installation was placed in a museum. While a museum has a lot of features of a public space (people do not know each other, everyone can enter given they pay a small fee, the stationary devices can not be influenced by the visitors…) it is still rather “secure” – there are usually security cameras or guards around, and it has opening times. An installation on the street is exposed to more dangers and poses additional challenges: For example, it might be turned on and functional for 24 hours a day. Different people would pass by it on different times of the day, and it would be more susceptible to vandalism. When creating an interactive installation for the street, there will possibly be more contingencies to consider. If the installation is guarded (e.g. like it might be on a festival or similar event), the Weisskunig Model could apply to such an installation as well, though.

6 Conclusion

At the beginning of this thesis, the following research question and sub questions have been posed:

How does a multi-device setting have to be designed so that it offers the best user experience to visitors of a museum exhibition?

- *Which kinds of multi-device concepts already exist, and what are the relationships between the individual devices used in those concepts?*
- *What kind of challenges arise when designing a multi-device setting for a museum, and how can one overcome them?*
- *How can a visitor's own device be incorporated into a multi-device setting in a museum?*

There are three different approaches for multi-device design described in literature: The “Consistent Approach” (devices are not connected in any way, but the application looks and behaves consistently), the “Continuous Approach” (the application is intended to help solve a task on multiple devices in a row), and the “Complementary Approach” (devices have their interaction possibilities spread amongst them and form the interactive experience together). While there are also mixes of the three approaches, only the latter really describes what a “multi-device environment”, as described in this thesis, really is: A set of spatially nearby devices which form a unique, interactive environment.

Incorporating personal devices into multi-device environments has a few advantages. On the one hand, it is a low-cost alternative to providing rental equipment, and on the other hand, people are already familiar with their own devices. Additionally, most people own a smartphone already and carry it with them wherever they go. Personal devices can assume different roles as a part of an MDE: They can be used for personalization, e.g. public parts of the installation could be accessible to everyone while private parts are only visible on the user’s device. They can be used as input (or output) devices, like a controller, or they can function as co-displays by augmenting the content of another screen, for example. What is especially interesting for museum scenarios is the possibility of taking information away from the installation with smartphones, tablets or even smartwatches. By using the variety of built-in sensors, personal devices can also be used as “tracking devices”, making exhibition content dependent on where the

visitor is standing or where they have already been and creating an immersive museum experience. However, when including the visitors' own devices in an MDE in a museum, the devices should play an integral role in the intended interaction. Otherwise, it will become an inconvenience which the users will try to resolve.

The greatest challenge which arises when designing a multi-device setting for a museum is people's fear of social embarrassment. They will always try to maintain a certain social role and therefore behave differently in public than they would do in private. This leads to "zones" forming around the interactive installation. To pass from one zone to the next, passers-by have to overcome certain thresholds. For example, before approaching an installation, a visitor will want to find out what it is about, how others behave towards it, and how to disengage without raising too much attention. Until a visitor finally interacts with a system, they follow a sort of funnel, and the installation including the space around it have to be designed in a way that the transitions through the zones occur smoothly. This includes three steps: First, the installation has to attract the visitor's attention. Second, it has to convey that it is interactive. Lastly, the potential user has to be motivated to interact.

In scientific literature, various researchers specify interaction models for public interactive installations, which describe how this challenge can be overcome. However, none of these models is suited for interactive installations which incorporate visitors' own devices. This is why I propose the Weisskunig Model and a set of design guidelines, which address such scenarios and describe how to design an MDE and its surroundings accordingly. The insights on which this model is based on have been gained through the creation and evaluation of an interactive multi-device installation, the "Weisskunig Quiz", which was deployed and tested in a real museum exhibition.

Future Work

The Weisskunig Quiz could still be improved in some aspects. For example, in its current state, it is not accessible for museum visitors with visual impairments, since the game heavily relies on images which are shown on the large screen. Which kind of methods of conveying images to visually impaired people are suitable, and how to balance the game for seeing and non-seeing persons is still a subject of research.

During the evaluation of the quiz, two minor issues have been discovered, which could however still be resolved by adding some improvements to the game. The first issue is the static time of 25 seconds, which is too long for some questions, and too short for others. This could be resolved by conducting more user tests, to get a feeling for how long visitors need to answer each question, and then implement different times for each question. Eventually, this process could also

be automated, with the system always changing the available time according to the mean answer times of the visitors. However, the viability of such a feature would also have to be evaluated. The second issue is the visitors' problem to recognize the connection between the own devices and the large screen. This problem only occurs when one visitor plays the game alone, because they do not see the animation of the "answer bubble" on the main screen. A possible solution would be to add an animation to the visitors' devices, which show an answer bubble appearing whenever they choose an answer, and then flying off the screen. Whether this addition does indeed help to better connect the individual devices is also a matter of evaluation.

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List of Figures

List of Tables

Appendix

A. User Test Questionnaire

MEETeUX Weißkunig Quiz Evaluation – Post Observation Questionnaire

Time:

Device used: ☐ Own Device ☐ Stationary Tablet

Time spent interacting with the application:

How many people were at the exhibit when person started to interact?
Active: _____ Passive: _____

General Data

Age:

Gender: ☐ Female ☐ Male ☐ Other ☐ No answer

How many minutes per day do you spend using your smartphone?
☐ None / I don't have one
☐ I don't use it daily
☐ Less than 10 minutes ☐ 10 to 15 minutes ☐ 15 to 30 minutes ☐ 30 to 60 minutes
☐ More than 60 minutes

How experienced are you with digital devices?

	1	2	3	4	5	6	7	
Not experienced	☐	☐	☐	☐	☐	☐	☐	Very experienced

How much do you like quiz shows/games/etc.?

	1	2	3	4	5	6	7	
Not very much	☐	☐	☐	☐	☐	☐	☐	Very much

Weißkunig Game

Please describe to us what you saw – just how the application looked like, what you noticed…

Why did you approach the installation?

How easy to use did you find the game?

	1	2	3	4	5	6	7	
Difficult	☐	☐	☐	☐	☐	☐	☐	Easy

Why?

How did the simultaneous usage of two screens feel to you? (Tablet/Phone and big screen)

	1	2	3	4	5	6	7	
Overwhelming	☐	☐	☐	☐	☐	☐	☐	Easy

Why?

How understandable was the visualization of right and wrong answers?

	1	2	3	4	5	6	7	
Not understandable	☐	☐	☐	☐	☐	☐	☐	Understandable

Why?

How much did you like the design of the game?

	1	2	3	4	5	6	7	
Not at all	☐	☐	☐	☐	☐	☐	☐	Very much

Why?

When did you notice that the little balls on the big screen represent the given answers?

How do you feel about the time you had to answer a question?

☐ It was too short ☐ It was just right ☐ It was too long

Did you notice the Guest List on the right screen here? Do you have an idea on what role it plays in the game?

Do you have any suggestions on how we could improve the game?

How likely is it that you will use a smartphone in an exhibition?

	1	2	3	4	5	6	7	
Unlikely	☐	☐	☐	☐	☐	☐	☐	Likely

Why?

System Usability Scale

I think that I would like to use this system frequently.

	1	2	3	4	5	
Strongly Disagree	☐	☐	☐	☐	☐	Strongly Agree

I found the system unnecessarily complex.

	1	2	3	4	5	
Strongly Disagree	☐	☐	☐	☐	☐	Strongly Agree

I thought the system was easy to use.

	1	2	3	4	5	
Strongly Disagree	☐	☐	☐	☐	☐	Strongly Agree

I think that I would need the support of a technical person to be able to use this system.

	1	2	3	4	5	
Strongly Disagree	☐	☐	☐	☐	☐	Strongly Agree

I found the various functions in this system were well integrated.

	1	2	3	4	5	
Strongly Disagree	☐	☐	☐	☐	☐	Strongly Agree

I thought there was too much inconsistency in this system.

	1	2	3	4	5	
Strongly Disagree	☐	☐	☐	☐	☐	Strongly Agree

I would imagine that most people would learn to use this system very quickly.

	1	2	3	4	5	
Strongly Disagree	☐	☐	☐	☐	☐	Strongly Agree

I found the system very cumbersome to use.

	1	2	3	4	5	
Strongly Disagree	☐	☐	☐	☐	☐	Strongly Agree

I felt very confident using the system.

	1	2	3	4	5	
Strongly Disagree	☐	☐	☐	☐	☐	Strongly Agree

I needed to learn a lot of things before I could get going with this system.

	1	2	3	4	5	
Strongly Disagree	☐	☐	☐	☐	☐	Strongly Agree

B. In-Game Quiz Questions

This table shows the questions and answers as they were provided by the museum curators and implemented in the game.

Question ID	Text in German and English
1	In welchem Sternzeichen war Maximilian I. geboren? *(What was Maximilian's zodiac sign?)* a) Steinbock *(Capricorn)* b) Löwe *(Leo)* **c) Widder *(Aries)*** d) Stier *(Taurus)*
2	Wie hießen Maximilians Eltern? *(Who were Maximilian's parents?)* a) Philipp und Johanna *(Philip and Joanna)* b) Ludwig und Anna *(Louis and Anne)* c) Rudolph und Margarete *(Rudolph and Margaret)* **d) Friedrich und Eleonore *(Frederick and Eleonor)***
3	Welche Kopfbedeckung ist hier rot eingefärbt? *(Which headgear is coloured red?)* a) Tiara *(tiara)* b) Pileolus *(zucchetto)* **c) Kardinalshut *(galero)*** d) Bischofsmütze *(bishop's mitre)*
4	Welches Ritual wird hier dargestellt? *(Which ritual can be seen here?)* a) Fußwaschung *(footwashing)* b) Beichte *(confession)* **c) Taufe *(baptism)*** d) Beschneidung *(circumcision)*
5	Maximilian trägt einen Ehrenkranz. Wie oft ist er auf dem Bild zu sehen? *(Maximilian is adorned with a laurel wreath. How many times can he be seen on the picture?)* a) zwei Mal *(two times)* b) vier Mal *(four times)* c) **sechs Mal *(six times)*** d) acht Mal *(eight times)*
6	Welches Schreibwerkzeug benutzt Maximilian hier? *(Which writing tool is Maximilian using?)* **a) Gänsefedern *(goose quills)*** b) Wildknochen *(animal bones)* c) Straußenfedern *(ostrich feathers)* d) Nussholzstäbchen *(nutwood sticks)*
7	Was ist hier auf den Schriftstücken rot markiert? *(Which features of these documents are coloured red?)* a) Briefmarken *(postal stamps)* b) Adressaufkleber *(address labels)* c) Stempel *(stamps)* **d) Siegel *(seals)***
8	Wo ist Maximilian hier zu Gast? *(Where is Maximilian?)* **a) Münzwerkstatt *(in the mint)*** b) Küche *(in the kitchen)* c) Gericht *(at court)* d) Waffenschmiede *(in the armoury)*
9	Welchem Hobby ging Maximilian sehr gerne nach? *(What was Maximilian's favourite hobby?)* a) dem Reiten *(horseback riding)* **b) der Jagd *(hunting)*** c) dem Wandern *(hiking)* d) der Hundezucht *(dog breeding)*

10	Welcher Helm ist hier rot eingefärbt? *(Which type of helmet is coloured red on this picture?)* a) Korinthischer Helm *(corinthian helmet)* b) Kübelhelm *(great helm)* **c) Stechhelm *(frog-mouth helmet)*** d) Bügelhelm *(barred helmet)*
11	Wie hieß Maximilians erste Ehefrau? *(Who was Maximilian's first wife?)* **a) Maria von Burgund *(Mary of Burgundy)*** b) Margarethe von Schottland *(Margaret of Scotland)* c) Isabella von Kastilien *(Isabella of Castile)* d) Beatrix von Aragón *(Beatrice of Naples)*
12	Wie kommunizierten die Fürsten im Mittelalter und der Frühen Neuzeit miteinander? *(How did nobles communicate with each other during the Middle Ages and the Early Modern Period?)* a) Brieftauben *(messenger pigeons)* b) Rauchzeichen *(smoke signals)* **c) Boten *(messengers)*** d) E-Mail *(e-mails)*
13	Auf diesem Bild wird eine bedeutende Reliquie präsentiert. Um welche handelt es sich? *(On this picture a truly important relic is shown. What is it?)* a) Jacke von Regensburg *(Divine Jacket of Regensburg)* **b) Rock von Trier *(Seamless Robe of Jesus in Trier)*** c) Hemd von Bamberg *(Blessed Shirt of Bamberg)* d) Hose von Aachen *(Holy Trousers of Jesus in Aachen)*
14	Woher kennt man das rot eingefärbte Wappen heute? *(What is the red-coloured coat of arms associated with today?)* a) Wappen von Oberösterreich *(coat of arms of Upper Austria)* b) Wappen von Wien *(coat of arms of Vienna)* **c) Wappen von Niederösterreich *(coat of arms of Lower Austria)*** d) Wappen der Steiermark *(coat of arms of Styria)*
15	Wann und wo wurde Maximilian zum römisch-deutschen König gekrönt? *(When and where was Maximilian crowned King of the Romans?)* a) 1495 in Prag *(1495 in Prague)* b) 1490 in Wien *(1490 in Vienna)* c) 1492 in Stuhlweißenburg *(1492 in Székesfehérvár)* **d) 1486 in Aachen *(1486 in Aachen)***
16	Wo wurde Maximilians Vater, Friedrich III., 1493 bestattet? *(Where was Frederick III, Maximilian's father, buried in 1493?)* a) Stiftskirche Klosterneuburg *(Klosterneuburg Monastery)* b) Kapuzinergruft *(Imperial Crypt)* c) Schottenkirche *(Scottish Abbey)* **d) Stephansdom *(St Stephen's Cathedral)***

C. Visitors‘ Answers

This table summarizes the automatically collected data on the quiz answers. The fields with a thicker border mark the highest/lowest values.

Question ID	Total Answers	Correct Answers	Wrong Answers	Skipped	Average Time (s)	SD Time (s)
1	202	79	81	42	11.27	5.83
2	204	117	37	50	9.37	4.52
3	208	115	51	42	11.21	5.23
4	210	154	14	42	7.63	3.95
5	201	52	90	59	14.46	7.22
6	206	115	43	48	11.58	5.51
7	202	145	11	46	9.26	3.95
8	203	135	31	37	11.50	5.09
9	205	146	14	45	11.50	5.09
10	212	77	92	43	13.43	5.89
11	220	161	22	37	9.44	5.16
12	226	156	29	41	9.86	4.36
13	208	73	89	46	15.81	5.76
14	211	115	55	41	12.06	5.57
15	202	81	79	42	13.00	5.37
16	210	77	93	40	11.76	5.65