Switched-On Malmö Live

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MASTER THESIS

Switched-On Malmö Live

Exploring Directions for the Future of Classical Music Streaming Experiences

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Abstract

Classical music institutions are confronting declining attendance among younger and diverse audiences, fearing an aging visitor demographic. The LUDICH Project at Lund University, in collaboration with several industry partners, academic institutions, the Malmö Symphony Orchestra and their home concert hall of Malmö Live aims to address this challenge by investigating innovative digital solutions with the hopes of enhancing accessibility and engagement in classical music experiences for a wider demographic.

This master's thesis was conducted within the LUDICH project and in collaboration with the innovation management team of the IT consulting firm Capgemini. The aim was to explore directions for how a classical music streaming solution could look, feel and work. This was done by applying a Double Diamond design process by first fully understanding the problem area of declining interest in classical music by younger audiences through a literature review, an attitude survey and in-depth interviews. The gathered data was then analyzed to discover the pain points, wishes and requirements of the target demographic which was used for several concept design and ideation sessions. These insights worked as the basis for the development and evaluation of two prototypes. The first iteration was created with pen and paper and the second was an application for both immersive technology and desktop.

The usability testing of the final prototype showed positive results regarding several types of interaction and the sense of *being there* within the virtual concert hall. This underscores the potential of innovative digital solutions to enhance accessibility and engagement in classical music experiences for a broader audience.

Keywords: classical music, immersive technology, digital concerts, interaction design, usability testing

Sammanfattning

En stor utmaning för klassiska musikinstitutioner är det faktum att konsertsalarna saknar en yngre och mer mångfacetterad publik, som istället utgörs av en åldrande demografi. LUDICH-projektet på Lunds Universitet samarbetar med ett flertal industripartners, akademiska instutioner, Malmö Symfoniorkester och deras hemmakonsertsal Malmö Live i ett försök att addressera utmaningen genom att undersöka innovativa digitala lösningar för att öka tillängigheten och engagemanget för klassiska musikupplevelser för en bredare demografi.

Denna masteruppsats genomfördes inom LUDICH-projektet i samarbete med innovationsförvaltningsteamet på IT-konsultbolaget Capgemini. Syftet var att utforska innovativa sätt för hur en streamingapplikation för klassiska konserter skulle kunna utformas, upplevas och fungera. Detta genomfördes genom en Double Diamond-designprocess som inleddes genom en noggrann förståelse för problemområdet kring det minskade intresset för klassisk musik, vilket inkluderade en litteraturstudie, en attitydundersökning och djupgående intervjuer. Den insamlade datan analyserades sedan för att identifiera användarnas smärtpunkter, önskemål och krav, vilket låg till grund för flera koncept- och idégenereringssessioner. Baserat på insikter från dessa sessioner påbörjades sedan utvecklingen och utvärderingen av två prototyper. Den första prototypen skapades med penna och papper, medan den andra var en applikation som fungerade både med immersiv teknologi och i webbläsaren.

Den slutgiltiga prototypen utvärderades genom användbarhetstester och fick en positiv respons från användarna gällande olika typer av interaktion och känslan av att *vara närvarande* i den virtuella konsertsalen. Detta resultat understryker potentialen hos innovativa digitala lösningar för att öka tillgängligheten och engagemanget för klassisk musik bland en bredare publik.

Nyckelord: klassisk musik, immersiv teknologi, digitala konserter, interaktionsdesign, användbarhetsutvärdering

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Thank you all Capgemini employees who made us feel at home at the office, this thesis could not have been done without your eagerness to participate in user studies and beat us in table tennis. Without you and everyone else who answered surveys, was interviewed and participated in user studies this project would not have been feasible. We are so grateful for your participation, honesty and input. We also want to thank A Norborg for the inspiration for the title by linking the thesis' themes to Wendy Carlos's work.

Lastly, we want to express our deepest gratitude to our friends, family and loved ones. Completing five years at LTH would have been impossible without you. Thank you for everything.

Lund, June 2024
Kaspian Jakobsson and Moa Björkman

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List of Acronyms and Abbreviations

AI	artificial intelligence
AIE	Applied Innovation Exchange
Hi-Fi	high fidelity
IPQ	IGroup Presence Questionnaire
LLM	large language model
Lo-Fi	low fidelity
LUDICH	Lund University Digital Interactive Music Hall
ML	machine learning
MSO	Malmö Symphony Orchestra
SUS	System Usability Scale
VR	virtual reality
XR	extended reality

1 Introduction

This chapter introduces the thesis work. It will present the company and project which the work is done in collaboration with, as well as the thesis's background, research questions, scope and related work in the field of digital concerts and classical music attendance factors.

1.1 Background

Classical music concert attendance has seen an under-representation or decline of younger audiences, causing an increasing concern for music institutions and orchestras around the world that their audience is aging [15, 27]. In 2017, the non-profit organization The Audience Agency, published a survey detailing the demographics of classical music concerts, covering 6989 concerts between 2014 and 2016, all located in England [8]. According to the survey, 42% of the concert audience were likely to be between 41 and 60 years, and 37% to be over 61. Only 7% are likely to be under 31 years. The classical music institutions also struggle to reach people with lower education levels or with a non-western background [17, 28].

In order to survive, the classical music institutions must find a way to reach and include a younger and more diverse audience. In response to the challenges posed by declining classical music concert attendance among younger and diverse audiences, the LUDICH Project at Lund University conducts research on innovative digital solutions that could be applicable to the classical music space, aiming to make these kinds of cultural experiences more accessible and engaging.

1.1.1 The LUDICH Project

The Lund University Digital Interactive Concert Hall (LUDICH) project is a cross-disciplinary initiative aiming to build "the concert hall of the future" [32]. The project also goes under the name Kalaudioscope. The goal is to lay the groundwork for innovative digital live performances by exploring interactive streaming solutions and digital formats catering for individual cultural experiences. The project runs for three years, and aims to find new methods to produce culture and make it more accessible for a wider audience.

The project is of thematic collaborative nature and led by the Faculty of Arts at Lund University, together with other faculties at the university and several external partners providing technological insight and development. As a test bed for the project, the concert hall residing in Malmö Live is being used. Malmö Live concert hall is the home of Malmö Symphony Orchestra (MSO) and feature of 800 concerts and events each year [33]. The concert hall has been equipped with video and audio recording technology to enable its usage as a "living lab" for the project.

1.1.2 Capgemini

Capgemini is an IT and management consultancy company founded in 1967 [10]. It originates from France but are currently operating in over 50 countries, globally having over 350 000 employees. The Malmö office is located in Västra Hamnen and is home to the Nordic branch of the Applied Innovation Exchange (AIE). AIE is a global innovation platform that aims to foster collaboration and operate at the forefront of technology. Its goal is to help organizations utilize technology to attain business objectives while nurturing long-term innovation competences.

The Malmö based AIE is one of the industry partners of the LUDICH project. They provide expertise on innovation management and the immersive aspects of the project.

1.1.3 Title Explanation

The main title of this thesis, *Switched-On Malmö Live*, is a reference to the 1968 album *Switched-On Bach* by electronic musician Wendy Carlos [11]. The album features ten compositions by Johann Sebastian Bach played entirely on MOOG synthesizers. Carlos re-introduced Bach's baroque compositions to a modern generation of listeners with her transformation of classical orchestral music to electronic music, using the most current technology available within the music landscape at the time. The album bears high cultural significance within the genre, and the cover can be seen in Figure 1.1. For the authors of this thesis, Carlos's then-modern reimaginings of classical music is an inspiring example of how technology can be harnessed to breathe new life into this traditional art form.

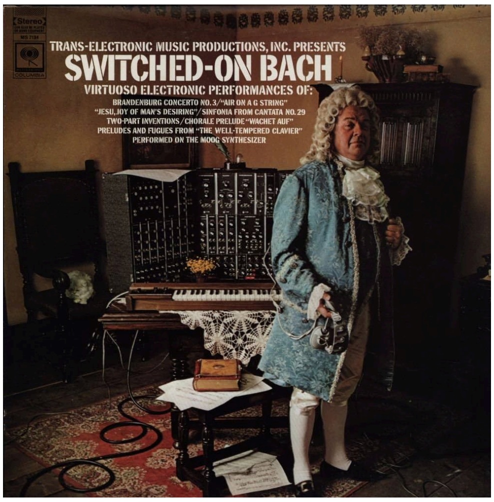

Figure 1.1 Wendy Carlos *Switched-On Bach* (1968)

1.2 Purpose and Goals

The purpose of this thesis is to explore directions for how a classical music streaming application could work, and investigate if and how increased interactivity can influence the experience of said application. The overarching goal is to contribute meaningfully the LUDICH project in their mission to build "the concert hall of the future" [32]. This is to be achieved through a comprehensive design process involving user research and iterative prototype creation and evaluation.

In particular, the goal of the thesis is to answer research questions presented below.

1.2.1 Research Questions

The research questions are stated as follows:

- **RQ1**: What is the state of the art in terms of streamed live media?
- **RQ2**: How can one increase interactivity in a streamed classical music concert solution?
- **RQ3**: How does increased interaction affect the user experience?

1.3 Scope and Limitations

Since the purpose and problem area of the thesis allow for a wide range of solutions, a decision was made after the initial user research to proceed with the path that the authors of the thesis thought satisfied the user's wants and needs the most while also being the most viable option in terms of implementation. One could imagine that comparing two different solutions against each other would be an interesting methodology for this thesis, but with a time limit of 20 weeks for the completion of the thesis, only one solution was finalized into a prototype. The final prototype is however multi-platform, meaning that some comparative testing could still be conducted.

Due to the limited time and resources, the extent of the final prototype implementation was also inevitably restricted.

1.4 Global Sustainability Goals

The UN *Sustainable Development Goals* are a set of 17 defined goals for sustainable development that is a part of Agenda 2030 [51]. This thesis works to expand and diverse the audience of classical music concerts by digitalizing and enhancing the experience of a being in a concert hall and find directions for the development for the classical music streaming application of the future. This work is done with close ties to the UN sustainable development goal number 9: *Industry, Innovation and Infrastructure*, seen in Figure 1.2.

Figure 1.2 Goal 9: "Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation."

1.5 Ethical Considerations

There are many ethical considerations to take into account when designing and implementing new technology. As recommended by Lennerfors [30], firstly a problem statement is formulated and the owner of the problem is identified. Then information regarding the problem and the technology in question is brought forward, and thereafter an analysis based on different ethical theories.

One imaginable problem statement, related to this work might be:
Young people do not attend classical music concerts and immersive technology is introduced to entice them to attend.

The problem owner in this case might be Malmö Live.

To analyze this the framework presented in [30, p. 101] is used which presents the following questions to take into consideration:

- What impacts will the action produce?
- Have I considered relevant duties and rights?
- What is the impact on me as a virtuous agent?
- What is the impact on the freedom of me and others?
- What is the impact on my relationships to others and their relationships?
- Is my solution fair?
- Is my solution taking environmental issues into account?
- Are there any other ethical aspects that I have not taken into account?

Based on the above, a scenario matrix can be constructed, listing different feature sets and analyzing the pros and cons for each feature set, but that might be superfluous for this problem scenario.

The most obvious ethical question that arises is that of accessibility, in which the technology developed must be designed and developed in a way which tries to encompass a broad scope of users, with ranging abilities. Another aspect to keep in mind is that the technology makes users not otherwise able to attend classical music concerts, able to attend. That in which increases the demography and accessibility of the concerts as a whole.

Another ethical aspect to consider is the environmental impact. One aspect might be that introducing a need for more hardware might have a negative impact on the environment. On the other hand, reducing the need to travel to a concert hall might offset that impact.

Introducing immersive technology in a scenario which, in the real world, might be highly social, might impede on the social relations to others. This is one important factor to keep in mind when designing as well, but the thesis reflects on that further.

For an imagined application in which a concert is being streamed for Malmö Live, the musicians must be filmed or otherwise captured somehow, to be streamed across to remote devices. Thereby an ethical question is raised — how are the musicians captured in an ethical way? One simple aspect to keep in mind is to inform the musicians and take their opinions into consideration.

1.6 Related Work

In this section, the result of a literature study will be presented. It encompasses both the current state of digital elements in concerts and motivations and frustrations from (non-)audiences of classical music.

1.6.1 The Need for New Audiences

Many people appreciate classical music when exposed to it in everyday life, in movies or in video games. However, attendance to live classical music concerts by a younger population is on decline [15, 27].

To investigate why young people do not attend classical music concerts, especially those who engage with other kinds of cultural events, Dobson [16] invited nine participants to attend classical music concerts for the first time. The study was built upon the methodology and findings of Kolb [28] and also confirms its findings. Although participants in both studies were appreciators of music and concerts in general, both studies found that these non-attenders believed that the audiences of classical music concerts accessed certain 'special' knowledge which enabled them to find enjoyment in it. Participants considered themselves as lacking this knowledge, therefore being concerned about not being able to make the 'correct' judgments regarding classical music performances [16, 28]. Participants in the study of Dobson [16] expressed a sense of moral obligation to enjoy classical music and that certain norms and rituals within the realm of classical music concerts, such as a prolonged standing ovation, felt alienating to them because of the lack of insight and knowledge. Other studies point to a lack of time and interest to explain the declining younger audiences, where the lack of time is more dominant regarding higher educated people, and a lack of interest concerning lower education levels [17]. Dobson [16] also found that embedded information, such as introduction to the played pieces, significantly enhanced the experiences of the first time attendees of the study.

1.6.2 Digital Modalities For Classical Music

Erdbrink et al. [17] discusses how games can be used as a tool to invite new audiences to classical music concerts, both as an educational tool but also as a promotional one. They recruited 540 participants where each participant either got to test a game, called Listening Space, which they hypothesized would increase the engagement in a classical concert, or the participant did not get to test the game. After completing a pre-questionnaire the participant got a free ticket to a classical music concert. The participants were identified according to their listening habits as either a *passer by* or a *regular visitor*. The game was designed to teach the users about different listening techniques, identified in a previous step, and to increase the users' involvement in the concert experience. The results showed that new concert attendees benefited from using the game, in the sense that they had broader toolbox of listening techniques of the real-world concert compared to their control group counterpart. Similarly to the findings from Dobson [16], Erdbrink et al. [17] found that embedded information such as facts and details about the pieces performed, and its context played a significant role for how included the participants felt when attending a classical music concert for the first time.

1.6.3 Concerts in the Digital Space

The music sector has been increasingly evolving into a digital space. With digital music content widely accessible, platforms such as Spotify and YouTube has become the dominant means of music consumption for many people [12]. Digital concert experiences increased in popularity drastically during the Covid-19 pandemic when concerts in the material world came to a halt and audiences were locked inside [17, 31, 13]. These digital concerts managed to maintain some level of both the live and social aspects of regular concerts. However, the presence aspect of feeling *there* can be hard to achieve in digital formats [12].

Deng and Pan [13] conducted a recent study investigating the factors shaping audience attitudes towards virtual concerts. Their findings revealed that user autonomy, relatedness, and engagement positively influenced perceived usefulness, ease of use, and enjoyment of the virtual concert experiences. Moreover, these perceptions significantly predicted audience attitudes towards virtual concerts.

1.6.3.1 Digital Elements in Live Concerts and Live Elements in Digital Concerts

Digital enhancement of live concerts has also been popularized. For example, the ABBA Voyage concert, premiering in 2022 in London, features 3D avatars of the

Figure 1.3 Photograph from the ABBA Voyage concert. By Johan Persson.

band during the height of their popularity, shown on large LED-screens [38]. Artists such as Hatsune Miku, Tupac Shakur and Whitney Houston have been featured in avatar concerts before, but the immense success of the ABBA Voyage, making $2 million a week on sold out shows, is unprecedented [6, 29]. Although blurring the boundaries of a live performance, the show has proven to evoke a sense of presence, emotion and immediacy from its audience [38]. A photograph from the concert can be seen in figure 1.3.

The ability for avatars and virtual personas to evoke feelings and a sense of presence in a streamed or on-site setting has also been studied by Lee and Lee [29], focusing on VTubers. VTubers are YouTubers who have adopted a virtual avatar and use this persona as a medium for creating content such as streaming or music. The avatar is controlled in real time via motion-capture technology and other input modalities. The study shows that more interactivity with the performer increases enjoyment and participation from the audience during virtual concerts, and that the community aspect of the shows were crucial for the experience [29]. The concert in the study was streamed both on the web and in VR.

Vandenberg [53] describes relevant interactions between participants and musicians, using Twitch as the streaming platform, which enables audio and video streaming to multiple viewers, who can communicate with each other and with the broadcaster using a chat. The findings presented are summarized as that large-scale viewer interactions on Twitch are unsuccessful, resulting in a phenomenon described as *crowd-speak*, where a chant-like behavior emerges in the chat. Some viewers report small-scale interactions, such as the broadcaster saying the viewers' username, as emotionally significant.

1.6.3.2 In-Game Concerts

In recent years, virtual and interactive concerts within popular online video games such as Fortnite, Minecraft and Roblox have emerged. The concerts are set within the 3D world of the game, with creative visual effects and an avatar of the artist performing the songs. Attendees can interact with each other and the artist in different ways. Many instances of in-game concerts have been hugely successful among the younger audience of these games, and artists that have performed in this setting include Ariana Grande, Charli XCX, Elton John, Eminem and Twenty One Pilots [22]. The Fortnite concert with the rapper Travis Scott saw over 40 million in-game views, and over 215 million watches on the YouTube video capturing the event [49]. An image from the concert can be seen in figure 1.4.

Figure 1.4 Screenshot from the Travis Scott Fortnite concert. From [49].

1.6.3.3 VR Concerts

Another digital space where music concerts become more prevalent is within virtual reality (VR). Mentions of VR technology are frequent in speculations about future digital interactions, including in the context of music concerts. The main motivator is a higher feeling of presence than through other digital mediums due to the immersive nature of VR environments [12, 31]. Some have suggested that VR concerts, in particular, can help the elderly reduce feelings of loneliness [41].

The research of Lo and Lai [31] highlights the effectiveness of VR technology in creating a rich and immersive perceptual environment to induce this sense of presence. This heightened sense of presence proves important in shaping the concert experience and can be further intensified by granting users a sense of control over the environment through active navigation during the concert. Enabling users to move actively not only enhances the feeling of spatial presence but also facilitates a sense of embodying a different persona (role identification) [31].

A recent study by Onderdijk et al. [43] explored the experience of VR concert attendees through a survey answered by individuals with previous VR concert experience to find the motivations and attitudes of these users. Unlike previous research emphasizing social connectedness and togetherness as a primary motivator for concert attendance, Onderdijk et al. [43] found it to be of lesser importance. Attendees were instead motivated by the relationship with the artist(s) and the uniqueness of the experience, driven by the potential to engage with visually creative environments and interactions not possible in the real world. The accessibility that a virtual concert provides was also a positive factor in the study. The study show that 70% of respondents consider VR concerts as 'the future of the music scene'. However, all survey participants were interested in and experienced with VR technology, as they were recruited from different VR forums and interest groups. This result can thus not be applied to the public without further studies. Onderdijk et al. [43] mentions that there are several categories and ways VR concerts are created and distributed today, some ranging from *"metaverse music production companies"*, such as Wave XR, Stage11 and Xyris, to *"dedicated platforms"* which include AmazeVR, NOYS VR, VRTIFY and Prisms World among others.

Another study exploring VR as an interactive medium for concerts was conducted by Munoz-Gonzalez et al. [41]. To explore how social interaction can be facilitated through VR, audiences were equipped with an electroencephalogram (EEG) recorder to capture the participant's brain activity. The combined signals of the participants were then controlling visual elements of the VR concerts. This neurofeedback could potentially foster a 'sense of unity', or togetherness and connectedness, between users. To confirm any heightened sense of connectedness to others, derivative studies must be conducted [41].

Bouckaert [7] describes a study made to explore the subjective experiences of 74 VR concert participators. This study dissects the participants experiences' and tries to map the subjectively good and bad aspects of VR concerts. Even though the results are not statistically significant for the most part, some interesting reflections can be extrapolated from the findings. The most common benefits of VR concerts are, as reported by the participants, that of accessibility and view — i.e. that a VR concert can provide the best seats. The biggest drawbacks are reported to be the absence of physical engagement and social experiences.

2 Theory and Technology

This chapter will introduce the various technologies and design methodologies utilized throughout the thesis work. Each technology and methodology will be briefly described to provide insight into its functionality and application within the thesis. This chapter can serve as a reference point for further reading of the thesis.

2.1 Immersive Technology

Immersive technology is a vast term that encompasses several types of technologies. The technology outlined below are the ones present and relevant for this thesis.

2.1.1 Virtual Reality

Virtual reality (VR) is a technology that uses computer simulated environments to immerse a user within a virtual world, typically through the use of VR headsets [45]. The headsets contain displays that are positioned close to the eyes and often enables motion tracking. By blocking out the real world and replacing it with a digital simulation, VR creates an illusion of presence, allowing users to interact with and explore virtual spaces as if they were physically there.

2.1.2 Extended Reality

Extended Reality (XR) is an umbrella term that started appearing in academic contexts, while the general consensus regarding the meaning of the term remains undecided. According to Alce et al. [2], eXtended Reality and its abbreviation XR might be defined as a synonym to Mixed Reality, but that encapsulates a wider perception through external cameras mounted on for example robots or drones. Another explanation brought forward by Alce et al. [2] regarding the XR acronym is that the X can be replaced with a V or an A, i.e. contextualizing XR as the spectrum in which different immersive experiences place themselves within, ranging from *augmented reality* to *virtual reality* - or going even further to *extended reality*, with the definition stated previously.

2.1.3 Meta Quest 3

The VR hardware that is used within the thesis work is the Meta Quest 3 [37].

The Meta Quest 3 is a VR headset with passthrough capabilities and an inside-out tracking system, utilizing sensors and cameras mounted on the device to provide tracking and also mapping of the users space. It has two displays with a resolution of $2,064 \times 2,208$ pixels per eye, which maps to 25 PPD. It uses the Qualcomm Snapdragon XR2 Gen 2 chipset and has 8 GB of DRAM. Furthermore, it has a battery life from around 1.5 to 2.9 hours depending on the use case. The headset can be seen in Figure 2.1.

Figure 2.1 Meta Quest 3 VR headset. Source: Meta

2.2 Software

The software used within the thesis work will be presented below.

2.2.1 Babylon.js

Babylon.js is an open-source 3D rendering engine designed for creating web-based 3D applications [4]. It is a JavaScript framework that enables 3D graphics and game engine capabilities directly in web browsers. With the usage of WebXR, the 3D web application can also be experienced with a VR headset.

By utilizing Babylon.js, interactive 3D applications can be developed, and it is similar to other, native game engines available on the market. The difference is that by utilizing different web APIs, cross-platform compatibility is ensured. It offers several rendering backends such as WebGL1, WebGL2 and WebGPU.

Some of Babylon.js main features are:

- Scene graph support, with meshes, animations, materials, etc
- A collision engine
- CPU and GPU particles system
- Audio engine with spatial audio support
- A behavior system
- Animation engine

2.2.2 WebXR and WebGL

WebXR and WebGL are both examples of Javascript APIs for creating 3D, respectively XR experiences through web browsers [20, 26].

WebGL exposes 3D rendering capabilities through Javascript with a shader language similar to OpenGL ES. This also enables hardware accelerated rendering, with modern rendering features available.

WebXR enables support for XR devices to digest web-based content through immersive experiences, exposing new XR specific APIs to web applications.

WebXR is governed through W3C and WebGL is governed by The Khronos Group.

2.2.3 Blender

Blender is an open-source 3D graphics creation tool that includes features such as 3D modeling, animation, simulation and rendering [5]. It is driven and maintained by The Blender Organization.

2.2.4 Generative AI

Generative AI is an umbrella term for computational techniques capable of generating new types of content such as text, images, audio or other from a dataset [18]. The term encapsulates both generating original content but also working as a question-answering system, which can be assistive to humans as a tool. The most widely known examples of generative AI seen today are GPT-4, Dall-E 2 and Copilot.

2.3 Data Collection and Design Methodology

Different data collection strategies and design methodologies utilized for the thesis work will be described in this section.

2.3.1 User Experience

As per ISO 9241-20, user experience (UX), is defined as "a person's perceptions and responses resulting from the use and/or anticipated use of a product, system, or service" [25]. The definition highlights the emotional responses a user can have when interacting with a product. Essentially, UX encompasses how users feel and their level of satisfaction during product interaction.

2.3.2 Usability

Usability is a term that by ISO 9241-11 as "the extent to which a system, product, or service can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use" [24]. This definition highlights the degree that a system is able and is fit to be used as intended. Rubin and Chisnell [46] defines six key aspects of usability to take into consideration when designing and evaluating a product. These are usefulness, efficiency, effectiveness, learnability, satisfaction and accessibility.

2.3.3 Design Methodologies

A design methodology is a structured approach to solution design and innovation. The methodologies and paradigms used for the thesis work will be presented here.

2.3.3.1 User-Centered Design

User-centred design, as pioneered by Gould and Lewis [21], prioritizes the needs and behaviors of uses throughout the whole product design process. An understanding for what drives the user and what their goals are, should be the center of the product development[45]. Gould and Lewis [21] distilled the design process down to three primary principles that lead to good usability for the user:

1. **Establish an early focus on users**
   Designers must understand who the intended users are, and what they want to accomplish.

2. **Run field studies and get empirical data**
   By testing prototypes and simulations throughout the design process, designers can observe and analyze how the intended users interact with the product.

3. **Iterative design**
   A cyclic design processes (design, test, measure, redesign) must be used as many times as needed to fix problems found in user testing and to refine the product.

2.3.3.2 Double Diamond

The Double Diamond is a design methodology and framework for innovation presented by the Design Council [14] that emphasizes the importance of both divergent and convergent thinking throughout a design process. It is widely used in the field of innovation and design thinking. In Figure 2.2 the methodology is visualized. It consists of four distinct phases represented as two diamonds. They are presented below with a brief description of each.

1. **Discover**
   The first stage is about understanding the user and the problem area in its context. Rather than assuming, this is done by observation and interaction with those affected.

2. **Define**
   When a wide range of information is gathered, the designers are to identify the key observations and define the problem area given what they have learned.

3. **Develop**
   Once the problem is clearly defined, designers can start to generate ideas on how to provide a solution to the problem.

4. **Deliver**
   Delivery is the fourth phase. Solutions are built and tested in an iterative manner.

The double diamond methodology encourages an iterative process with collaboration and user-centered thinking.

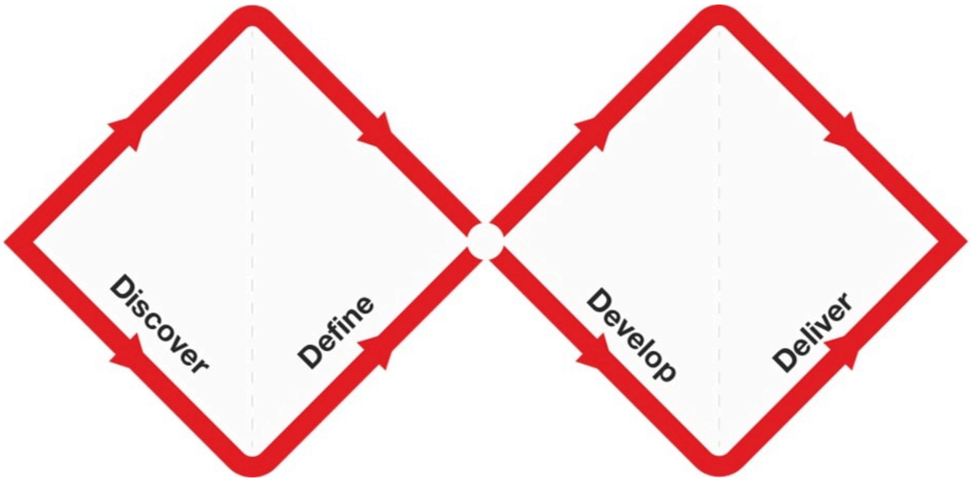

Figure 2.2 The Double Diamond design methodology

2.3.4 Brainstorming

Brainstorming is an ideation technique that promotes free thinking and creativity with the goal of coming up with new ideas and solutions in a nonjudgmental setting [45]. It is a method often performed in group but can also be performed individually. Participants are encouraged to write down whatever comes to mind and be creative. The brainstorming session can be free-form or more structured and time-boxed. Often, some kind of thematic clustering and sorting follows the ideation session [45].

2.3.4.1 Bodystorming

Bodystorming is another ideation method aiming to create a more hands-on and less abstract process than brainstorming. The idea is to imagine what it would be like if the product or solution already existed, and use that as a base to generate new ideas and envision solutions. Bodystorming can also use low fidelity prototypes to interact with them physically during the ideation process [45].

2.3.5 Prototyping

A prototype is a model of a product that lets users interact with the intended product in an early development stage. Prototyping plays a vital role in interaction design, serving as a tool to create simplified yet illustrative versions of the final product and design. These prototypes can serve various purposes throughout the design process, adapting to different stages needs for detail. They can facilitate ideation processes, exploration, and communication among designers, clients, and stakeholders. Prototypes also play an important role in user testing and usability evaluation by providing concrete products for users to interact with. Prototyping is cost-effective and allows for quick iterations. Prototypes can be categorized into low-fidelity (Lo-Fi) and high-fidelity (Hi-Fi) prototypes based on their level of detail. Lo-Fi prototypes can be made of paper or cardboard and are used in the early stages for idea organization and exploration. Hi-Fi prototypes are often created with software and more closely resembles the final product.

2.3.6 Data Gathering Methods

Data gathering is the process of gathering information. In the case of this thesis, data are gathered about potential users and their attitudes towards classical music and streamed media. Data is also gathered in the form of user testing. Both quantitative and qualitative data gathering methods are used. These are presented below.

2.3.6.1 Surveys

Surveys are a great option for gathering data quickly and in bulk [45]. They allow the collection of large amounts of information quickly and efficiently from different demographics. Surveys are versatile and can be conducted online, thus reaching a wide audience, independent of geographical location, in a short time. Questionnaires can offer anonymity to respondents, which can encourage them to provide more honest answers. The standardized format of surveys makes analyzing data straightforward, facilitating the identification of trends and patterns.

Surveys can collect both quantitative and qualitative data, however the format suits quantitative data best, since numerical values are easier to compare and that type of questions require less motivation to answer from the respondent [45]. Asking for answers in free-text can give good qualitative data, but the answers are harder to compare and are limited by the structured nature of a questionnaire. Quantitative data can be collected in the form of multiple choice questions, scales and intervals. For example, attitudes and opinions can be measured using Likert scales [45]. Likert scales typically consist of a series of statements to which respondents indicate their level of agreement or disagreement on a predetermined scale.

2.3.6.2 Interviews

Interviews, as outlined by Preece et al. [45], serve as a data gathering method for both quantitative and qualitative data, but excels at the latter. They involve a more or less structured conversation between researchers and participants, with the objective of delving deeply into participants' viewpoints, experiences, and insights on a specific subject. Interviews can capture intricate and detailed data that may not be easily quantified, enabling exploration of the subtleties and complexities of the responses.

Interviews come in structured, semi-structured, or unstructured formats, which indicate different levels of guidance and flexibility in questioning [45]. Structured interviews are similar to questionnaires with a static structure to be followed. Unstructured interviews are on the other end without significant structure and heavily dependent on where the conversation goes. Semi-structured interviews combines these two methods and make use of both structured and open questions. It combines predetermined questions as a framework for the interview, while allowing the moderator the flexibility to pose follow-up questions and delve deeper into areas when it is suiting.

2.3.6.3 Testing With Users

In usability testing, a test participant is invited to try and evaluate a program or product regarding the user experience and usability, as introduced in sections 2.3.1 and 2.3.2 [40]. The test is usually led by a test facilitator, and consists of the participant completing tasks given by the test leader and providing important feedback. The purpose of usability studies can be to identify problems in the design, uncover improvement opportunities and learn about the behavior of the intended and other users. Many problems, or unintuitive interaction processes, can be hard to identify without letting the users interact directly with the product. It is common to include data gathering methods such as interviews or questionnaires before or after the test session to further evaluate the product under test and the user's attitudes towards it [40].

2.3.7 Data Analysis Methods

Once data is gathered, one can analyze and interpret it to make informed decisions and observer eventual patterns. Qualitative and quantitative data analysis methods used for the thesis are described below.

2.3.7.1 Affinity Diagrams

Affinity diagrams are a method used to analyze qualitative data by organizing ideas and responses into groups that share common themes and similarities [45]. Inherent relationships between data points are found and clustered together. The data is grouped into different themes and categories, which gives an organized view of the whole data collection, making it easier to understand.

Typically conducted by a group, the process starts with transferring the data to individual notes. One note is chosen as a starting point, and thematic similarities are then searched for in the group of unsorted data notes. This process continues iteratively until different clusters appear. The categories and themes are to emerge naturally during this process, and not be determined beforehand.

2.3.7.2 Quantitative Usability Evaluation

Questionnaires employing rating scales can yield quantitative data about the usability of the product that is being evaluated. The responses obtained offer direct and measurable insights, which can then be compared. Two types of questionnaires utilized in the usability testing process of will be presented below.

2.3.7.2.1 System Usability Scale (SUS)

The system usability scale (SUS) was introduced by Brooke [9] as a way to measure the usability of systems. It has since then been a widely adopted tool for usability testing for a wide range of applications. SUS consists of ten questions designed to assess the perceived usability of a system. Participants rate their agreement with statements about the system on a five-point Likert scale, ranging from strongly agree to strongly disagree. The Likert scales are then converted into a single SUS score, providing a quantitative and comparable measure of usability of the system.

The calculations for the SUS score are done as follows, where Q denotes the question, and k is the participants rating for that particular question. The odd numbered questions have *positive* statements, and the even numbered questions have *negative* statements, leading to the normalization of the data below.

$$Q_{\text{odd}} = k - 1$$

$$Q_{\text{even}} = 5 - k$$

This gives the correct range of each question mapping from 0 to 4.

$$\text{Total score} = \sum_{i=1}^{5} \left(Q_{\text{even } 2i-1} + Q_{\text{odd } 2i}\right) \times 2.5$$

This total score can then be used to get a letter grade, introduced by Sauro and Lewis [47]. This translation can be done with the SUS score seen in table 2.1.

Table 2.1 SUS Score to grade letter translation table, presented in [47], with the line presenting where the average score at the 50$^{\text{th}}$ percentile is, which is 68.

Grade	SUS score	Percentile range
A+	84.1 - 100	96 - 100
A	80.8 - 84	90 - 95
A-	78.9 - 80.7	85 - 89
B+	77.2 - 78.8	80 - 84
B	74.1 - 77.1	70 - 79
B-	72.6 - 74.0	65 - 69
C+	71.1 - 72.5	60 - 64
C	65.0 - 71.0	41 - 59
C-	62.7 - 64.9	35 - 40
D	51.7 - 62.6	15 - 34

2.3.7.2.2 Igroup Presence Questionnaire (IPQ)

The Igroup Presence Questionnaire (IPQ) is a tool used to measure the sense of presence experienced in virtual environments [23]. The questionnaire evaluates presence based on three dimensions:

- Spatial Presence - the sense of being physically present in the virtual environment.
- Involvement - measuring the attention devoted to the virtual environment and the involvement experienced by the user.
- Experienced Realism - measuring the subjective experience of realism in the virtual environment

Except for these three dimensions the questionnaire includes a fourth, more general item regarding the sense of being there, which ties into the three categories established above.

The questionnaire consists of 14 statements, where participants rate their agreement or experiences on a 7-point Likert scale. The results can be used to evaluate how "real" and immersive the virtual environment felt to the user.

The cumulative score of each category is calculated according to the method proposed by www.igroup.com - project consortium [55], and described below. Each question in the questionnaire map to a specific category, either *spatial presence*, *involvement* or *experienced realism*. There is also one question mapping to the general sense of being there. Three of the questions are negated, these three questions are corrected for in the calculations. The normalization and calculation of the score are done according to the formulas below.

$$Q_{positive} = k - 1$$

$$Q_{negative} = -1 \times (k - 1) + 6$$

This gives the correct range of each question mapping from 0 to 6.

Then the mean is calculated for each category.

This can in the same way as the SUS score be converted to grade letters, for easy comparison, using the translation table introduced by Melo et al. [36], and shown in table 2.2

Table 2.2 IPQ grade letter translation table, presented in [36].

	Grade					
	A	B	C	D	E	F
General Presence	≥ 4.41	≥ 4.07	≥ 3.86	≥ 3.65	≥ 3.47	≤ 3.47
Spatial Presence	≥ 5.25	≥ 4.76	≥ 4.50	≥ 4.25	≥ 4.01	≤ 4.01
Involvement	≥ 4.87	≥ 4.50	≥ 4.00	≥ 3.75	≥ 3.38	≤ 3.38
Experienced Realism	≥ 4.50	≥ 3.75	≥ 3.38	≥ 3.00	≥ 2.63	≤ 2.63

3 Understanding the Users

This chapter covers the part of the thesis work that was conducted as the discover and define phases of the double diamond design process. To get a better understanding of the problem area, surveys were distributed and interviews were held about attitudes towards classical music, concert streaming and concert attendance. The gathered data was then analyzed using affinity diagrams, quantitative analysis and sentiment analysis by a generative AI tool built by the authors for analysis assistance. The insights from the data gathering procedures are also presented. The chapter relative to the roadmap can be seen in figure 3.1.

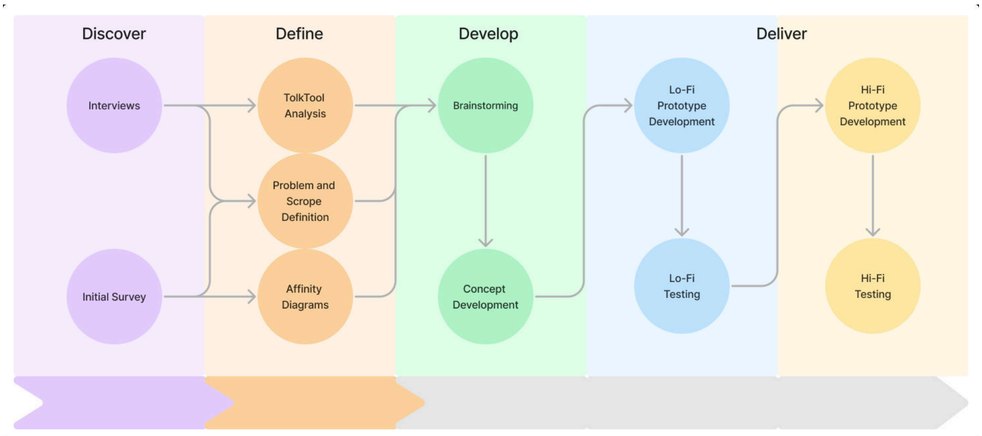

Figure 3.1 Project roadmap

3.1 Surveying Potential Users

A questionnaire using Google Forms [19] was sent out to gather information about the attitudes towards classical music and digital concert streaming experiences in the general public. Questions were surface level to get a good overview of the attitudes. However, some open-answer questions were asked to gather a greater volume of opinions. The survey was distributed in various social platforms such as LinkedIn and messaging groups. It was open between 2024-02-05 and 2024-02-12 and received 53 answers. The survey can be found in Appendix B.

The questionnaire was named *Attitudes Towards New Digital Interactions of Streamed Classical Music Concerts* and was structured as stated below:

- **Brief and General Information**
  Three demographic questions regarding age, gender and occupation.

- **Attitudes Towards Classical Music**
  Four questions regarding the respondent's relationship and experience with and attitude towards classical music. If the respondent had not attended a classical music concert in the last 12 months, they were presented with two new questions, prompting them to explain why and judge on how interested they would be in streaming a classical music concert.

- **Attitudes Towards Digital Music Interaction**
  This chapter consisted of five questions regarding the respondent's views on digitally streamed music concerts on any platform. This chapter also explored technologies, now and in the future, that can be used to stream digital music concerts.

- **Debrief and Thank You**
  This chapter functioned as a recruitment tool for user tests, which was completely optional.

Various response formats were employed, including multiple-choice questions with checkboxes and an open-text "other" option, single-choice questions, and full open-text questions for qualitative responses. Likert scales were primarily utilized for attitude inquiries [45]. Ranges were employed for age classification and frequency of concert attendance.

The survey was implemented in English, but open-text answers could be answered in both English and Swedish. The questionnaire was tested on two pilot subjects before launch. This step was conducted to catch eventual spelling or grammatical errors, to make sure that instructions were clear and that the flow of the survey structure was understandable and correct [45].

3.1.1 Survey Results

3.1.1.1 Respondent Demographic

As seen in Figures 3.2 and 3.3, the majority of respondents were men (34 of 53) and between the ages of 19 and 25 (30 of 53) or 26-35 (15 of 53). Most subjects were students (30 of 53) or full-time employees (17 people), as seen in Figure 3.4.

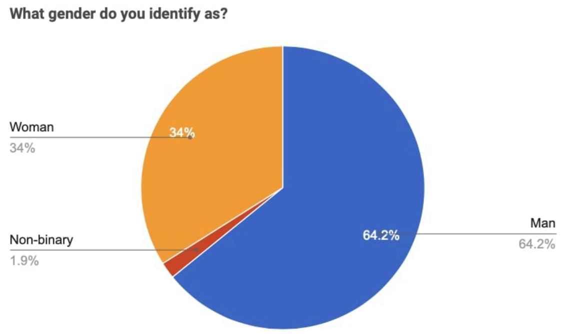

Figure 3.2 Gender distribution amongst all survey respondents

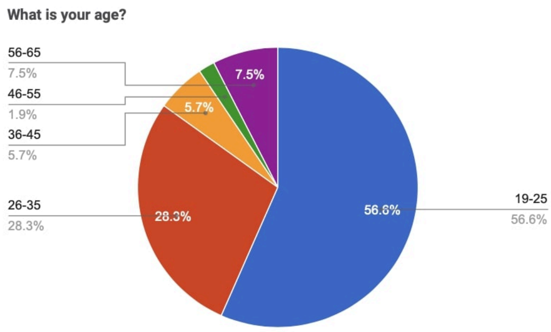

Figure 3.3 Age distribution amongst survey respondents

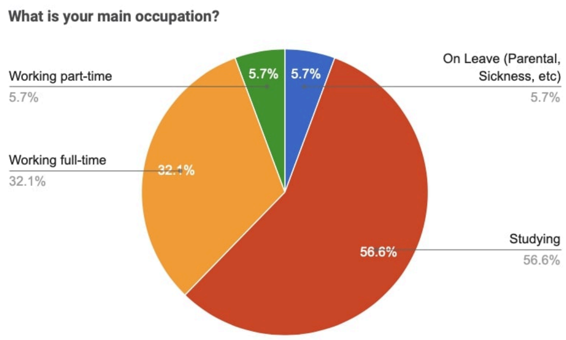

Figure 3.4 The main occupations amongst all survey respondents

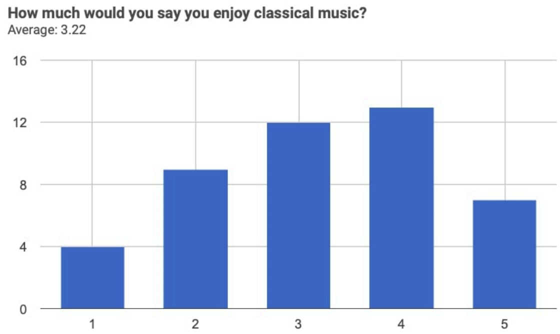

Figure 3.5 Enjoyment level of classical music in the age range 19-35. The Y axis shows the number of respondents and the X axis the level of agreement ranging from 1 (not at all) to 5 (very much)

3.1.1.2 Attitudes Towards Classical Music

To better represent the target audience of our study, we filter the results for the age intervals 19-25 and 26-35. These age intervals are representing 84.9% of the total survey results 3.3. Amongst these younger respondents, the average enjoyment level of classical music was 3.22 out of 5, as seen in Figure 3.5. Many listen to classical music in some capacity, but 39 of the 53 respondents have not attended a classical music concert in the latest year, as seen in Figure 3.6 and 3.7. Respondents in the age range that did not attend any classical concerts cite reasons such as a *lack of social motivation*, that the *price is too high*, *disinterest in the genre* or *specific events*. One respondent says that:

> *I have not seen any ads. But even if I did, I would not go on my own and it is probably too costly.*

Those who have attended a classical music concert describe the experience as *enjoyable, soothing, powerful* and *a deep and fulfilling experience*. The majority of responses are positive, but a few negative comments show up, such as:

> *Too pompous for my liking. Let me go in with T-shirt and shorts.*

When asked how interested they would be in streaming a classical music concert, respondents between ages 19 and 35 gave an average point of 2.21 out of 5. Taking all ages into account, that number changes marginally to 2.3.

3.1.1.3 Attitudes Towards Digitally Streamed Concerts

In the questionnaire chapter regarding digitally streamed concert experiences, we learn that most concert streaming experiences amongst the respondents have been

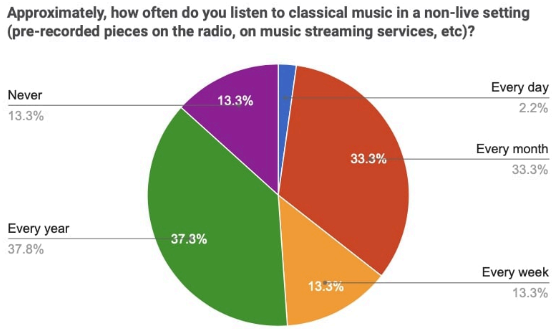

Figure 3.6 Listening habits of classical music in the age range 19-35

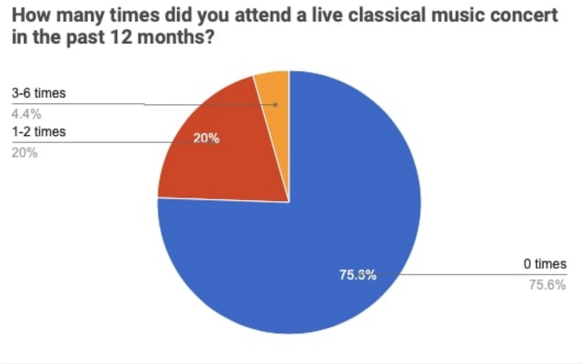

Figure 3.7 Attendance level of classical music concerts in the age range 19-35

via a web interface, where Youtube is often mentioned as the preferred platform. Other used mediums are TV, stand-alone applications and radio. One respondent have been to an online game concert.

The responses show that people have mixed feelings the streamed music concert experience. The free-text answers responds provided will be discussed more in section 3.1.1.3.

When asked the multiple-choice question: *Imagine the concert streaming experience of the future, what medium/technology would you use to stream it?*, the five highest rated were:

1. Web (33 people, 66%)
2. VR (27 people, 54%)
3. TV (18 people, 36%)
4. AR (17 people, 34%)

5. Stand-alone application (mobile or computer) (12 people, 24%)

When asked to imagine the concert streaming experience of the future, many respondents express interest in emerging immersive technologies like AR or VR to enhance the sense of live presence and *being there*. Others highlight the importance of high-quality audio and visual elements, such as 360-degree sound and comprehensive visual experiences, to better replicate the feeling of attending a live concert. More detailed analysis of the provided answers can be found in section 3.1.1.3.

3.1.2 Affinity Diagrams From Survey

To understand the open-text answers from the survey better, affinity diagrams were made. The survey questions that were analyzed were

> 1. *If you have streamed a music concert, on any medium, what did you like? What did you not like?*

and

> 2. *Imagine the concert streaming experience of the future, how would it differ from the experience(s) you have already had? Is there anything you would like to be able to do?*

The affinity diagrams for the questions can be seen in Figure 3.8 and 3.9 respectively.

For question 1, regarding the concert streaming experiences of today, sentiments from the answers have been categorized into what respondents did and did not enjoy with the experience. The answers have then been divided into subcategories of different themes. For question 2 about the concert streaming experience of the future, responses have been divided into different categories like 'immersivity' and 'visuals', to get a better overview of what respondents are desiring.

Regarding the streamed concert experience of today, in Figure 3.8 we can see that respondents enjoy the accessibility of watching concerts from the comfort of their own home, while missing the feeling of presence in the venue. They also missed the sound experience of real concerts. Respondents seemed to enjoy the any visual enhancements done digitally, and the possibility to see the show from different angles. Multiple people also mentioned that they enjoy playing a concert in the background while doing other things. It can be assumed that these experiences were had on the web, through stand-alone apps, on TV or in an online game.

When imagining the concert streaming experience of the future, in Figure 3.9, we see that most respondents mentioned a higher degree of immersivity or innovative

Figure 3.8 **Affinity diagram of the digital concert streaming experiences of today**

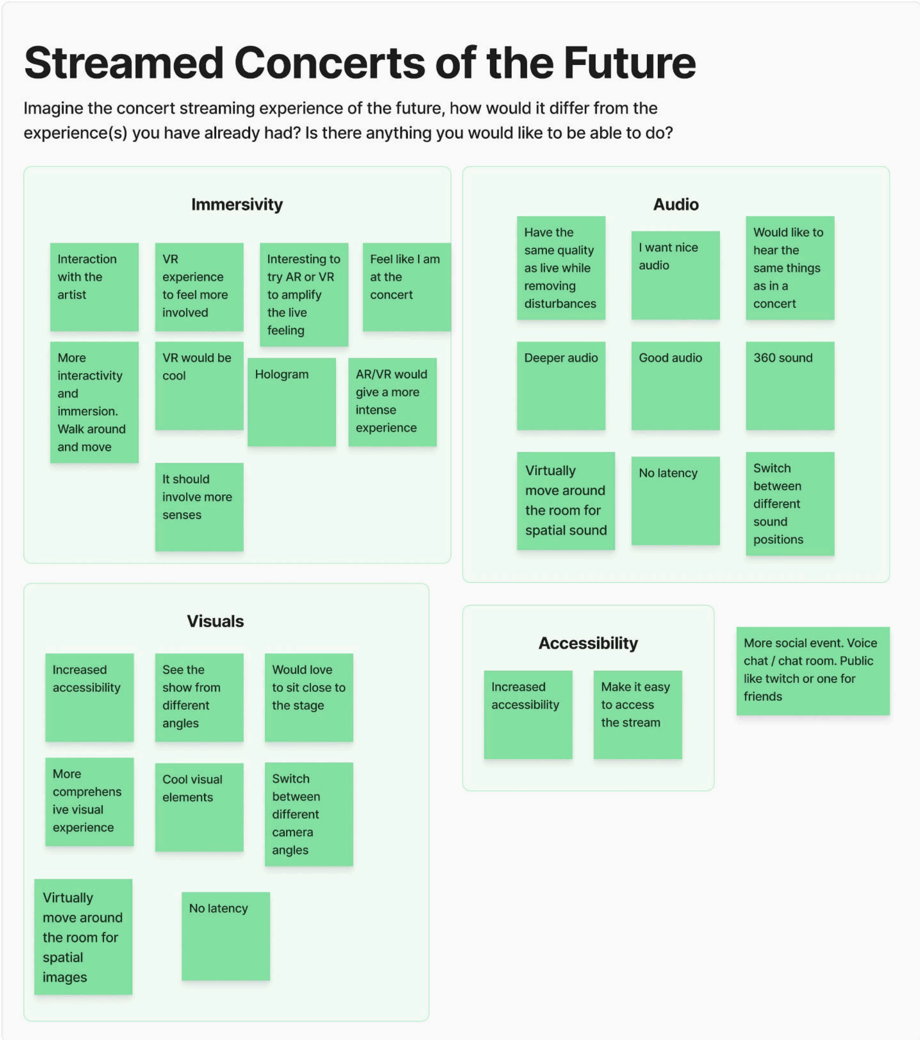

Figure 3.9 Affinity diagram of the imagined digital concert streaming experience of the future

approaches to visual or auditory elements. One person wished for a more social experience when streaming concerts digitally, suggesting an open chat room for the audience or a private one for a group of friends watching the concert together.

VR and AR technologies are frequently mentioned throughout the responses. One respondent suggests holograms as a means to enhance immersion. It appears that respondents believe these technologies could amplify the sense of presence and ways of interaction during the concert. Specific features mentioned include the option to move around in the venue to experience the concert both visually and auditory from different perspectives. Interesting visual effects is another feature suggested to enhance the experience, as well as deeper audio.

3.2 Interviews

To gain deeper insights into people's relationship to classical music and that concert experiences, a set of interviews were conducted. The interview format was semi-structured to enable a more free-flowing discussion [45]. A set of interview questions were written to make sure that key questions were asked and to have something to fall back on. The interview question skeleton can be seen below.

Interview Questions

- What is your relationship to music?
- What kind of concerts do you attend?
  - How do you find information about upcoming concerts?
  - What do you look for when deciding to attend a concert?
- What is your experience with classical music?
  - What is your perception of it?
  - Are there any specific features or aspects you expect from a classical music concert experience?
- Have you ever been to a classical music concert?
  - If yes: What was your experience going to a live classical music concert?
  - If no: How come you haven't?
  - What would make you attend more classical concerts?
  - Do you see any barriers or challenges?
- What is the coolest use of technology you have encountered in a concert setting?
- How do you imagine the classical music concert of the future? Live or streamed, anything is possible!

The interviewees consisted of five people with different relationships to classical music. The participants are described below. The participants were recruited via expressed interest in the initial survey, at the office at Capgemini and through social forums of the authors. The interview length ranged between 9 and 31 minutes.

Interview Participants

P1 28 years old. Female. Educated composer. This interview subject has great insight to the world of classical music. She attends bigger orchestral classical music concerts about five times per year, and performances featuring more modern pieces of art music several times each month.

P2 26 years old. Male. Cognitive researcher. This interview subject enjoys classical music and has an emotional investment in the genre. However, he does not frequently visit concerts.

P3 26 years old. Female. Engineering student. She has never attended a concert strictly for the classical music, but has enjoyed orchestral performances in other contexts.

P4 26 years old. Male. Engineering student. Has never attended a classical music concert, and does not feel that he *'understands it'*.

P5 26 years old. Female. Engineering student. Enjoys the classical music concert experience, but does not actively seek it out.

3.2.1 Sentiment Analysis of Interviews

3.2.1.1 TolkTool

Figure 3.10 Sentiment analysis by TolkTool for interview participant 2

To aid us in extracting the key learnings from the interviews, a prototype tool using generative AI for qualitative analysis was developed by the authors of the thesis. It is called TolkTool and is built using Gradio, an open source package for Python that can be used to easily build user interfaces for machine learning models [1]. TolkTool was built to be able to transcribe and then analyze interviews. After the transcip- tion is complete, the user can categorize the speakers as interviewer and responder, analyze the main sentiments in the interview, extract interview keywords and also access a chatbot where they can ask whatever they want about the interview. The chatbox is provided with a few examples like *'What is important to consider when designing for this user?'* and *'Are there any especially interesting observations from the responder?'*. The speech-to-text transcription machine learning model utilized is Whisper by OpenAI [44]. The natural language processing needed to to sentiment and keyword analysis is done by the large language model (LLM) Mistral AI [39] using the transcript. This model is also the base of the chat bot. The Mistral AI model is run locally with the use of Ollama, a platform that enables local builds and running of large language models [42]. The user interface can be seen in 3.11 and an example of the sentiment analysis can be seen in Figure 3.10.

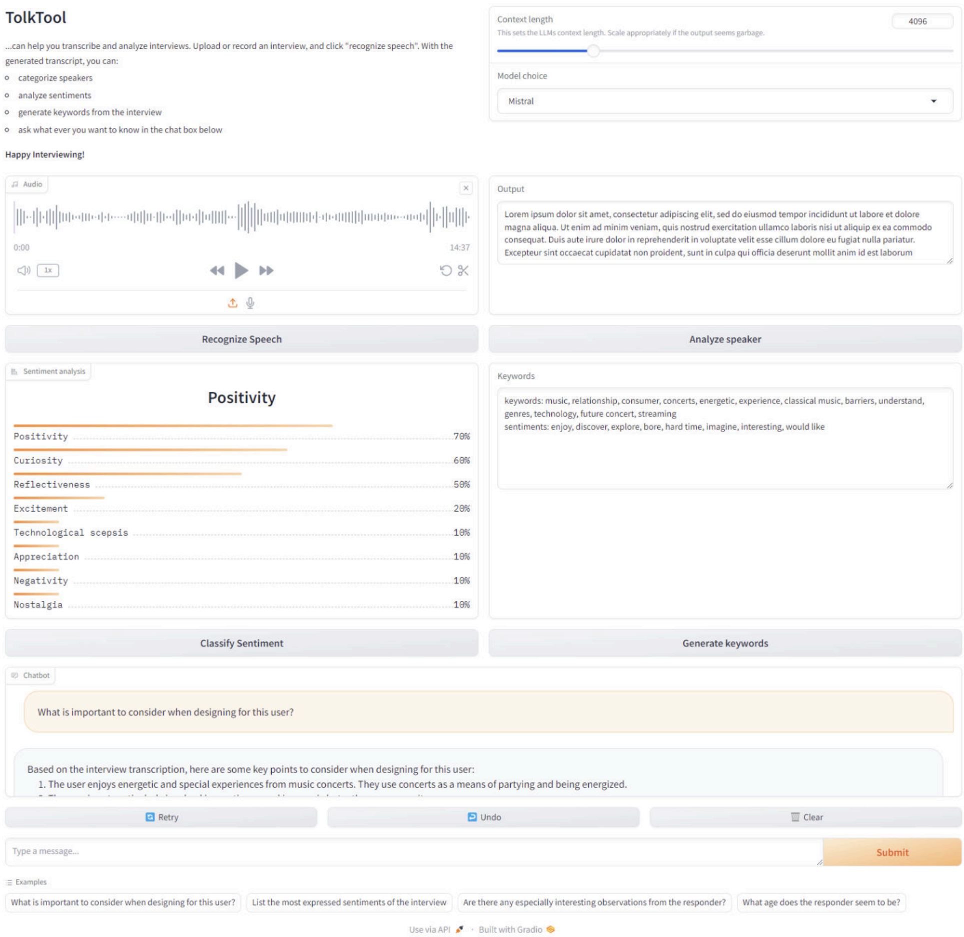

Figure 3.11 The user interface for TolkTool

TolkTool will be used as a complementary tool in the analysis of the interviews.

3.2.2 Interview Insights

Here the interviews will be described and divided into two categories - classical music enthusiast and non-frequent visitors. The insights from them will be presented.

3.2.2.1 Classical Music Enthusiast

Interview subject P1 has a close relationship to classical music and is herself operative in the world of performative art and music, often with a tech-heavy approach. When finding concerts to attend she looks for *'interdisciplinary performances, and to experience something new'*. This driving force differs from what she is looking for when attending a classical music concert, where she is drawn to the *'strictly classical, the high romanticism and baroque performances'*, and *'good music performed well in a classic setting'*. The interview subject shows high interest in technological integration into music performances, but mainly outside of the classical music scene were she shows great respect for the historical significance and value of it. She believes that the primary obstacle preventing more audience members from attending classical music concerts is high costs, and does explicitly not believe that a more diverse concert programming converts audiences to attending other classical concerts. She once attended and enjoyed a concert with a *'clarinet player controlling a virtual orchestra by motion capture technology'*, which she describes as one of the most interesting ways of incorporating technology into classic music performances she has encountered. These statements show that even though P1 is protective of the classical music performance culture as it is, she is enthusiastic about some technological experimentation within the genre, albeit rather as a complement than a new norm.

3.2.2.2 Non-Frequent Visitors

The other interview subjects have a less intricate relationship with classical music. P2 explains that classical music can evoke strong emotional reactions in him by letting him play out different stories in his mind. This experience he thinks is different from any other music genre. In his life he as attended two classical music concerts, but often listen to the genre at home or when studying. He would like to attend more, but lacks social motivation to do so. Another motivating factor for him would be if he had more time and available information about concerts in his area. P3 also mentions social motivation as a key barrier to attending classical music concerts. P3 has less of a emotional connection classical music, but classifies the genre as *powerful*, a word that comes up during almost all of the interviews. She is perceived as neutral regarding the genre. In contrast to P2, none of P3, P4 and P5 listens to classical music at home.

All of the interview subjects attends concerts of different genres but only P2 has attended classical concerts explicitly in the past. P3 and P5 mentions going to a classical concert through a ballet performance, where P3 also mentions the familiarity of the ballet being a factor in attending the performance.

In the same vein, P4 mentions that as an attendee you have to learn the music or genre to be able to really appreciate it.

> **Interviewer:** *What would make you attend more classical concerts?*
> **Interviewee:** *I think I would have to find a way to understand it, to actually have the energy go to a concert with classical music. Yeah, because I think that's the problem. I don't really understand it.*

One differentiating factor seems to be that P2 has attended classical music concerts without the same social context that is mentioned by P3 - P5. Although P2 has attended concerts with family, he expresses that his friends are not as interested in classical music and would want to attend more classical concerts. This sentiment is shared among all interview subjects, where the social factor is mentioned. This is also mentioned to be a factor for when finding concerts to attend, where word of mouth is a common way of getting to know about upcoming concerts, combined with digital platforms or the internet providing information. Spotify and Facebook being the most mentioned, where the interview subjects get information through these platforms, either through the specific concert venues or through the artists they listen to the most.

All interviewees related music to an emotional experience, albeit with different relations to the specific genre inflicting that type of response. For example, P4 explicitly states that he goes to concerts to party and thereby prefers energetic and music special to him, compared to the music most often played at classical concerts, but he acknowledges that he has been exposed to classical music in different settings.

Price is interesting in the sense that it is only mentioned in interviews with P1 and P4, where both interviewees discussed pricing. P1 suggested that price is a significant barrier and wishes for lowering tickets prices in general. P4 mentions a specific price to be an affordable limit. This in contrast to the perceived audience might give some clues as to what is significant barriers. All interviewees except for P3 and P5 mentions the ordinary audience to be composed of old people, which P5 explicitly states to be a stereotype.

None of the participants relate classical music to high technology experiences, P1 mentions that for art music events technology can play a specific, immersive role in enhancing that experience, and P2 mentions a Rammstein concert with pyrotechnics.

4 Design Sprint I - Concept and Lo-Fi Prototype Development

From chapter 3, many ideas and insights that could be incorporated into a Lo-Fi, and respectively, Hi-Fi-prototype were brought up. In order to sort and develop the ideas further, several ideation and conceptualizing activities and sessions were conducted. To test the concept, a Lo-Fi paper prototype was developed and evaluated by users. These activities are documented below. The chapter in relation to the roadmap can be seen in figure 4.1 and figure 4.5.

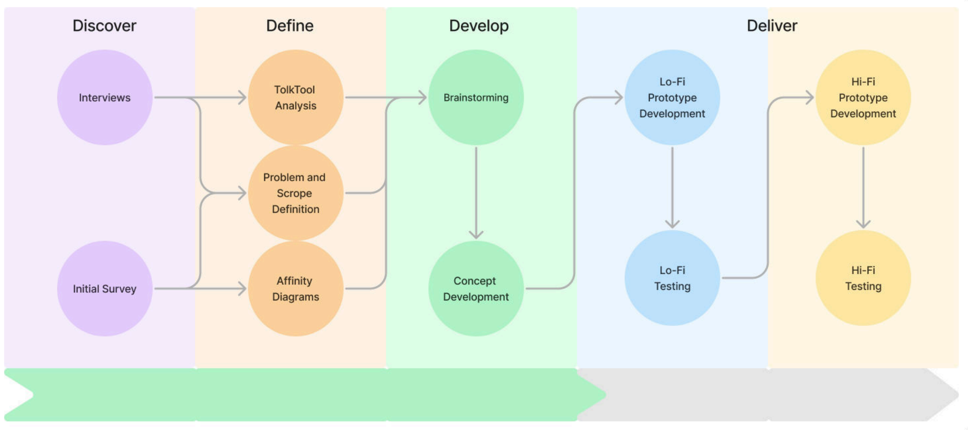

Figure 4.1 Project roadmap

4.1 Brainstorming Sessions

The insights compiled previously needed to be conceptualized and developed before they could be actualized as features. This entailed both development of ideas as well as mapping them into several affinity diagrams.

4.1.1 Concept Development

Two brainstorming sessions were conducted by the authors of the thesis to ideate on a product that would meet the wants and needs of the participants in the survey and interviews. The first brainstorming session focused on common wants and driving forces found in the interviews and in the survey. This is seen to the left in Figure 4.2. During the second brainstorming session, streaming app concepts and different features for a potential products were conceived. The notes were then grouped into clusters of similar themes in an affinity diagram, for example *visuals, artistic platform* and *service*, seen to the right in Figure 4.2.

Figure 4.2 The aftermath of two brainstorming sessions

From the brainstorming sessions three different streaming app solutions for classical music concerts were developed. These are quickly sketched in Figure 4.3. The idea of a 3D streaming platform for web and/or VR with floating widgets of different types was chosen as the core concept. Rejected were a 2D multi camera streaming platform since this already exists within the LUDICH project today, and a live streaming platform inspired by Twitch, with a live chat and different interaction possibilities between streamer and audience. The latter was rejected due to findings from the survey and in-depth interviews that showed positive sentiments for 3D and immersive technology. However, learnings and ideas from the rejected options could still be incorporated in the chosen app concept.

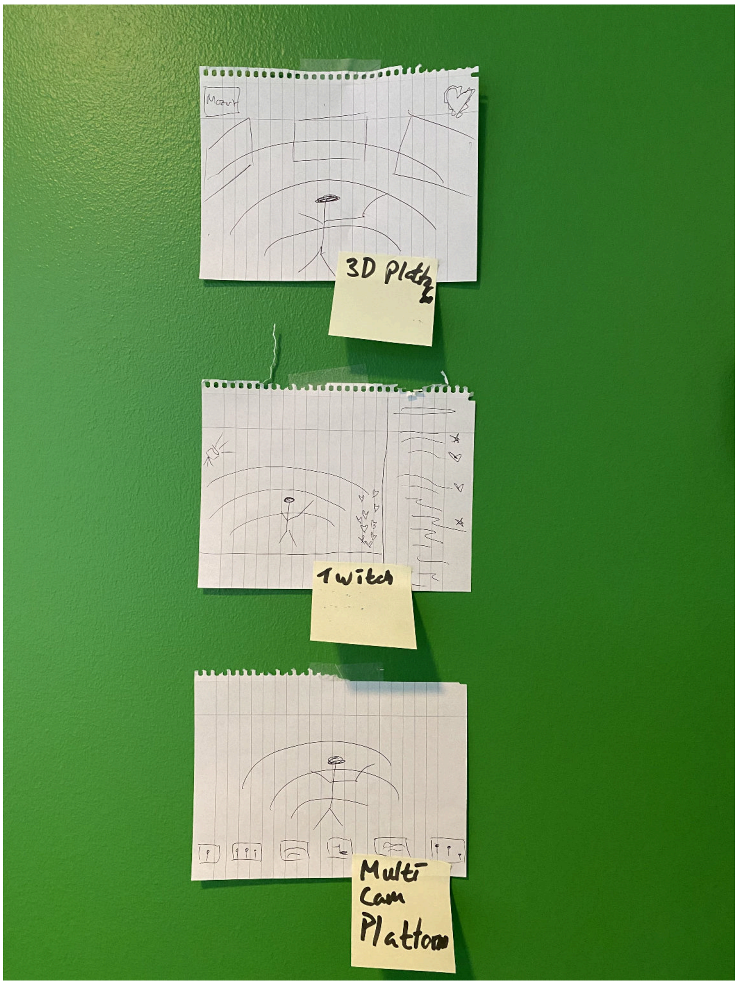

Figure 4.3 Three different ideas for a classical music streaming app

4.1.2 Feature Development and Selection

During the brainstorming process, various features were generated and subsequently assessed in relation to the chosen core concept idea. Infeasible or irrelevant features and ideas were sorted out. The remaining features were then plotted onto a matrix were their potential impact and required effort were estimated. This visual representation aimed to provide a clear understanding of which of the features were both feasible and capable of making a substantial difference in the experience of the app. The impact-effort matrix can be seen in Figure 4.4. The diagram aims to be of help when prioritizing which features to develop. The marked grey area in the figure represents the features that are to be developed for the first iteration.

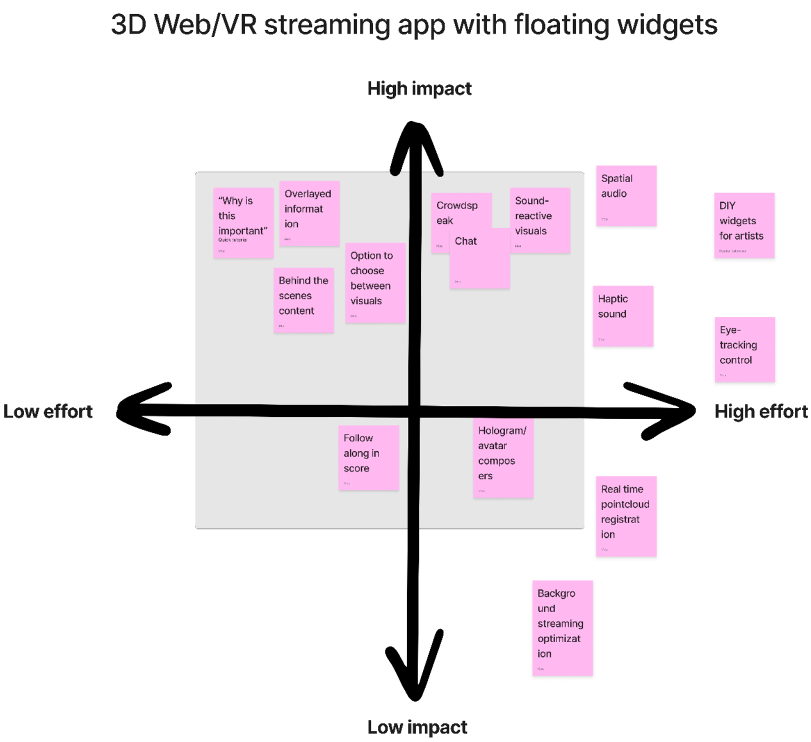

Figure 4.4 Impact/Effort diagram of proposed features

4.2 Lo-Fi Prototyping

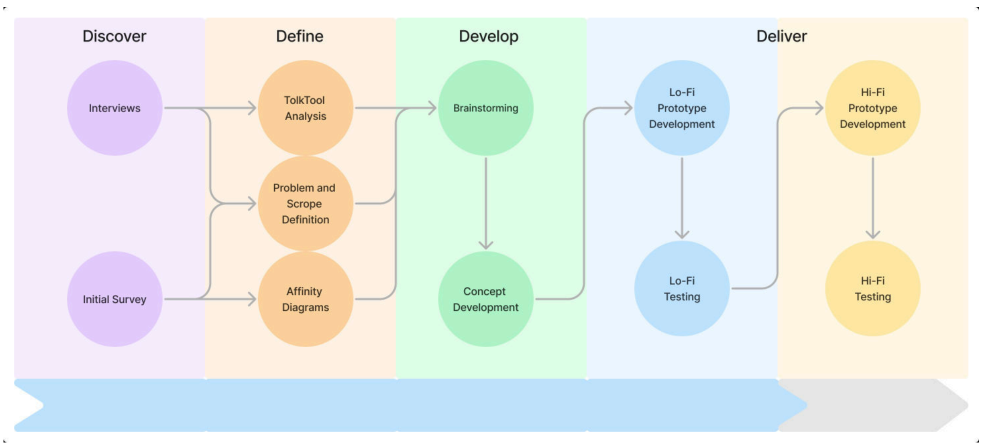

Figure 4.5 Project roadmap

The decision was made to make the Lo-Fi prototype with pen and paper. To emulate the immersive experience of 3D and VR, two large papers were put up with an angle of approximately 130 degrees between them.

The prototype features an orchestra in the Malmö Live concert hall. The orchestra is playing in the middle, with different camera angles being projected onto it. The orchestra is shown to be playing Mozart's Requiem in D-minor, more specifically the last part of section 2, Lacrimosa. This was chosen due to it being known by many people, regardless of their interest in classical music in general. It will also be played during user testing. There is an information box showing the composer and the name and year of the work in text and image, as well as additional information about the piece, as inspired by Dobson [16]. Additional information shows up during the performance as well, with small "fun facts" about a specific moment of the piece. The left side of the prototype also features an environment-picker, where the user can transport the orchestra to the woods, a beach or the mountains. This side also features a door that says "backstage", where the user can move backstage to engage with behind-the-scenes content.

The orchestra is lit up in different ways. There are visuals that are sound-reactive, for example a shimmer around a solo violinist. Other visuals are crowd-reactive, changing in colors depending on the engagement from users. There is a big heart symbol that the user can press, which will add colors and intensity to the latter mentioned visual component. A chat widget lets the users interact with each other.

To give the user a sense of temporal context, a widget showing which of the sections is currently played is added, as well as a widget to follow along in the score. The last features are a play and pause behavior, as well as a settings menu where widgets can be disabled.

This is a high amount of features. The idea was to see during user testing which ones are preferred, and scale back appropriately.

The Lo-Fi prototype can be seen as a panoramic image in Figure 4.6, and more detailed images can be seen in Figures 4.7, 4.8 and 4.9.

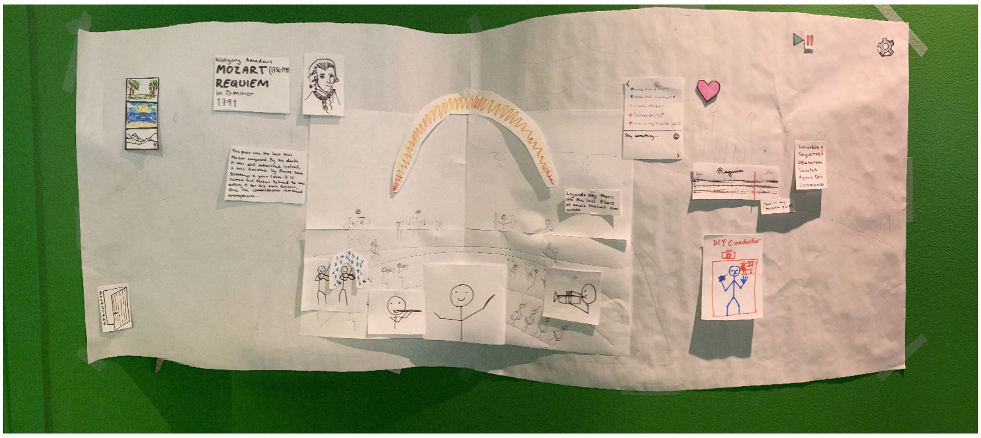

Figure 4.6 Panorama image of the Lo-Fi prototype

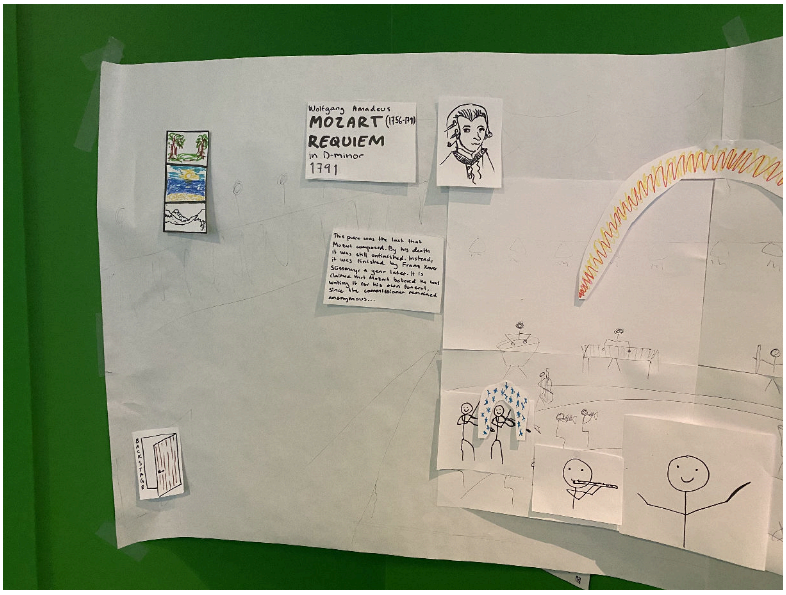

Figure 4.7 Left part of the Lo-Fi prototype

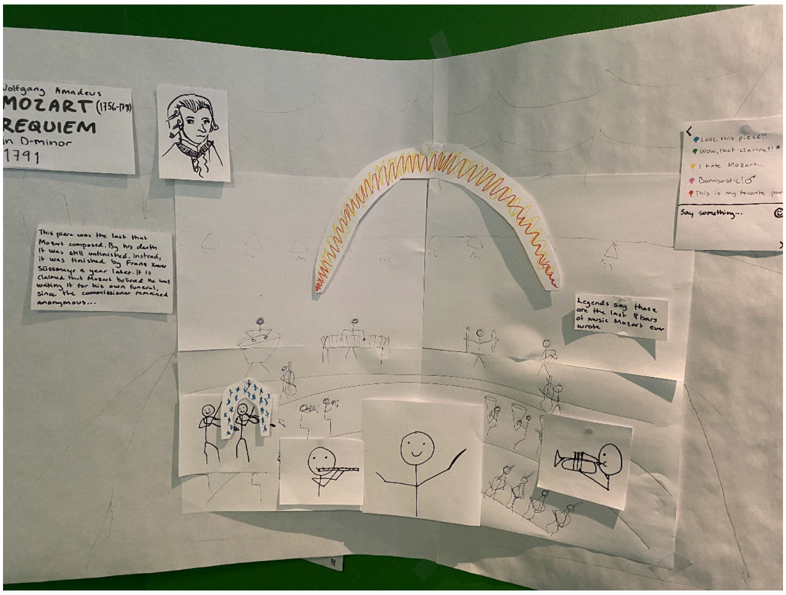

Figure 4.8 Middle part of the Lo-Fi prototype

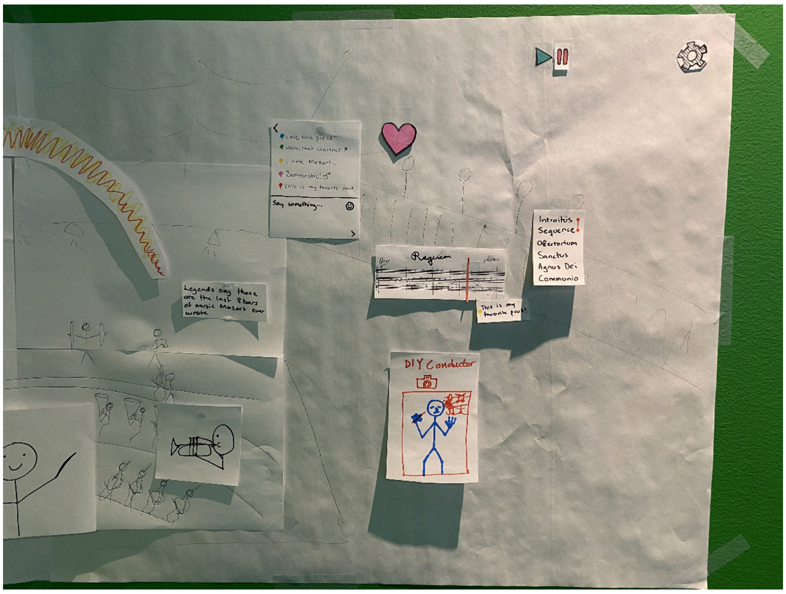

Figure 4.9 Right part of the Lo-Fi prototype

4.2.1 User Testing of the Lo-Fi Prototype

The user testing of the Lo-Fi prototype can be considered a combined concept evaluation and bodystorming. Users where therefore encouraged to propose ideas and

Figure 4.10 Setup with the Lo-Fi prototype

express interactions they would want to be able to perform. A total of six test subjects tried out the prototype and gave insights to continue the development forward. The test participants consisted of four IT consultants from Capgemini and two engineering students. All fall within an age range of 24-37, four of which being men and two were women.

4.2.1.1 Procedure and Set-Up

The test subject was positioned between two small audio monitors playing Mozart's Lacrimosa and in front of the prototype. They were then guided through the process, where each theme of widgets and features was introduces sequentially. They were asked specific questions, but the tests were conducted in a conversational manner.

The testing protocol can be read in its full in Appendix C. The setup can be seen in Figure 4.10.

The audio from the user tests were recorded for further analysis. Notes were also taken during the tests. The participants were encouraged to think out loud so that different sentiments, reactions and thought processes could be captured. The goal of the testing sessions was to evaluate the different proposed features and initial interactions. Since the prototype includes a myriad of features, one goal was to see which were enjoyable to the users and which were superfluous.

4.2.1.2 Test Results

Results from the Lo-Fi tests proved mostly positive. Test subjects enjoy the information widgets that give them more context and the fact that there are different interaction types. The widget types were added incrementally, which made it possible to test each concept at a time. However, this meant that in the end the participants had all widgets displayed concurrently. This proved to be overwhelming for many participants who wanted to be able to remove or hide widgets.

What widgets and features were most enjoyed differed between the test participants depending on their level of musical theory knowledge, classical music expertise and interest. One participant who sings in a choir was particularly interested in the "follow along" score widget, and saw it as a good tool for those who want to practice alongside the recording. Others, who were not as versed in classical music preferred the widgets with text information and more experimental features such as reactive lightning and placing the performances in different environments.

One sentiment that was shared between users was that the social features, such as the chat, felt disturbing during the actual music performance. Many saw positive potential in the social features during pauses and before and after the show, however - comparing it to the chatting in the foyer that can occur during a live performance.

In conclusion, test participants were positive regarding the Lo-Fi prototype and thought the application was innovative and fun. Many also commented on how an application like this could improve the accessibility of classical music concerts. One main learning from the testing of the prototype was that one needs to be able to remove and add widgets independently as to not become overwhelmed.

5 Design Sprint II - Hi-Fi Prototype Development

Based on the results from the previous design sprint, Chapter 4, a Hi-Fi prototype for desktop and XR headsets was constructed with the goal of representing a minimal viable example of how such an application could look and work. Many of the features of the Lo-Fi prototype were available with some being more interactive than others. The development and usability testing of the prototype will be documented in this chapter, which corresponds to the final iteration of the Deliver part of the design process seen in Figure 5.1.

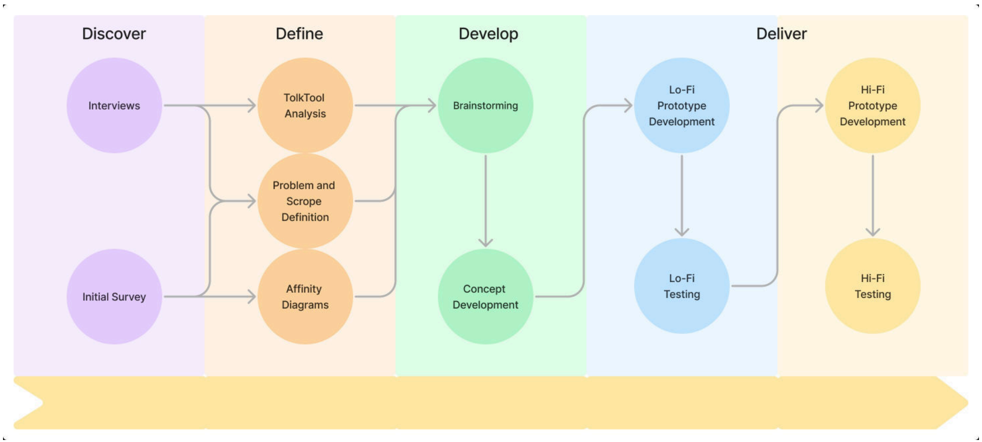

Figure 5.1 Project roadmap

5.1 Hi-Fi Prototyping

The Hi-Fi prototyping can be divided into two development parts, a mockup part for conceptualizing and deciding on a common visual direction and an implementation part for the actual development of a working prototype. A screenshot from the actual prototype with all feature widgets open can be seen in Figure 5.2

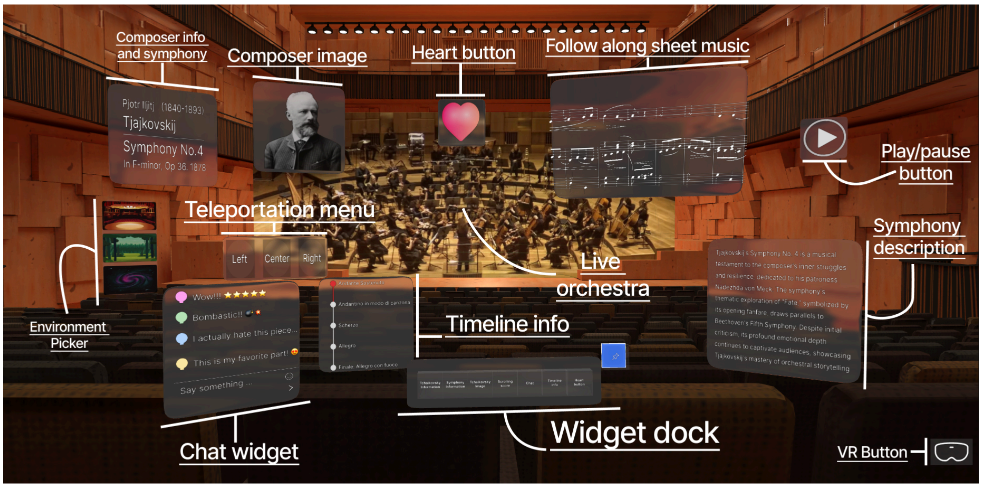

Figure 5.2 Screenshot from the desktop version of the prototype, with titles of each widget.

5.1.1 Learnings From Previous Design Sprint

From the Lo-Fi prototype testing described in Chapter 4 we learned what features to prioritize when developing the Hi-Fi prototype. One learning was that people enjoyed the overlaid information widget that provided them with context for the performed piece. Other features that was specifically mentioned by Lo-Fi test participants was the dynamic widgets providing temporal information for the users, such as the follow-along music score widget. Many of the test participants also mentioned that they enjoyed the idea of changing environment and moving around in the concert hall, and interactive features such as user-triggered lightning changes. All of these mentioned features have been prioritized when developing the next iteration of the prototype. One feature that was described as potentially disturbing during the Lo-Fi prototype testing was the chat feature. Since this was a very low effort to develop, a decision was made to still implement to evaluate users reaction to the idea in a higher fidelity setting.

5.1.2 Hi-Fi Prototype Mockups

Three prototype mockups were drafted in order to set a common ground for the visual direction of the Hi-Fi prototype. These can be seen in Figure 5.3. They consist of a start screen, a screen for selecting which preset the user feels most comfortable with, and a mock-up of the complete user interface within the 3D environment.

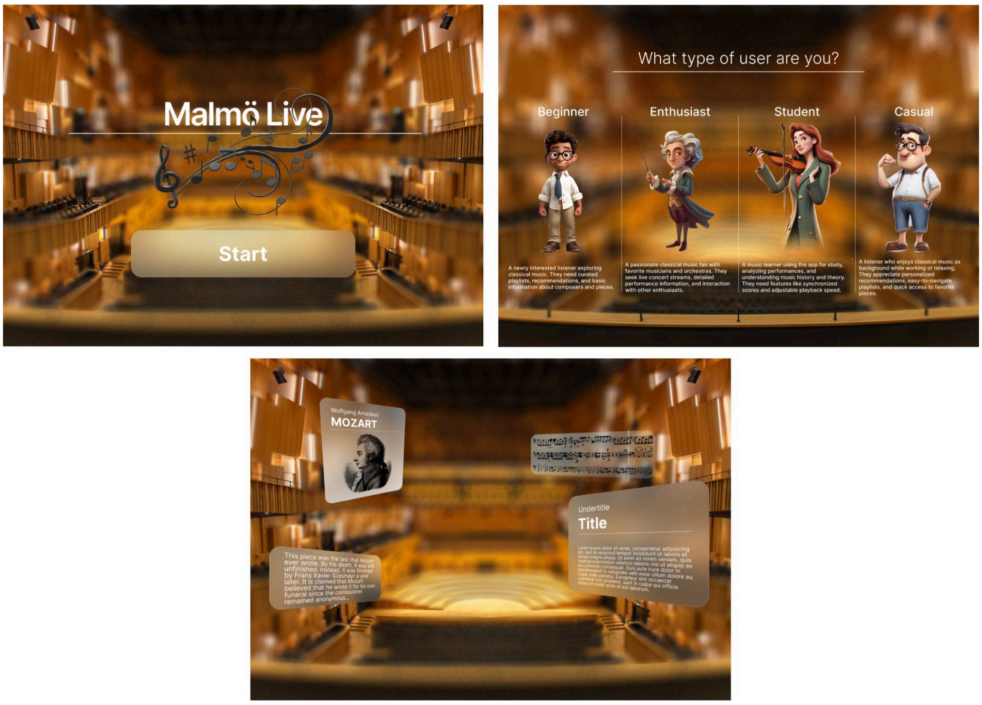

Figure 5.3 The three screens of the Hi-Fi prototype mockup. Start screen, preset selection and the user interface.

Everything presented in the Hi-Fi mockup was implemented, except for the start screen. The rest of the implementation will be described in the section below.

5.1.3 High Level Description

The result of the Hi-Fi prototype development is a 10-minute demonstration application of a symphony orchestra concert playing a Tjajkovskij symphony in a virtual replica of Malmö Live. During the concert, the user can interact with different feature widgets. They can also move the concert to a different environment or move around in the orchestra hall. A screenshot of the desktop application can be seen in Figure 5.4. All features will be described in greater detail in section 5.1.4. The program works both as a desktop application and on XR headsets. The technical considerations of the prototype development are discussed in section 5.1.5.

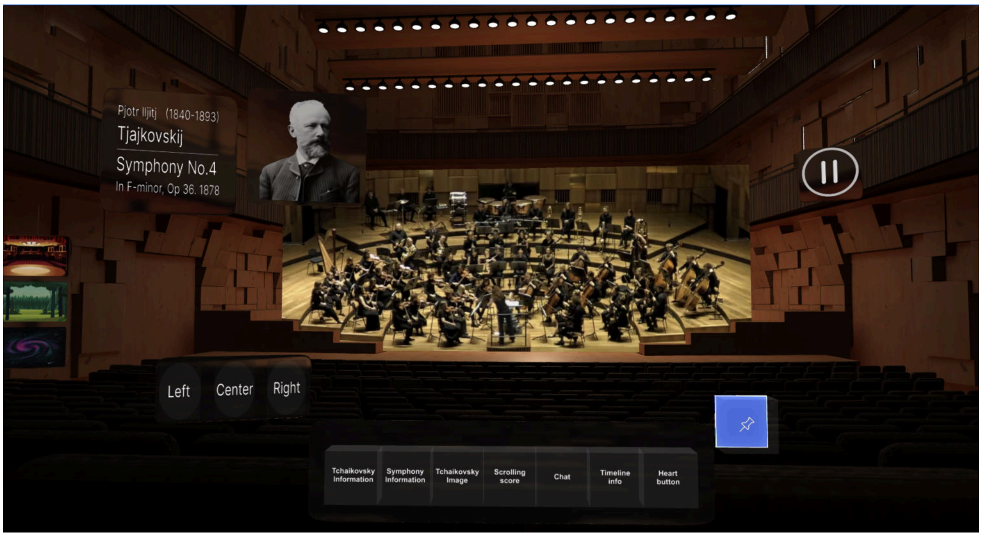

Figure 5.4 Start scene of the desktop version of the program

5.1.4 Features

5.1.4.1 Main Menu

The main menu serves as a starting point for the user. In the background, the sound of the orchestra tuning is playing on loop. The only clickable user type is, for the prototype, "beginner". It can be seen in Figure 5.5.

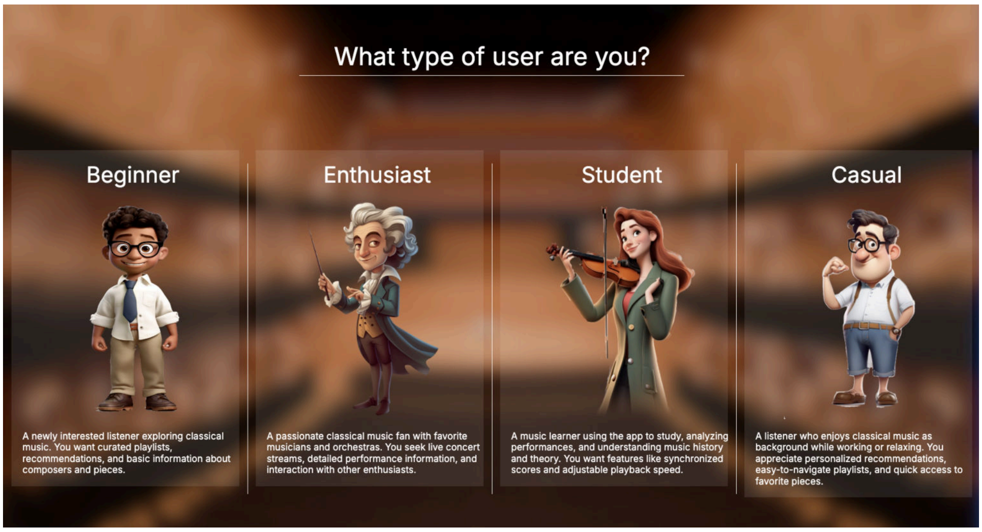

Figure 5.5 Main menu for the program

5.1.4.2 Start Scene

When the user has clicked the "beginner" image in the main menu seen in Figure 5.5, they are taken to the start scene. It presents a tutorial image, informing the user on how to click and drag widgets around. Once the tutorial image is clicked, the tuning sound stops, the light dims down and the concert starts. The desktop version of this scene can be seen in Figure 5.4. As seen in the figure, some widgets described below are already placed out for the user.

The different feature widgets that was developed for the Hi-Fi prototype will be presented below, grouped as themes of interactivity.

5.1.4.3 The Widget Dock

The dock is meant to hold the different widgets. It is seen in the bottom of the start scene of Figure 5.4. The user can drag different widgets out of the dock to place them wherever they want in the virtual space, and put them back into the dock, thus hiding them.

5.1.4.4 Static Information Widgets

Three widgets contained information about the performed piece. They can be seen in Figure 5.6.

- Name of the composer and the symphony
- Image of Tjajkovskij
- Description of the symphony

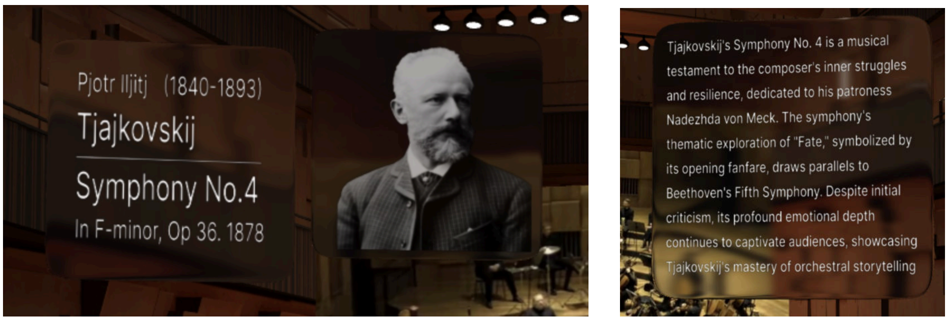

Figure 5.6 Static Information Widgets

5.1.4.5 Dynamic Information Widgets

Two widgets contained dynamic information about the performed piece. For the prototype, this was implemented as animations of images. They can be seen in Figures 5.7 and 5.8.

- Follow-along synchronized sheet music
- Timeline information, showing which movement of the Symphony that is played

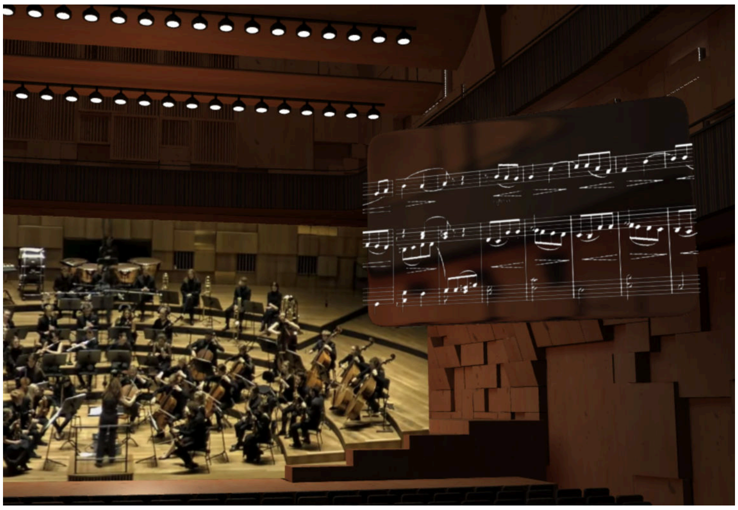

Figure 5.7 Dynamic Score Widget

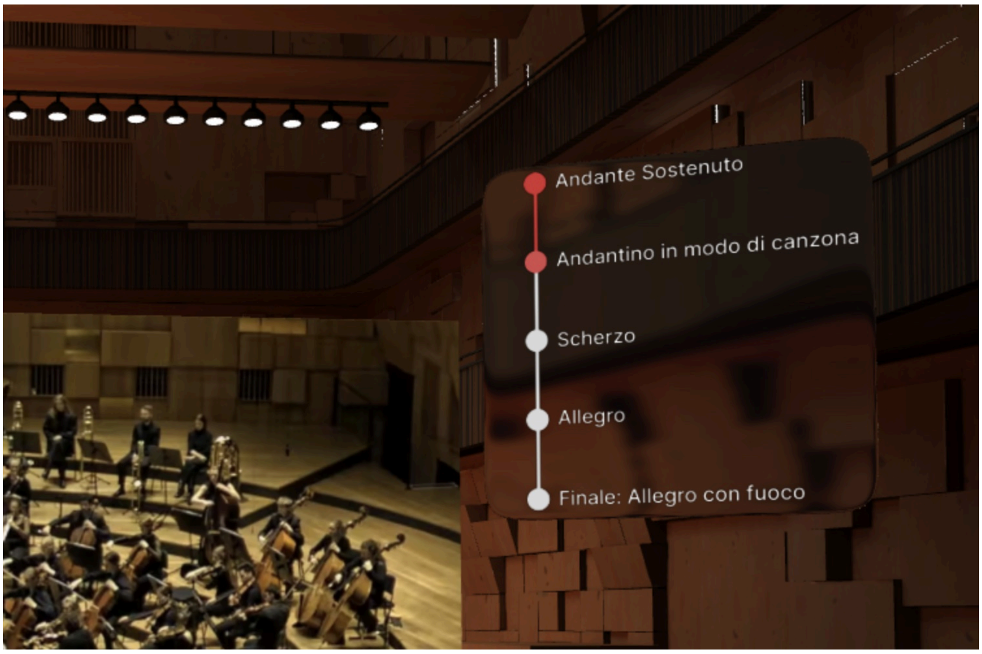

Figure 5.8 Dynamic Timeline Widget

5.1.4.6 Transportation and Environment Widgets

Users could move around in Malmö Live and change the environment. They can be seen in Figure 5.6.

- Positioning widget, allowing users to choose left, right or center seating in the concert hall. The widget can be seen in Figure 5.9 and the left and right position can be seen in Figures 5.10 and 5.11.

- Environment widget, seen in Figure 5.12, allowing users to change out the Malmö Live environment to a forest or the Milky Way galaxy, as seen in Figures 5.13 and 5.14.

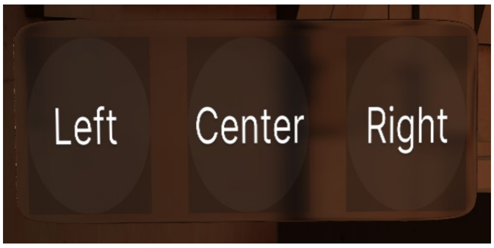

Figure 5.9 Transportation widget

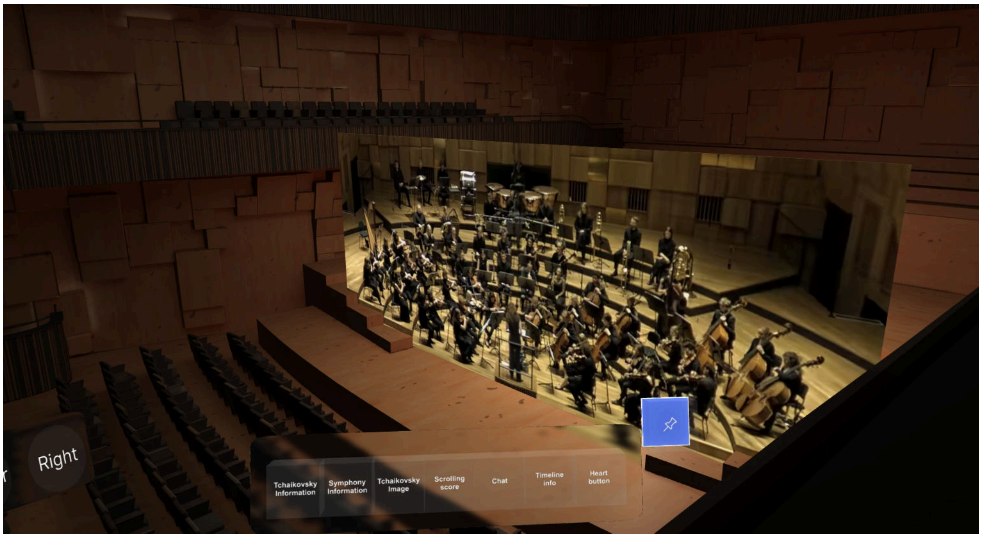

Figure 5.10 Right positioning

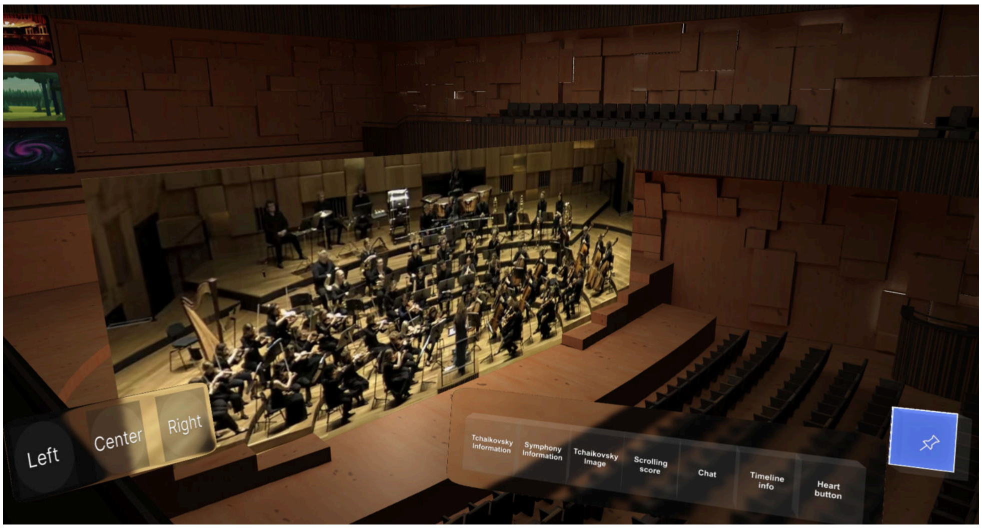

Figure 5.11 Left positioning

Figure 5.12 Environmental change widget

Figure 5.13 Change of environment, woods

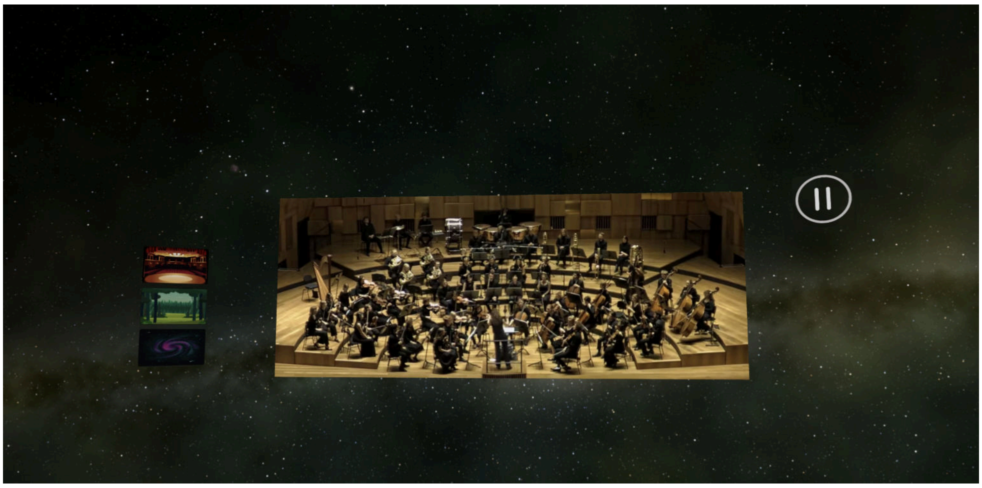

Figure 5.14 Change of environment, space

5.1.4.7 Social and Interactive Widgets

Users could interact with and change the state of the environment. Social features were also implemented.

- Chat widget, implemented as a static image for the prototype, seen in Figure 5.15.
- Heart button, which can be clicked to spread particles over the stage, as if the user "likes" the performance. The particle emission continues on for 30 sec-

onds. This behaviour can be seen in Figures 5.16 and 5.17, where the widget itself can be seen in the upper right corner.

- Play/pause button. When the concert is playing, the dynamic information widgets are moving accordingly and the lights in the concert hall is dimmed. When it is paused, so is the dynamic information widgets, and the lamps in the concert hall are lighted up. This can be seen in Figures 5.18 and 5.19, where the play/pause widget is positioned in the upper right corner.

Figure 5.15 Chat widget

Figure 5.16 Heart button, before click

Figure 5.17 Heart button, after click

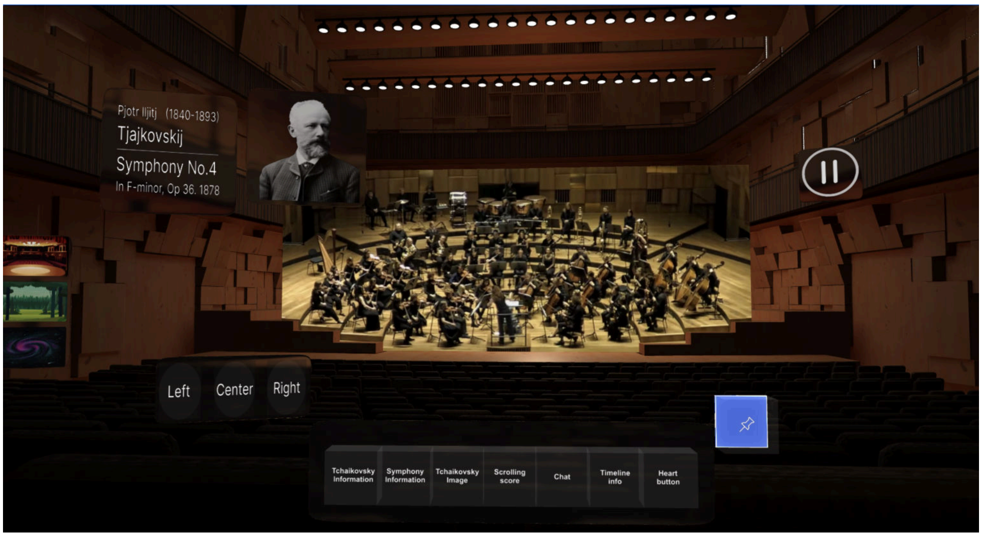

Figure 5.18 Play and pause behaviour, before pause

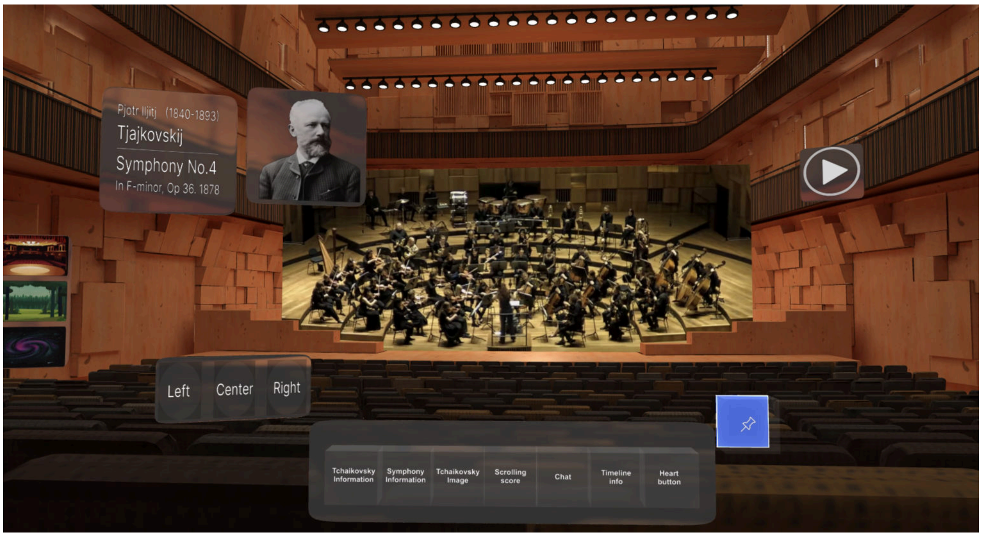

Figure 5.19 Play and pause behaviour, after pause

5.1.5 Hi-Fi Development

The Hi-Fi prototype was developed using the Babylon.js-framework, with the motivation being to build a cross-platform application being able to run on all operating systems capable of running WebGL-applications in an internet browser, coupled with WebXR, enabling immersive web applications being run on XR devices. Babylon.js, WebXR and WebGL is outlined in sections 2.2.2 and 2.2.1. The project was built using the programming language Typescript [50] and the build tool and local development server Vite [54].

The choice to use web technologies to build the application, compared to native engines, was due to the cross-platform capabilities. That is, the prototype could be built for the desktop platform as well as for XR devices during the same time, requiring only minimal changes between the versions. The performance was also evaluated compared to native engines and minimal performance was sacrificed for the cross-platform compability.

During the initial testing and development both Babylon.js, the game engine Unity [52] and the web 3D JavaScript framework Three.js [48] were evaluated but due to Babylon.js offering a more feature rich framework, with good support for WebXR it was chosen. A critical part of the evaluation was how easy it was to setup XR interactions, as the Hi-Fi prototype would be entirely dependent on interactions that worked on both desktop and on XR devices.

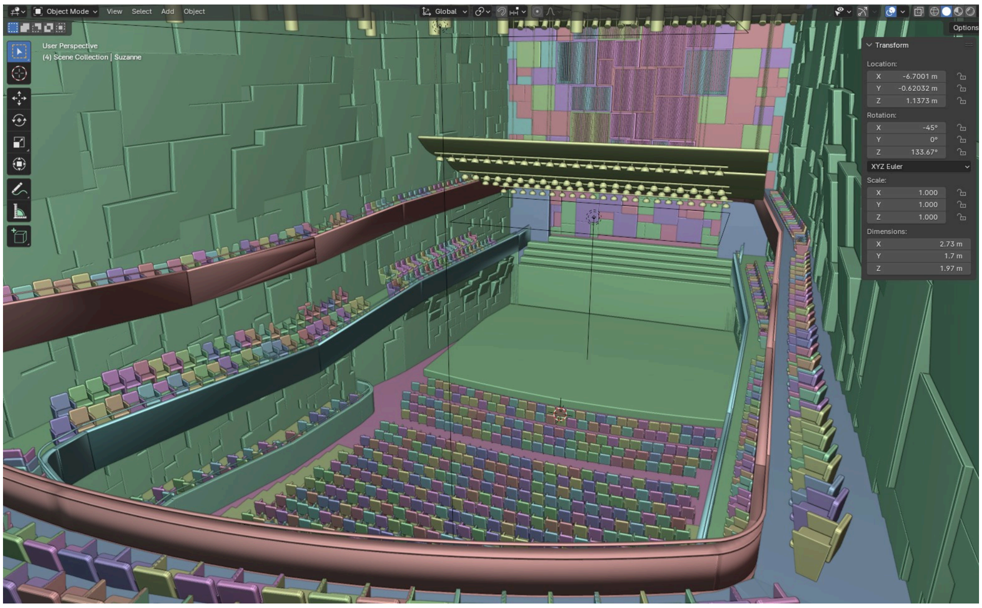

Figure 5.20 A screenshot of the 3D model, in the 3D modeling suite Blender [5]

3D Model

A 3D model of Malmö Live was modeled after accessible architectural plans coupled with a CAD-model of Malmö Live, provided by the LUDICH project manager. As the CAD-model was completely untextured and also unoptimized for real-time usage, the work was focused on recreating a model with the correct dimensions based on the CAD-model. The model was then sufficiently optimized for running in real-time on both desktops and the Meta Quest 3. An image of the 3D model can be seen in Figure 5.20.

Floating Widgets

One important feature from the Lo-Fi prototype was the inclusion of floating widgets, as seen in many of the features described in section 5.1.4. This was one of the first features implemented in the Babylon.js framework and thereafter tested. Since the widgets contain dynamic 2D information, such as information regarding the current piece being played or a mockup of chat functionality. The widgets were comprised of a smooth 3D model of a stretched box with rounded corners. Onto this box the content was attached. Due to the modular approach by the Babylon.js authors, the widget could inherit a lot of functionality already implemented. Likewise, the widgets themselves were constructed in a modular fashion where all the widgets shared the same parent. This enabled rapid development where all widgets were affected by the same interaction behaviour.

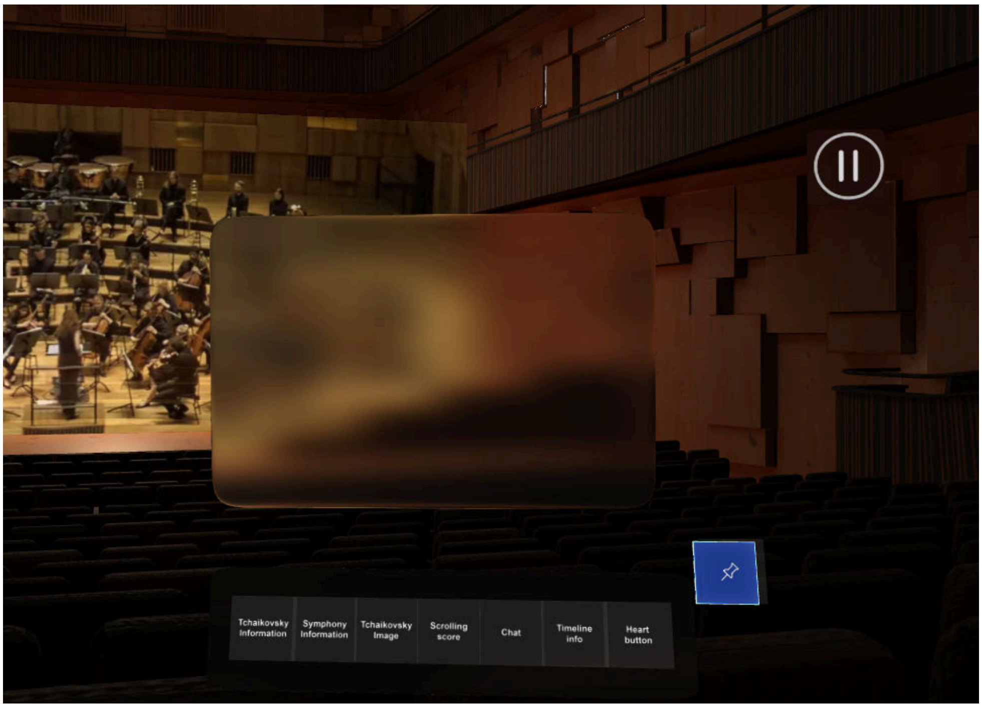

Figure 5.21 Frosted glass pane of the widgets.

The visual aspect of the floating widgets was important as the content displayed on the widget needed to be presented in a clear manner, whilst still being integrated into the environment without being disrupting for the user. Therefore, a decision was made to blur the background of the widget, and also utilizing Babylon.js's physically based rendering-materials to introduce refraction of the environment. This was implemented as a two pass blur, one pass blurring horizontally and another vertically. This gave the appearance of a frosted glass pane onto which content was displayed. This was inspired by the Apple Vision Pro development guidelines [3]. An example of the frosted glass effect can be seen in Figure 5.21.

Widget Helper Architecture

A helper class was constructed to make it easier to build different types of widgets. It contained all information about the individual widgets presented. In this helper class, every function returned a `WidgetSlate` (which was the name of the parent class) where the content was set by the helper function. This enabled quick content authoring with minimal redundancy in terms of code repetition.

Static Site Generation

An important side effect of choosing to use Babylon.js was the option to publish the application as a website. This is further strengthened by the fact that the project can be built into a static webpage, i.e. that it does not require any server side interaction but can be run entirely at the client. Using Vite, this is trivial, as Vite provides the tooling required to both bundle and assemble a static build of the web application, while also providing the ability to hot reload code which helps the development process.

Optimization

As mentioned earlier, the optimization of the 3D model was done. Other optimization steps included Babylon.js specific configurations to maximize performance. Some of these include:

- Freezing the world matrix for static meshes
- Not syncing bounding box information for static meshes
- Reducing the refraction texture resolution depending on the device
- Compressing 3D models and textures

One big optimization and visual fidelity feature is using pre-baked lighting. Pre-baked lighting is when a static lightmap is used for lighting the 3D scene, compared to real-time shadow maps, and is not a novel technique, industry usage going back to Quake or earlier. This enables rich lighting data to modulate the shading of the 3D model, without the need for global illumination calculations in real-time. This also enabled the functionality to dim the concert hall when the music piece starts playing, emulating the experience that concertgoers have in a real world concert hall.

Time Synchronization

In order to synchronize the time between the video feed and music, several events were published by different components. The assumption is that the slowest loading asset is the video feed, therefore an event is sent when the video feed is loaded and ready, which propagates and starts the dimming effect of the lightning and the music. Subsequent components then subscribe to a timesync event which is triggered by the music, to ensure correct timing is applied among time dependent components, detailed below.

Differences Between Immersive Version And Desktop Version

While the immersive application and desktop application contain total parity in terms of functionality, one important effect is missing and that is the frosted glass effect described earlier. Due to performance constraints a decision was made to only have the frosted glass effect in the desktop application, while the immersive application uses a low-resolution refraction texture which has trilinear interpolation applied, somewhat making widgets distinct from the background. This does not at all replicate the visual fidelity of the desktop version, but as the frame budget is tight for the immersive application as is, it was a worthwhile optimization required for the immersive application to run at all.

Audio Implementation

The audio is emitting from the video position. This makes the audio spatial, meaning that when the user moves in the space, the audio position is relative to the position. The spatiality of the audio is more noticeable in the immersive application, since the user can move their head freely and experience the movement of the sound direction, but it is enabled for the desktop application as well.

The audio played in the application was heavily compressed, to keep file size down. This was done through a blind test by one of the authors acting as a test subject, deciding which version sounds best. The different versions were arranged in a knock-out tournament, where each version would be compared to another one. The winner from that bracket then advances to next round. The result of the blind test was that the uncompressed audio sounded the best. Among the compressed versions a variable compressed mp3 was chosen with the bitrate ranging from 170 - 220 kbps. A Post-It describing the testing can be found in Figure 5.22, where the different numbers represent different bitrates of the compressed audio.

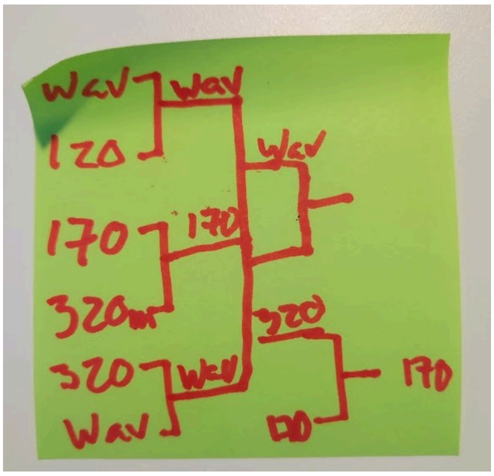

Figure 5.22 A post-it describing the audio blind test procedure. The lowercase m denotes mono audio.

5.1.6 Orchestral Performance

The piece of music played in the Hi-Fi prototype is the second movement from Pjotr Tjajkovskij's 4th Symphony in F-Minor, Op.36. The concert was recorded on the 28th of April 2024 in Malmö Live and was performed by the symphony orchestra of Malmö Musikhögskola, with Daniela Musca as the conductor. The concert announcement can be seen in reference [34]. During the concert, different audio recording techniques were tested in parallel for the LUDICH project. For the prototype, the recording using a Decca Tree microphone set-up was used. It is a commonly used audio recording technique for orchestral music. The video recordings used in the prototype came from the Axis cameras that are mounted in Malmö Live.

5.2 User Testing

To assess the performance of the Hi-Fi prototype a user test was conducted. The user test was mainly to compare the desktop and immersive application, but more general usability testing was also conducted.

Ten test participants were recruited for the user test. All the test participants, except for one, were IT-consultants from Capgemini, but all test participants had the occupation of working full time. The age of the test participants ranged from 24 to 56. Six of the test participants were men and four women. The interest in classical music reflected the results found in the survey.

5.2.1 Procedure And Set-Up

As the set-up was different between the desktop and immersive version of the application, the section below outlines the device and procedure differences present.

5.2.1.1 Hardware And Platform

For the desktop version of the test, the following hardware was used:
Device: Razer Blade Advanced (2018)
Audio: Superlux HD681 using built-in audio interface of the laptop
Input device: Mouse

And for the immersive version of the test, the following was used:
Device: Meta Quest 3 (2024)
Audio: Built-in speakers of the Meta Quest 3
Input device: Meta Touch Plus controllers
Monitoring: Meta Quest screen mirroring

Even though the immersive version works with hand tracking, a decision was made to use controllers for replicability across the tests.

5.2.1.2 Test Procedure

The procedure started with the test participants having to fill out a pre-test questionnaire, consisting of demographic questions such as *"What is your age?"* and *"What gender do you identify as?"*. After that some questions regarding their previous VR experience was asked, as well as their attitude towards classical music and attendance at classical music concerts.

The pre-test questionnaire ended with an acknowledgement that the participants were aware that their participation was completely anonymous and that they could interrupt the test at any time.

After that, the participants were assigned either the immersive version or the desktop version of the application at random, but with the available slots reduced for each respective category. This was done in order to get an equal distribution of test subjects testing the immersive and desktop version of the application.

After the test participants' platform was decided, the test leader gave a short explanation regarding what they would experience and how they could interact with each respective platform. During this introduction, the participants were instructed to explore the application and try to interact with all features present in the prototype. As the music piece was 10 minutes long, this was the around the maximum time that the participants interacted with the prototype, even though they could interact with it for longer if they wanted. The test participants were encouraged to ask the test leader if they had any questions or needed guidance.

After that, the test leader gave the participants initial help to access the application, and the testing started. During the testing no guidance was given, unless explicitly asked by the test participant. The test leader took notes during the test as well.

When the music piece in the prototype was nearing its end, the test leader gave some guidance regarding missed functionality for the participant.

After the test was done, the test participants filled out a post-test questionnaire, which consisted of a few open questions, a SUS questionnaire, and the IPQ.

The pre-test questionnaire, the SUS and the IPQ can be found in appendix D.

5.2.2 Testing Results

As the testing results range from pre-test questionnaire, observations during testing and post-test questionnaires, all results are described in the section below.

5.2.2.1 Pre-Test Questions

Five test participants (50%) claimed that they had tried VR one or a few times, while four participants (40%) had never tried VR before. Only one participant (10%) had tried VR many times.

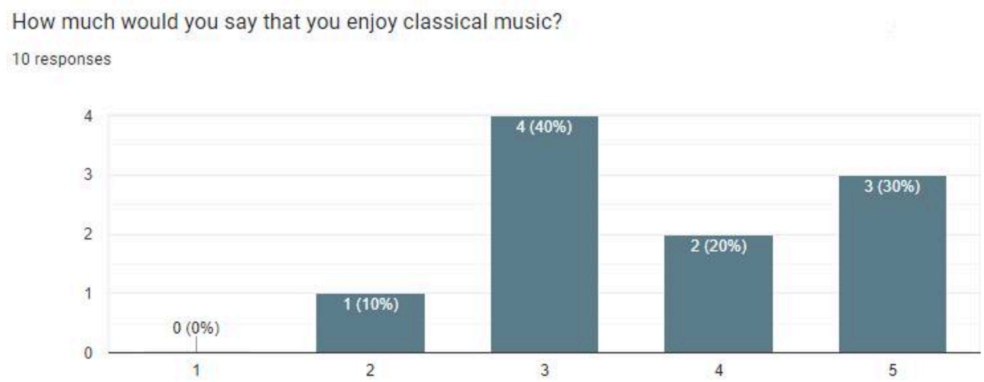

Figure 5.23 Classical music enjoyment among the Hi-Fi testing participants

Participants were asked how much they enjoy classical music on a scale from one to five, where one being *"not at all"*, and five being *"very much"*. The distribution was shifted slightly to the right, where only one participant selected two. The distribution can be seen in Figure 5.23.

Five participants (50%) had attended a classical music concert once or a few times, four participants (40%) had attended many times and one participant had never attended a classical music concert.

5.2.2.2 Open Questions

Three open questions were asked, the first being *"What are your initial thoughts and feelings about the application?"*, the second one *"Were there any features you liked in particular?"*, and the last one being *"Were there any features you disliked in particular?"*

To summarize, all test subjects expressed a positive attitude towards the application, both the immersive and desktop version. What specific features that were participants favorite were varied. There was also constructive feedback on how to improve the product and its usability, especially regarding the instantiation and destruction of widgets.

Regarding the first question, a common sentiment was that the application felt "cool", "fun", "interesting" and "innovative". Two participants said that they might need some more time to learn how to use and interact with the application as intended.

One test participant that tested the immersive application said that:

> *Really cool application. Almost felt like being in Malmö Live [...] during a concert. [...] The app felt quite well thought out and polished.*

Another, who tried the desktop application, said in a similar vein that:

> *Good Experience. I could project myself to be in Malmö Live.*

One user, who engaged with the desktop application, said that:

> *It was a cool experience, but I don't quite see how or if I would ever use this kind of application in my everyday life.*

When asked to point out the features they enjoyed the most, answers were varied and wide. All features discussed in section 5.1.4 were mentioned at least once, except for the chat. The increased interactivity, dynamic information and personalization aspect of the program is mentioned frequently, as well as the spatialized audio. The look of the 3D model and the widgets is mentioned in aesthetically pleasing terms. Participants who tried the immersive experience mentioned the possibility of changing environments and positions more often as a favorite feature than the test subjects of the desktop application.

The third open question asks the user to identify the parts of the application they particularly disliked. Two participants mentioned that they would not use the environment change feature. One of them, who used the desktop application said that it felt "gimmicky". The other, who tried the immersive experience, simply prefers the virtual concert hall, stating that:

> *Not particularly disliked but I did not have much use of changing the environment because I quite liked the concert due to me not attending concerts that often.*

Beyond these two responses, no other particular feature was regarded as particularly disliked. The process of dragging widgets in and out of the widget dock was mentioned by five of the participants as an unintuitive, cumbersome interaction. Three of them used the XR headset, and two the desktop. Issues regarding the opening and closing of widget was noted during almost all the tests by the test leaders.

One participant mentions having issues reading the widgets containing smaller text, and another mentions wanting to be able to enlarge the widgets. Both of these participants used the XR headset.

During the test, one participant opted to remove all widgets in the application, preferring an experience with only the virtual environment and the video stream of the orchestra.

5.2.2.3 System Usability Scale and I-Group Presence Questionnaire

The results from the System Usability Scale and I-Group presence questionnaire are presented in table 5.1.

Table 5.1 Overview of quantitative results from the user testing. * denotes p-value < 0.05. The categories presented under IPQ is the cumulative score for the questions regarding that category.

	Immersive			**Desktop**		
	Mean (μ)	SD (σ)	Grade	Mean (μ)	SD (σ)	Grade
IPQ*						
General Presence	4.2	1.3	B	4.2	0.8	B
Spatial Presence	4.9	0.2	B	3.6	0.6	F
Involvement	4.2	0.6	C	3.5	0.8	E
Experienced Realism	3.6	1.0	C	2.5	1.4	F
SUS						
Total score	76.5	7.8	B	81.5	12.1	A

The scores for each category in the IPQ as well as the score for SUS are calculated according to the method described in section 2.3.7.2. The p-value calculated for the IPQ scores were calculated using a Mann-Whitney U-test [35], but sufficient p-values could not be found for the SUS scores.

Further calculations were done, filtering based on classical music attendance. The results are presented in tables 5.2 and 5.3.

Table 5.2 IPQ results based on how many times a year the participant has attended a classical music concert.

Attendance		General Presence		Spatial Presence		Involvement		Experienced Realism	
		Mean (μ)	SD (σ)	Mean (μ)	SD (σ)	Mean (μ)	SD (σ)	Mean (μ)	SD (σ)
VR	Many times	5	0	5.2	0.5	4	0.4	3.5	0.6
	Once	3.5	1.4	4.8	0.8	4.4	0.3	3.3	1.2
	Never	2		4.2	1.3	5.3	0.5	3.5	1.3
Web	Many times	4.5	0.7	3.8	1.0	4.6	0.5	1.9	0.9
	Once	4	1.0	3.5	0.7	2.8	1.4	2.8	1.8

Table 5.3 SUS scores and grades based on how many times a year the participant visit a classical music concert.

Attendance		SUS Scores		
		Mean (μ)	SD (σ)	Grade
VR	Many times	80	14.1	A-
	Once	73.8	3.5	B-
	Never	75	1.8	B
Web	Many times	81.3	1.8	A
	Once	81.7	8.8	A

6 Discussion

This chapter discusses all parts of the design process as well as the final result of the last prototype testing. Discoveries in relation to the research questions are also presented as well as ideas for further research on the subject and expansion of the final prototype.

6.1 Process, Methods and Learnings

The project work has revolved around a double diamond design process, as defined in section 2.3.3.2. The four steps, *discover, define, develop* and *deliver* have all been conducted successfully through the sub-steps seen in the project roadmap that has been referenced throughout the thesis, see Figure 6.1. Two iterations were done for the *deliver* aspect of the double diamond design method, represented as two prototypes that were tested and evaluated.

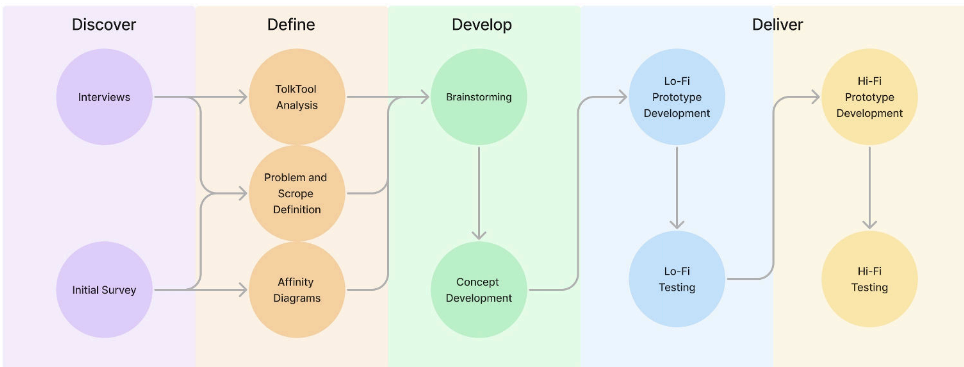

Figure 6.1 Project roadmap

From the *discover* and *define* steps we learned through interviews and a survey that many young people (19-35 years old) enjoy classical music, with an average enjoyment level of 3.22 out of 5. However, 75.6% of respondents in that age group have not attended a classical music concert within the past year. We also learned that if people were to stream a concert in an imagined future, they would prefer using web or immersive technology to do so. Respondents expressed an interest of an enhanced feeling presence through immersive technologies and spatial audio. Some wanted to see the show from different angles or move around in the room and have an experience that is closer to real life.

The interviews provided deeper information about potential user's relation to and attitudes towards classical music. We learn that those who are not already attending classical music concerts feel positive towards doing so if there was a social incentive, such as being invited by a friend. Some also feel like they do not understand the genre good enough to participate. Both of these sentiments are in line with the findings of Kolb [28] and Dobson [16]. We know from related work in the field that more and relevant information about the music to provide the listener with a context and help them understand what is interesting about the piece, can significantly improve the experience of new attendees [16, 17].

These learnings and more discussed in greater detail in section 3 were the basis of the ideation and concept creation sessions that were held under the *develop* part of the double diamond process. During those sessions the concept that would be further developed into prototypes was created.

6.2 Lo-Fi Prototype and Usability Study

The Lo-Fi prototype was created with pen and paper and was mounted onto the corner of a wall to emulate the immersive aspect of a VR application while being analogue. Features were added quite liberally, to let testers decide what was superfluous and what was engaging and fun. The testing, which was also partly a bodystorming session, was a success where users were positive about the concept and its potential for fun and accessibility. We learned that people had different favorite feature widgets depending on, for example, their knowledge about classical music. One sentiment shared between users was that too many feature widgets proved to be overwhelming, thus the idea of the widget dock for instantiation and destruction of widgets was born.

The testing pool consisted of six test subjects. Two were women, four were men. All are professionally active within the IT field. This is not representative of society as a whole and recruitment could have been done with more diversity in mind. There might also be some bias since the test subjects all knew the authors, which might have inflated the positive responses that were received.

Learnings from the Lo-Fi testing was taken into account for the next iteration - the Hi-Fi prototype.

6.3 Hi-Fi Prototype And Usability Study

The development and use of the Hi-Fi prototype was mostly successful in the sense that a prototype was conceived which could be tested. As the goal of this thesis was not to analyze or find results regarding individual interactions with components, devices or interfaces but the design concept as a whole, that too can be regarded as successful.

The results reported in section 5.2 contain interesting findings regarding the application itself but also relevant findings for the LUDICH project as a whole.

6.3.1 Findings From the User Testing

The most interesting, and also trivial, finding is the statically significant result that participants using the VR version of the application reported a higher presence compared to participants using the desktop version, as can be seen in table 5.1. As mentioned previously this might be considered to be a trivial result, but confirming the fact that the application coupled with the Meta Quest 3 results in a higher immersion confirms the viable usage of VR as a future interface for streamed classical music concerts.

This also raises interesting questions - what would happen if the visual fidelity was decreased? Would participants report the same experience or what factor is most significant? Looking at table 5.1, the biggest differences between the immersive version and the desktop version in regard to the IPQ results are *Spatial Presence*, but since *General Presence* was equal among the two versions, the *Spatial Presence* might be influenced by other factors. In the same vein, *Experienced Realism* scored a bit higher in the immersive version compared to the desktop one, so that might also factor in.

Regarding the SUS scores, we can see that the desktop version scored ever so slightly higher compared to the immersive version. This might be due to the test participants' familiarity with the input method and established ways of interaction, such as drag-and-drop and using a "dock". Although the immersive version used the same kind of interaction, but with the pointer being the VR controller, this might not translate as well. Hand tracking is an alternative input method which works, but was not used during the testing - which might be an interesting comparison to follow up this study.

Another alternative would be to more closely adapt the interaction to a *near-touch* interaction method, where the controller or hand interacts with touchable screens, widgets, button and other components as similar to real world interactions as possible. As an example, when a person grasps a newspaper, the person physically grabs the newspaper and then proceeds to interact with it, maybe unfolding the paper. In the same way, a person in the immersive application would grasp the widget to move it, not relying on pointer interaction projected onto the widget. This might enable users to more intuitively interact with the immersive environment compared to the current pointer interaction.

With the results from filtering on classical music attendance, seen in table 5.2 and table 5.3, not much can be said. The *General Presence* was higher on participants who had attended classical concerts many times or once compared to the participants who never attended a classical music concert, but compared to that the *Involvement* scored much higher on the participants who never attended a classical music concert.

Due to the low number of participants in the study and especially in each group, nothing significant can be observed and no results in tables 5.2 and 5.3 can be taken for truth, but can give interesting hints regarding phenomena to study more closely in upcoming studies.

6.3.2 Development Findings and Reflections

The decision to use a web-based 3D framework, such as Babylon.js was not done without careful considerations regarding what eventual advantages respective disadvantages would be present. This can be further discussed for the future development of this prototype or an application which might provide equal functionality.

One of the biggest drawbacks with web-based 3D frameworks, currently, is the subpar performance. Even though no comparison was done with a native application, it can be assumed that certain performance drawbacks are present. This could be seen with the *frosted glass*-effect, which worked well in the desktop version but was not able to be done in the immersive version. One big advantage of using the Babylon.js.js-framework is that the entire framework is open source, which provides the developer with an opportunity to debug features which, compared to a closed-source engine, would be impossible to study. This means that for future developments of the application, visual fidelity parity could be achieved, by digging deep down in the Babylon.js source code and further debugging what is causing the performance drop.

Another aspect to keep in mind and which also is imperative for all immersive development is the developer ergonomics, both in terms of tooling available to the developer but also the physical ergonomics when developing for external devices - in this case a VR headset. When developing immersive applications usually tooling is provided to either:

1. Emulate the target device/functionality on the host device - i.e. providing the developer with the interactions needed to test the application. See either XCode iPhone emulation, Android studio android emulation or Unity's XR Interaction Toolkits XR Device emulator. *Or*

2. Run the application on the device, either through actually compiling the code to an application or through some kind of connection to the device. In the case of desktop VR the VR headset is running on the host device, the HMD acting as display and input, but in the case of mobile VR a network based connection can be used to stream visuals and input to and from the host device.

Utilizing a web-based framework enables developers to take advantage of an already established developer work cycle in which the application is hot-reloaded when new code is saved. This also works for immersive devices, so the *develop-save-observe*-cycle is somewhat seamless, without the need for long waiting when the code is compiled. This greatly increases the developers efficiency and user experience when developing an application.

One consideration also present was the maintainability and extensibility of the prototype. As Babylon.js builds upon Javascript and Typescript, it should therefore be more easily be familiar to developers who already have some experience with web development. Although this fact is overshadowed by the game development paradigm, as the language familiarity does not directly translate to knowledge regarding game development and the structure thereby. In contrast, it would most likely be easier for a developer familiar with game development through Babylon.js to start with Unity or Unreal engine development, with the requirement to learn new syntax, C# in the Unity case or C++ for Unreal Engine.

6.4 Research Questions

RQ1: What is the state of the art in terms of streamed live media?

The state of the art in terms of streamed live media are hard to map out completely. But some examples from this thesis are concerts with digital elements, such as the ABBA Voyage concerts, livestreamed concerts through YouTube and Twitch, concerts through non-typical mediums, such as through Fortnite or Minecraft to fully immersive concerts through VR applications, either taking place in a *metaverse*-setting or through a fully immersive custom-built environment.

Whether this constitutes as state of the art is hard to tell, but it gives some clues regarding what spaces and solutions are being explored within the industry.

RQ2: How can one increase interactivity in a streamed classical music concert solution?

Interactivity can be added in several different ways — both live within the concert hall and within a media solution. For this thesis, several interactivity layers were added for an XR/desktop prototype. Users could move around in the concert hall, as well as teleport the concert into another environment, such as the Milky Way or a forest. Several feature widgets were added to provide static and temporal information. The concert that was streamed within the Hi-Fi prototype could be paused and the user could "like" the concert, filling the stage with a rain of pink glitter particles. A social interactivity layer was added in the form of a chat, although this was represented as an image for the prototype. The sound was implemented as 360 spatial sound to further improve the sense of *being there*.

The idea of creating an immersive application came from responses of the survey and interviews, where respondents expressed a wish for a digital application that could replicate or enhance the feeling of being in a concert hall. The fact that the application also works on desktop is a great addition for accessibility and demonstration purposes. Further inspiration came from the digital classical music enhancement studies of, among others, Erdbrink et al. [17] and Onderdijk et al. [43], the classical music engagement studies of Dobson [16] and Kolb [28] and examples of other digital concerts solutions on desktop, in game or as immersive experiences.

In conclusion, interactivity can be added in a myriad of different ways to digital concerts and will have different effects depending on the motivating factor of the user — a sense of presence, a sense of togetherness or maybe a relationship between the performing artist and the user. In this thesis, several different types of interactions were explored.

RQ3: How does increased interaction affect the user experience?

Based on the qualitative results from the study, users seemed to enjoy the increased interaction offered in the Hi-Fi prototype. Users seemed positive as a whole regarding the functionality offered, but some users expressed a concern in seeing how they would integrate it into their everyday life. Another user, when using the application removed all widgets as they want a *"clean-slate"* experience. As a whole, the users expressed great enthusiasm towards increased interaction, but as the sample size is small and with a majority of test participants working with IT and technology in some sense, it does not reflect the public, and therefore more studies would need to be conducted.

The results from the quantitative part of the study supports the qualitative part. The score from the SUS are high both for the immersive version but also, even higher, for the desktop version, which can be in part due to users being more familiar with the desktop input method. The immersion was also high for the immersive version of the prototype, which can be integral for considering VR as a viable option for similar types of applications.

6.5 Future Work

Thanks to very fruitful ideation sessions as well as substantial and iterative input from users, the authors of the thesis have many ideas on how to expand and improve the classical music streaming application.

6.5.1 Improvement of the Hi-Fi Prototype

Many test subjects of the Hi-Fi prototype identified a significant pain point revolving around the instantiation and destruction of feature widgets, a concern presented in section 5.2.2.2. This is a frequent task within the application's interaction flow, thus critical to resolve for further usage.

6.5.2 Expansion of the User Study

The thesis employed various data gathering methods, including an initial survey, interviews, and iterative user testing. However, it's worth noting that the sample sizes for each of these methods were relatively small. Expanding the testing pool to include a larger and more diverse sample could provide insights into the robustness and generalizability of the results. Test subjects in the study consisted mainly of people working at Capgemini and from social and professional channels of the authors, which does not represent the diversity of society as a whole. By increasing the sample size, one could assess whether the observed trends and findings remain consistent. This expansion would enhance the credibility of the study's conclusions and could offer more intricate insights to the LUDICH project as a whole.

All data gathering methods made use of the social and professional circles of the authors. This could potentially have introduced bias in the results. Further studies should be conducted without personal relations between the test and interview subjects and the facilitators.

It would also be beneficial for the study to introduce a task list, to ensure that participants had the same goals and tasks in mind when exploring the application. Due to the goal and scope of this thesis, the authors felt it was not appropriate to further expand the study based on time restrictions but also due to the more general approach, but this is worth noting if one were to expand the study further.

6.5.3 Expansion of the Application

The directions for expansions are endless. Thus, we will only discuss parts and features of the application that have already been implemented for the prototype here.

The final product under test was a prototype, therefore not all features were implemented to their full extent. For example, the chat widget shown in section 5.1.4.7 was implemented only as an image and was not interactive. Another example is that only "beginner" could be chosen as the user type in the main menu, see section 5.1.4.1. To expand on the application, other user configurations should me implemented and all feature widgets in the prototype should be developed further. An example of future expansion is that the "timeline" feature widget discussed in section 5.1.4.5 could act as an interactive menu, in which the user could navigate between different movements in the symphony, rather than just displaying temporal information.

6.5.4 Alternative Concepts

During the brainstorming sessions during the design process several other concepts to increase and diverse the attendance of classical music concerts were conceived, which span from high-technological components without a clear use case or application tied to it, to larger service design concepts which targets a broader scope than what this thesis encompasses.

For the sake of documentation and for the potential usefulness of similar work, they are described down below.

6.5.4.1 Prices and Marketing

One recurring sentiment across interviews, literature and the survey was that price is an important factor for concert goers and users alike. Even though Malmö Live and similar music halls in Sweden provide a discount for students and younger concert goers, there does not seem to be familiar to the interviewees. This indicates a lack of communication in this specific target group, and could be remedied by marketing more heavily towards this specific audience segment.

Likewise, — a continued focus on subsidized ticket prices is relevant if a younger audience is to be reached. It does not have to be implemented directly through a discount or similar, but engaging activities could help promote the venue and reach the target audience segment. Some examples of how to implement this could be:

- Raffle tickets to a target audience segment through an application or website
- Market specifically to students through student discount platforms
- Inject Malmö Symphony Orchestra in alternative contexts such as at festivals
- Make sure the streaming platform is free-to-use in order to reach as big online audience as possible, which might increase the interest to attend the physical concerts as well

Another marketing idea that arose was to offer concerts with a radical different experience than what is offered today. Some of these could include:

- Concerts with food and drinks served directly in the concert hall
- Concerts where participants are encouraged to walk around the concert hall and engage
- Participatory concerts where participants either get assigned a "simple" instrument, or where participants (in this case musicians) are encouraged to bring their own instruments and jam and create together with the orchestra

6.5.4.2 Symphony Concerts Everywhere

A broader idea that we call *Symphony Concerts Everywhere* was brought forward with two distinct separate directions — one is to decentralize the orchestra across different places and the second would be to distribute the concerts across Malmö as much as possible.

Concept 1 would be compromised of splitting the orchestra to different physical locations, where the conductor could stay in Malmö Live, but have the musicians in different places of Malmö or visiting selected ticket holders. Then, through high throughput connectivity, they could play together, with real-time audio and visual streaming from and to the conductor and the other musicians. This would function more as a marketing activity rather than as a regular, reoccurring concert, showcasing the technological advancements made.

Concept 2 would be to spread the live concerts as much as possible - plastering all digital screens in Malmö with live feeds from Malmö Live, albeit without sound. The public digital screens that could show this would be the screens in public transport, such as on busses and trains, digital advertising screens, screens on public squares, et cetera. The video stream would include a QR code, where users could scan it and be taken to a audio-only feed which they can listen to using their smartphones. In this way, users would participate and enjoy a shared but individual concert. For example, on the bus or train the users might recognize that both parties are listening to the same concert.

6.5.4.3 High Technological Components

There were three ideas with high technological components which are advanced enough to constitute master theses on their own. Below follows a title with a short description.

Real-Time Pointcloud Registration Since we have multiple cameras, overlapping the orchestra from different point-of-views, real-time pointcloud registration could be possible. This would then generate a pointcloud of triangulated points for each frame. This would require a clock sync between the cameras but would provide an interesting visualization.

Hologram Composers Generating a hologram of historical composers would consist of using a holographic or lightfield display paired with a 3D rendering of a composer, either manually created or generated by artificial intelligence or similar. Even though the context of classical music might not suit this type of technology it would be a technological challenge and scientific exploration.

Full Orchestra Multi-View Motion Capture Multi-view motion capture from monocular camera feeds is an ongoing research field. The certain limitations of a symphony orchestra might add additional complexity to fully solve poses from the individual musicians. Since both musicians and instruments overlap each other this makes it difficult for existing algorithms and methods. But considering the fact that the orchestra layout are mostly the same with limited changes across concerts this also makes it suitable for a more specific method, where the training data can be specialized enough. The output from a full orchestra motion capture can be fed into visualization frameworks to provide novel, real time, reactive visuals.

7 Conclusions

This chapter presents the conclusions made in the thesis. This chapter presents no new information nor findings.

7.1 Conclusions and Summaries

This thesis has described the process of using design methodologies to define, ideate, prototype and test an application for streaming classical music.

This thesis details the design process of an application for streaming classical music, aimed at attracting younger and more diverse audiences by digitalizing the experience of being in a concert hall. An extensive literature review highlighted the absence of younger listeners in classical music and the potential of digital concerts to bridge this gap. A survey and interviews revealed that affordability and social experiences are crucial for concert attendance. A Lo-Fi prototype was created, featuring interactive elements like chat widgets and lighting controls. User testing of the prototype showed positive reactions in general, but also that too many widgets could be overwhelming.

A Hi-Fi prototype followed, using BabylonJS to create a 10-minute VR and desktop experience set in a virtual replica of Malmö Live. This version included customizable widgets and environmental interactions. User testing, conducted with both VR headsets and laptops, received positive feedback, though some found widget interactions cumbersome. The prototype scored high on the SUS scale, achieving grade A for the desktop version and grade B for the immersive version. The IPQ score indicated a significant increase in presence for the immersive version compared to the desktop version. Overall, the thesis provides valuable insights into user preferences and needs regarding digital classical music experiences. It also revealed that while users find increased interactions fun and engaging, these interactions must be seamless to avoid disrupting the experience.

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A Work Distribution and Time Plan

A.1 Work Distribution

All work has been conducted in collaboration between both of the authors with equal effort. The only difference between their efforts is that Kaspian took the role of lead developer for the 3D model of Malmö live and Moa for the feature widgets.

A.2 Project Plan and Outcome

The initial project plan is visible as a Gantt chart in Figure A.1. It was defined during the first week of the thesis work. The actual project time distribution can be seen in Figure A.2. The differences between the planned and the effective project plan are minor, but one can see that the *deliver* phase of the project (i.e. the Lo-Fi and Hi-Fi development) had to be done over a shorter period of time than planned. We also added an interview phase to gather more insightful data. We also helped the AIE team with a small haptic XR application for a customer to Capgemini. This was done in parallel with the development of the Lo-Fi prototype, as seen in Figure A.2.

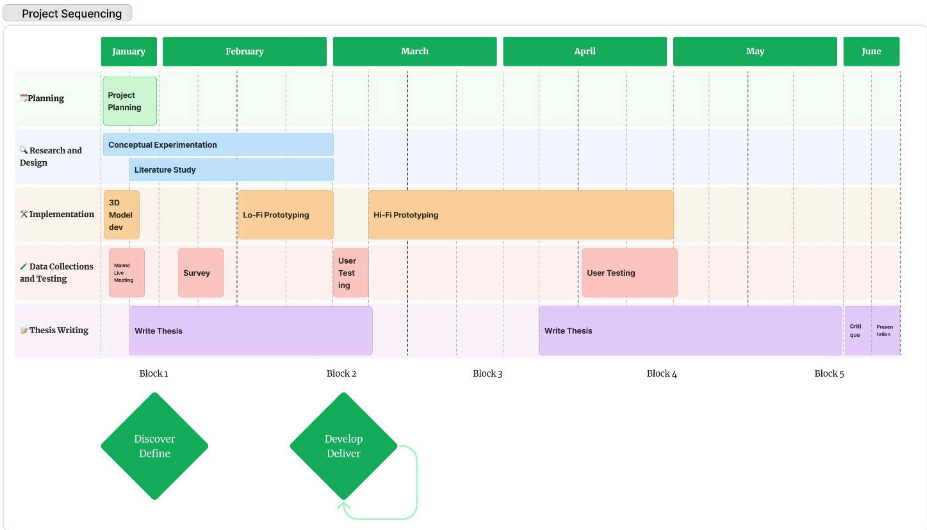


Figure A.1 Initial Project Plan - Gantt Chart

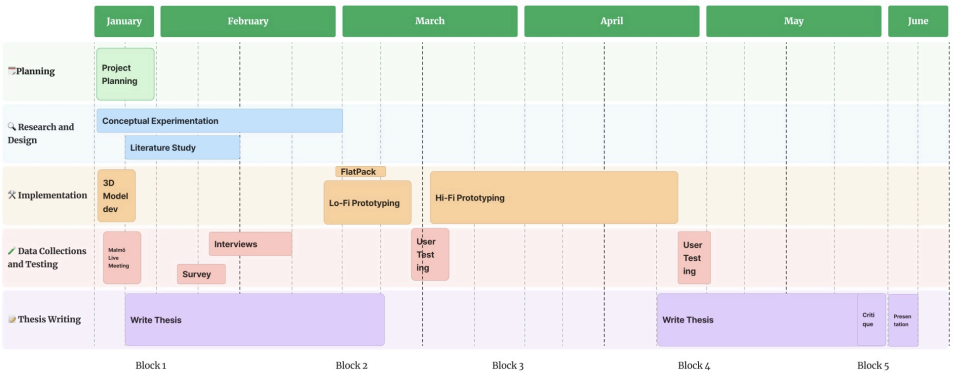


Figure A.2 Actual Project Plan - Gantt Chart

B Initial Survey

Attitudes Towards New Digital Interactions of Streamed Classical Music Concerts

Who are we, and what is this survey?

We are Kaspian Jakobsson and Moa Björkman, two students from Lunds Tekniska Högskola doing our master's thesis in IT engineering, specialising in interaction design. We are working together with the cross-disciplinary project LUDICH to explore new digital interactions when streaming classical music concerts. How can technology help with the outreach of classical music, and what will this cultural experience look like in the future?

If you are interested to know more about the LUDICH project as a whole, read more here: https://www.arts.lu.se/collaboration/lund-university-digital-interactive-concert-hall-ludich

This survey is the first step to map out the opinion of the general public regarding streamed media and classical music. The results will serve as the basis for our design process and be of great help. You will be asked questions regarding your interest in classical music and your digital streaming habits.
Anyone can participate in the survey, regardless of your interest in classical music or your experience with streamed media. All free-text questions can be answered in English or Swedish.

All data is anonymous, and the gathered results will be presented in our thesis.

Thank you so much for participating!

Contact information:
Moa Björkman - mo2675bj-s@student.lu.se
Kaspian Jakobsson - ka1251ja-s@student.lu.se
Supervisor: Günter Alce, LTH

moaviola11@gmail.com Byt konto

Inte delad

* Anger obligatorisk fråga

What is your age? *

- ◯ 12-18
- ◯ 19-25
- ◯ 26-35
- ◯ 36-45
- ◯ 46-55
- ◯ 56-65
- ◯ 66+

What gender do you identify as? *

- ◯ Woman
- ◯ Man
- ◯ Non-binary
- ◯ Do not want to specify
- ◯ Övrigt: ____________________

What is your main occupation?

- ◯ Working full-time
- ◯ Working part-time
- ◯ Studying
- ◯ On Leave (Parental, Sickness, etc)
- ◯ Retired
- ◯ Job-seeker
- ◯ Övrigt: ____________________

Attitudes Towards Classical Music

How much would you say you enjoy classical music?

	1	2	3	4	5	
Not at all	○	○	○	○	○	Very much

Approximately, how often do you listen to classical music in a non-live setting (pre-recorded pieces on the radio, on music streaming services, etc)?

- ○ Every day
- ○ Every week
- ○ Every month
- ○ Every year
- ○ Never

How many times did you attend a live classical music concert in the past 12 months?

- ○ 0 times
- ○ 1-2 times
- ○ 3-6 times
- ○ 7 or more times

Please describe your feelings towards live classical music concerts, if you have ever been to one. What was your experience, in short? Did you enjoy it? Why? Why not?

Ditt svar

Attitudes Towards Digital Music Interaction

How many times did you attend a digitally streamed music concert (of any genre) in the past 12 months?

- ○ 0 times
- ○ 1-2 times
- ○ 3-6 times
- ○ 7 or more times

If you have streamed a music concert, what technology/medium did you use?

- ☐ Web
- ☐ Stand-alone app (mobile or computer)
- ☐ VR
- ☐ TV
- ☐ Radio
- ☐ Online game
- ☐ Övrigt: ____

If you have streamed a music concert, on any medium, what did you like? What did you not like?

Ditt svar ____

Imagine the concert streaming experience of the future, what medium/technology would you use to stream it?

- [ ] Web
- [ ] Stand-alone app (mobile or computer)
- [ ] VR
- [ ] TV
- [ ] AR
- [ ] Radio
- [ ] Online game
- [ ] Övrigt: ____________________

Imagine the concert streaming experience of the future, how would it differ from the experience(s) you have already had? Is there anything you would like to be able to do?

Ditt svar ____________________

Almost done!

Can we contact you for future user tests?
The user tests will be conducted in the Malmö-Lund area, and one batch will be done in the beginning of March and one will be done during the end of May.

By saying yes and filling out the form below you will lose your anonymity towards us as we will keep your contact information until the user tests are done.

The results of this survey will still be completely anonymous and your personal information will be deleted the 31st of May at latest. If you wish to get your data removed before this date, feel free to contact us:
Moa Björkman - mo2675bj-s@student.lu.se
Kaspian Jakobsson - ka1251ja-s@student.lu.se

Name

Ditt svar

E-mail Adress

Ditt svar

C Lo-Fi Test Protocol

Material: Lo-Fi prototype with paper, computer

Introductory questions:
Welcome to a test of our lo-fi prototype! This is a prototype of an application that will be developed, and all feedback is warmly received. You are welcome to speak during the testing and say everything you think of, also known as think aloud. Criticism and thoughts are worth their weight in gold. You can interrupt the testing at any time. We will ask questions and guide you during the course of the test. There is no right or wrong. We will take notes on a computer and record the sound to use as a reference, but the test itself is completely anonymous.

- How old are you?
- What gender do you identify as?
- What is your occupation?
- How often do you go to classical music concerts?
- Do you give consent for us to record this lo-fi test?

Context: You have in front of you an application in 3D, where a classical music concert is being streamed. You see things happening on stage, and you have a symphony orchestra in front of you. Mozart's Requiem is playing, specifically the last part of the second movement, Lacrimosa.

Part 1: Basic Interaction with 3D Interface
Material: Background Orchestra + individual musicians

- What do you think the boxes on the musicians in front of you represent?
- Is the rest of the orchestra a camera feed or are they, for example, 3D models? Or images?

- How do you imagine navigating in the 3D space? Is it like Google Street View? Is it like The Sims? Is it like a FPS game? Is it based on your head or your hands?
- How is the sound? Do you want to be able to adjust the sound in any way?
- What happens if you click on different parts of what you see?

Part 2: Metadata
Material: Title, artist, year, description, play-bar with notes, piece-specific description, image

- How do you move the boxes?
- Is the information relevant?
- Do you want to be able to remove all boxes at once?
- Do you want to be able to bookmark certain parts?
- What happens if you click on the metadata?

Part 3: Social Features
Material: Chatbox, like button

- What happens in the chatbox?
- What happens if you click on the heart?
- Do you want to be able to communicate with others in any other way than chat?
- Do you see others in the virtual environment or are you alone? Do you see the real audience?

Part 4: Augmented Visual Elements
Materials: Crowdspeak visuals, sound-reactive visuals, backgrounds

- What are the flying lines above the orchestra?
- What happens if you click on the images to the left?
- What are the stars above the violinist?
- What happens if you click on the backstage door?

- Is there anything you miss?

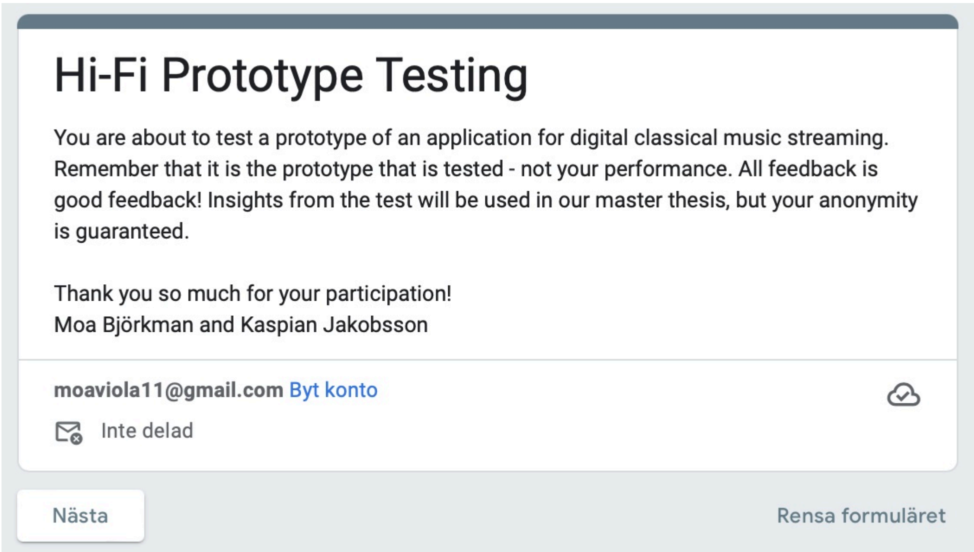
Part 5: Experimental Interactive Elements
Materials: DIY conductor

- What is DIY conductor?
- What would happen if things start flying in front of you?
- What happens if you click on the settings button?

Closing section

- What are your thoughts on the program?
- Was it too much, too little, or just enough features?
- Anything you miss or would change?

D Hi-Fi Prototype Testing Questionnaire



Hi-Fi Prototype Testing

You are about to test a prototype of an application for digital classical music streaming. Remember that it is the prototype that is tested - not your performance. All feedback is good feedback! Insights from the test will be used in our master thesis, but your anonymity is guaranteed.

Thank you so much for your participation!
Moa Björkman and Kaspian Jakobsson

moaviola11@gmail.com Byt konto

Inte delad

Nästa

Rensa formuläret

Pre-test questionnaire

What is your age? *

Ditt svar

What gender do you identify as? *

- ◯ Woman
- ◯ Man
- ◯ Non-binary
- ◯ Övrigt: ____

What is your main occupation? *

- ◯ Working full-time
- ◯ Working part-time
- ◯ Studying
- ◯ On leave (parental, sickness, etc)
- ◯ Retired
- ◯ Job-seeker

Have you tried VR before? *

- ◯ Yes, many times
- ◯ Yes, one or a few times
- ◯ Never

How much would you say that you enjoy classical music? *

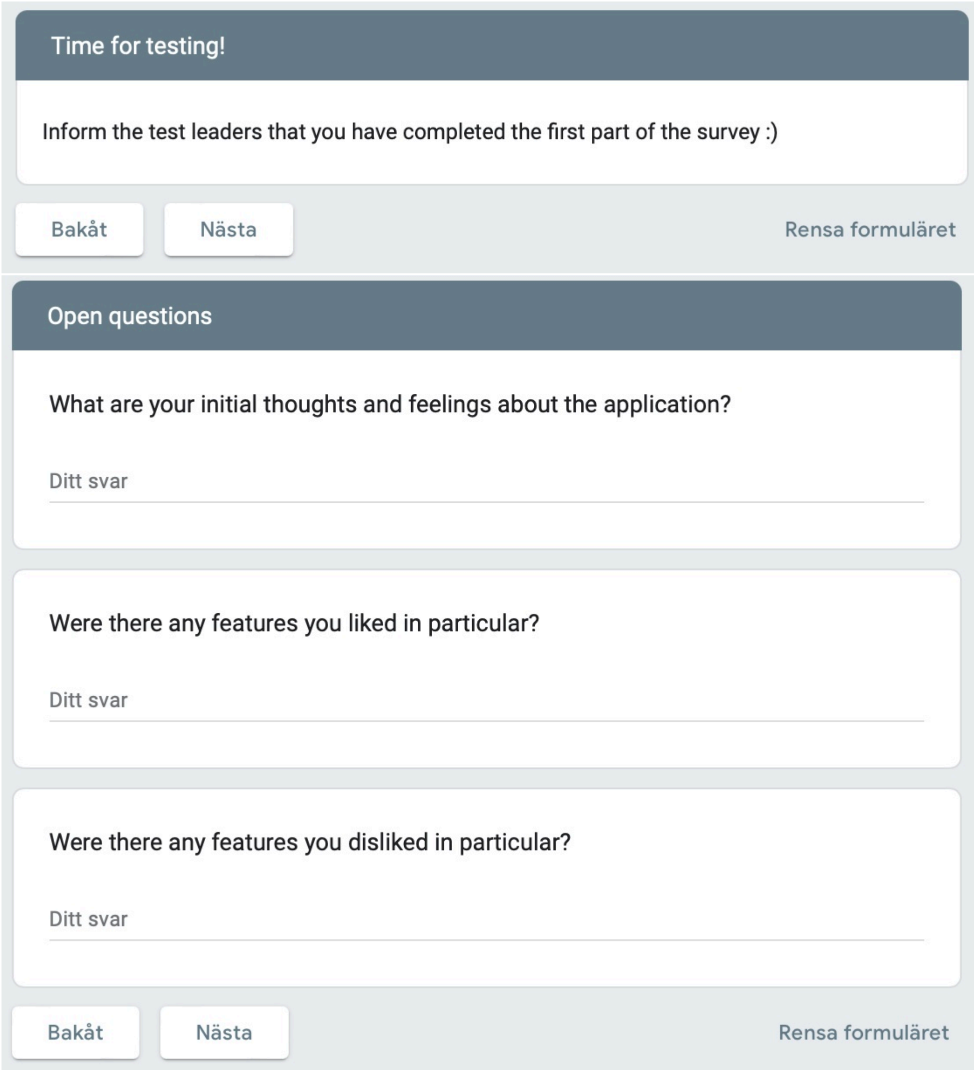
	1	2	3	4	5	
Not at all	◯	◯	◯	◯	◯	Very much

Have you ever attended a classical music concert? *

- ◯ Yes, many times
- ◯ Yes, once or a few times
- ◯ Never

I am aware that I at anytime can stop the usability test and also that participation is completely anonymous and will only be used for the master thesis *

- ◯ Yes


Time for testing!

Inform the test leaders that you have completed the first part of the survey :)

Bakåt | Nästa | Rensa formuläret

Open questions

What are your initial thoughts and feelings about the application?

Ditt svar

Were there any features you liked in particular?

Ditt svar

Were there any features you disliked in particular?

Ditt svar

Bakåt | Nästa | Rensa formuläret

Presence Questionnaire

What technical set-up did you use? *

- ◯ Web application
- ◯ VR headset

For how long did you interact with the virtual world?

Ditt svar

Presence statements

Now you'll see some statements about experiences. Please indicate, whether or not each statement applies to your experience. If a question is not relevant to the virtual environment you used, just skip it. You can use the whole range of answers. There are no right or wrong answers, only your opinion counts.

You will notice that some questions are very similar to each other. This is necessary for statistical reasons.

How aware were you of the real world surrounding while navigating in the virtual world? (i.e. sounds, room temperature, other people, etc.)?

	1	2	3	4	5	6	7	
extremely aware	◯	◯	◯	◯	◯	◯	◯	not aware at all

How real did the virtual world seem to you?

	1	2	3	4	5	6	7	
completely real	◯	◯	◯	◯	◯	◯	◯	not real at all

I had a sense of acting in the virtual space, rather than operating something from outside

	1	2	3	4	5	6	7	
fully disagree	○	○	○	○	○	○	○	fully agree

How much did your experience in the virtual environment seem consistent with your real world experience?

	1	2	3	4	5	6	7	
not consistent	○	○	○	○	○	○	○	very consistent

How real did the virtual world seem to you?

	1	2	3	4	5	6	7	
about as real as an imagined world	○	○	○	○	○	○	○	indistinguishable from the real world

I did not feel present in the virtual space

	1	2	3	4	5	6	7	
did not feel present	○	○	○	○	○	○	○	felt present

I was not aware of my real environment

	1	2	3	4	5	6	7	
fully disagree	○	○	○	○	○	○	○	fully agree

In the computer generated world I had a sense of "being there"

	1	2	3	4	5	6	7	
not at all	○	○	○	○	○	○	○	very much

Somehow I felt that the virtual world surrounded me

	1	2	3	4	5	6	7	
fully disagree	○	○	○	○	○	○	○	fully agree

I felt present in the virtual space

	1	2	3	4	5	6	7	
fully disagree	○	○	○	○	○	○	○	fully agree

I still paid attention to the real environment

	1	2	3	4	5	6	7	
fully disagree	○	○	○	○	○	○	○	fully agree

The virtual world seemed more realistic than the real world

	1	2	3	4	5	6	7	
fully disagree	○	○	○	○	○	○	○	fully agree

I felt like I was just percieving pictures

	1	2	3	4	5	6	7	
fully disagree	○	○	○	○	○	○	○	fully agree

I was completely captivated by the virtual world

	1	2	3	4	5	6	7	
fully disagree	○	○	○	○	○	○	○	fully agree

Bakåt Nästa Rensa formuläret

Usability Questionnaire

Please enter your level of agreement with the statements below, regarding your experience with the application.

I think 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 function 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 *

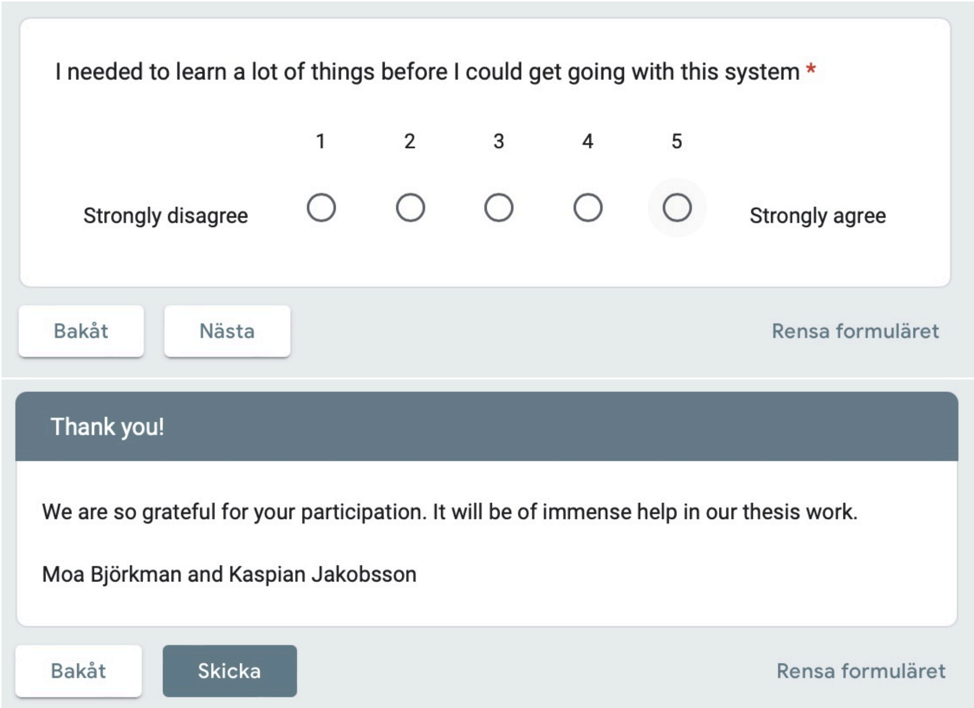
	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

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

Bakåt Nästa Rensa formuläret

Thank you!

We are so grateful for your participation. It will be of immense help in our thesis work.

Moa Björkman and Kaspian Jakobsson

Bakåt Skicka Rensa formuläret