HOW CAN WE USE AUGMENTED REALITY TO ENHANCE A MUSEUM EXPERIENCE WHILE TEACHING AUDIO MIXING CONCEPTS?

Enrico Momo
Aalborg University - Copenhagen
emomo19@student.aau.dk

Riccardo Russo
Aalborg University - Copenhagen
rrusso19@student.aau.dk

Aïli Niimura
Aalborg University - Copenhagen
aniimu19@student.aau.dk

Silke Rottmann
Aalborg University - Copenhagen
srottm19@student.aau.dk

ABSTRACT

Beat Painter is an application prototype created for the Music Museum in Copenhagen which demonstrates how mobile Augmented Reality can increase the value of a physical experience while making music virtually. Augmented Reality (AR) is a valuable resource for interactive educational experiences but is still under-utilized and in its experimental stages. Audio-based AR in particular can be a powerful and entertaining tool for creative, educational, and experiential use. This project aims to explore how one can mix audio using mobile AR, teach audio production techniques, and in addition, enhance a physical location based experience such as a museum.

1. INTRODUCTION

With the rise of Augmented Reality (AR) applications, there has been an increase in audio-focused AR experiences. Mobile AR, in particular, has been taking the art world for a spin, with artists such as Lucas Blalock exhibiting work on the high line, or apps such as *Aery* bringing museums out of the confines of four walls, and into the public sphere [1]. *Bose AR* spatial audio sunglasses have quickly been adapted in art events around the world [2]. The potential for this technology seems limitless, however, its success highly depends on its implementation. In order to understand the extent to which AR technology can be embedded into museum experiences, we developed an AR sampler and mixer application. The application supplies an architecture for the creation of new instrument interfaces as well as for museum guidance and interactive experiences. With this application as a testing ground, we aim to explore whether AR applications have the potential to increase viewers' engagement with the museum's exhibit. The application's features are designed to impact museum-specific engagement and demonstrate a flow for a basic audio mixing tool and gaming in AR.

Copenhagen's music museum, the *Musikmuseet*, features historic artifacts, paintings, and instruments. The interactive areas include a room where visitors can try out traditional musical instruments themselves as well as an area designated for interactive contemporary works, sound installations, and new interfaces for musical expression. The museum also provides a tablet application that makes use of *Near-Field-Communication* (NFC) technology for hearing audio samples and showing additional information. By holding the device close to an NFC sticker, the user can play the sound samples associated with a particular instrument. Several testers have reported that the software functionalities lack interactivity and many of the interviewed visitors claimed that engagement with the application drops quickly due to the lack of freedom to fulfill interactive tasks in a non-prescribed order. The tablet primarily provides information without any entertainment, suggesting room for improvement. The application proposes an alternative to the NFC experience currently provided, in addition to a method for AR music production.

2. STATE OF THE ART

Audio composing, recording and mixing in AR is a craft that has yet to be standardized. Creative technologists such as Zach Lieberman have experimented with sonification and visual representation of audio in AR, however, there is yet to be one standard tool or approach [3]. That said, best practices and promising prototypes are establishing themselves rapidly [4]. In their patent published in October 2019, Avid describes the potential of mixing in AR in section 0016 as the following: *"Augmented reality provides a means of expanding and enhancing the user interface in mixing consoles in which traditional user interface real estate has been curtailed as a result of cost and/or size constraints."* [5]. Hardware products such as Microsoft's *Hololens* or *Magic Leap* have demonstrated robust generative music creation tools with apps such as *Bloom* for Hololens, or *Tònandi* for Magic Leap [6], and mobile AR has even more eclectic explorations. *Hear*, for example, is an iOS app that lets the user alter the audio of their environment in real time, but has been in the market for several years with varying degrees of success [7]. Facebook is rapidly changing the landscape with *SparkAR*. In a hackathon hosted in November 2019 by Abbey Road Red (Abbey Road Studios' Incubator Program), in partnership with SparkAR, the winning project was an AR interactive music player [8]. Our application *Beat Painter* was conceived in anticipation of the ways in which AR may change the way we interface with musical instruments and creative audio tools.

3. THE APPLICATION: GAME DESIGN AND FUNCTIONALITIES

3.1 Game Design

Target-based AR is largely dependent on visual anchors, so in order to indirectly interact with museum material, it was important to design an experience that would seamlessly blend visual components on view within the museum with auditory interactions within the app. The initial design proposal came into being through the perceived lack of emphasis on the paintings on view. Though the instruments are beautifully encased, a viewer could easily neglect looking at the paintings, which are quite interesting and whimsical. Although the final prototype of *Beat Painter* did not incorporate the paintings on view, they were an important part of the vision and design process. Paintings in museums open up a new realm of creative possibilities for viewers to interact with the exhibit, and provide surfaces upon which one can design AR interactivity – in our case for a musical and educational experience. Basic AR experiences in museums have exploited this interface in an attempt to bring paintings to life. Because AR is so portable, a similar idea could extend the exhibit out of the confines of its physical space and out into the street, providing a pre-museum experience accessible to any passerby. In her paper 'The Audience and Artist Interactivity in Augmented Reality Art: The Solo Exhibition on the Flame Series', Cecilia Suhr writes that "the augmentation of paintings does not only imply changes in the original format, but it also pertains to sound supplementation. Thus, the paintings do not always remain just paintings—they can become video art, animations, music, etc. AR lends itself to a variety of creative possibilities without resulting in an attachment to a specific genre or medium." [9]. Suhr's words respond to the narrow and stereotypical applications of visual art based AR, often limited to animating a painting and no more. The text 'Museum Experience Design', contains several studies that offer detailed reports of the ways in which AR has been tested as part of Museum Experience Design. Studies such as 'Augmenting the Experience of a Museum Visit With a Geo-Located AR App for an Associated Archaeological Site' [10] provide a better understanding of the conglomeration of four colossal topics: children, education, museums, and AR, as well as the precedents for similar investigations. With this information we could tailor the question of 'how to make a music production game in AR' to the specificities of education and museum environments and users.

3.2 Application design

Beat Painter is an AR treasure hunt game which relies on image targets positioned around the museum. The design targets younger viewers, such as those in their twenties, but is intuitive to children as well, demonstrating basic music production techniques disguised through simple gamification. Four *instrument stations* are placed throughout the museum, and one *mixer station* lies in the heart of the interactive-new instruments area. Each image depicts an instrument related to four samples, and the images were strategically placed inside the museum (i.e saxophone in the woodwind collection). At each of the four instrument stations – the *Drum station*, the *Bass station*, the *Synth station*, and the *Saxophone station* – the image target triggers a set of four instrument loops that the player can choose from. The user can also apply a variety of audio processing effects, and the processed sample is automatically saved in the app's memory. The final image target is the mixer station where all four collected samples can be heard simultaneously and can be panned to the left and right channel using X-axis coordinates. This structure entails the player navigating around the museum and exploring the collection, thereby enriching the overall experience.

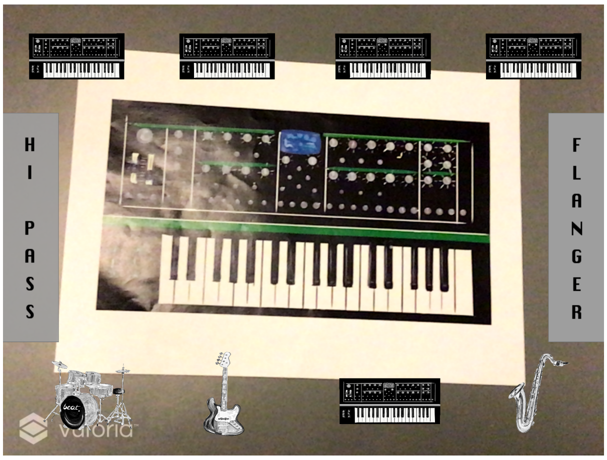

Figure 1. Screenshot of the *Synth Station*.

When building the application, the UX and UI were designed to be intuitive for a mobile AR application. As a result, graphic components were optimised for touchscreen devices. Figure 1 represents a screenshot of the Synth Station: in this situation none of the samples are playing, the effects are deactivated and there are no sample choices saved in the other stations. The top section of the UI contains four icons, which are identical to the corresponding image target; these represent the four different instrument loops. By touching one of these icons, the associated audio file plays and it is stored as the *current chosen sample*. Touching the image again will stop the sample from playing and delete the saved choice. If a different icon is selected, the current one automatically stops, the new one plays and is stored as the new sample choice. The lower section of the UI is identical for all instrument stations and functions as a collection mechanic for the user to keep track of which stations have a selected loop. At the start of the experience, all of the icons are rendered in greyscale. When the player chooses a sample from a particular station, the relative icon turns from greyscale to color. This mechanism is represented in Fig. 2. If a sample of a instrument station has been selected, its associated

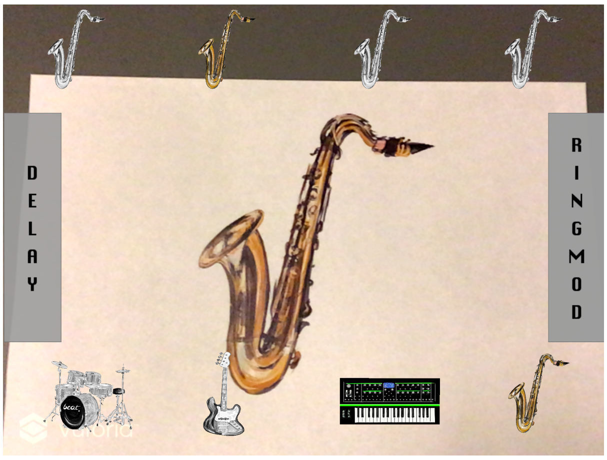

Figure 2. Screenshot of the *Saxophone Station*. In this situation one of the four samples is playing, and a sample choice is saved for the *Synth Station*

Figure 3. Screenshot of the *Mixer Station*. The saxophone and drum samples are panned slightly to the right channel, while the synth sound is panned to the left channel. No choice is saved for the Bass Station

icon on the lower section of the panel transforms into color as well. The middle section of the UI has two different buttons placed on the left and right sides of the screen. Each button triggers one of two audio effects that were designed for each instrument. Once pressed, the effect is activated and a cursor appears in the middle of the screen. For a more intuitive mobile AR experience, an XY panel system that blended into the real environment was implemented, rather than traditional effects sliders. This was specifically designed in order to avoid the trope of transferring graphics and UI from analog technologies to novel ones without consideration. The cursor controls the effects by mapping X-Y coordinates to specific parameters of the effects, for example the amount of gain, or the cut-off frequency. Each effect has only two controllable values so that the user is limited with respect to the amount of effects that can be applied to the samples in order to maintain the quality of the final mix. In the Mixer Station UI, all the instrument icons are placed vertically at the center of the screen. In this stage, the user can listen to their personalized and completed arrangement and place final touches by panning the single instruments to the left or right by dragging the images to the left or right of the screen. If the user did not choose a sample from a particular station, the correspondent instrument symbol stay in greyscale and none of the related samples are played. A screenshot of the Mixer Station is represented in Fig. 3.

3.3 Choice of Music

The musical style was chosen to appeal to children as well as 20–30 year olds who experienced a similar musical style growing up. Descriptors such as *rhythmic, driving, impulsive, agitated, dance-ey* and *thriving* were used to guide the composing process. Concrete references included pop hits like *I Like to Move It* by Reel to Real, eurodance sensations such as Harold Faltermeyer's *Axel F*, and other 80s and 90s hits. The references were successfully picked up by users. All of the loops were composed in Ableton using the same key (G Minor) with 128 BPM so that users could feel as though they were creating music that would be successful no matter what they chose, and could focus on the creative manipulation of the effects. The saxophones were recorded live and processed, the synths were composed and customized using Pigments, a synthesizer VST plugin created by Arturia, and the bass synth was created using Massive, a Native Instrument Kontakt synth plugin. By providing the user with the possibility of choosing between four loops, they are given the impression that they are creating their own personalized song. All loops were composed such that any given loop could fit musically with any of the others – a completely modular design.

3.4 Image design

The images for the image targets were hand drawn using Adobe Draw and Sketchbook. They were then exported as icons with a transparent background using GIMP-2.10. The instruments drawings were designed to be visually intuitive for the user, to symbolize what they would expect to hear. Some images were more abstracted from their sound source, for example, a drum-set represented the beat, though a drum machine was used. An image of an electric bass guitar was used rather than a synth to express the bass line which was composed using a Massive synth. The other symbols were more literal representations, such as a saxophone for the saxophone shouts and the synth. Though hand drawn in 2D, the art style focused on a 3D-like effect, giving them shadows, metallic effects, and playing with the use of colors to insinuate depth.

3.5 Audio effects

Each instrument station has two audio effects the user can interact with. The players can customise their sample choices by applying the audio processing units listed below. The following audio effects, with two corresponding controllable parameters, were created for every station. The effects were selected among a variety of commonly used audio effects.

1. Drum Station
    (a) Low-Pass Filter: cutoff frequency, gain/Q
    (b) Flanger: modulation rate, effect amount
2. Bass Station
    (a) Low-Pass Filter: cutoff frequency, gain/Q
    (b) Ring Modulation: modulator frequency, effect amount
3. Synth Station
    (a) High-Pass Filter: cutoff frequency, gain/Q
    (b) Flanger: modulation rate, effect amount
4. Saxophone Station
    (a) Delay: delay time, effect amount
    (b) Ring Modulation: modulator frequency, effect amount

The cursor is set such that the lower the coordinate, the lower the applied amount of the relative parameter. The (0,0) cartesian coordinates correspond to the minimum value of both parameters, and are located in the bottom left corner of the effect canvas. The maximum value for both parameters therefore corresponds to the top-right corner. The low and high pass filter parameters are set using the values of the y-axis to control both the gain and Q. The gain of the filters is modified when the cursor is located on the lower half of the y-axis. The Q is controlled by moving the cursor above the middle point: in this case gain is kept to the maximum value. The values of the x-axis control the cutoff frequency. The flanger parameters are set as follows: y-axis is mapped to the effect amount, going from *no processed audio* to *only processed audio*; the x-axis controls the modulation rate. Internally, a value for the modulation depth was chosen to accommodate the composition genre. The ring modulator effect amount is controlled by the y-axis – with the same process that was used for the flanger. The x-axis cartesian values are used to control the modulator frequency. In the case of the delay the x-axis controls the delay time and the y-axis values corresponds to the effect amount, as with the previous two effects. The delay feedback was set internally to fit the music. As mentioned above, a linear panner is applied to each track in the Mixing Station, allowing the user to virtually place single instruments left or right from the center. In Fig. 4 represents a screenshot of the Drum Station with the low pass filter activated

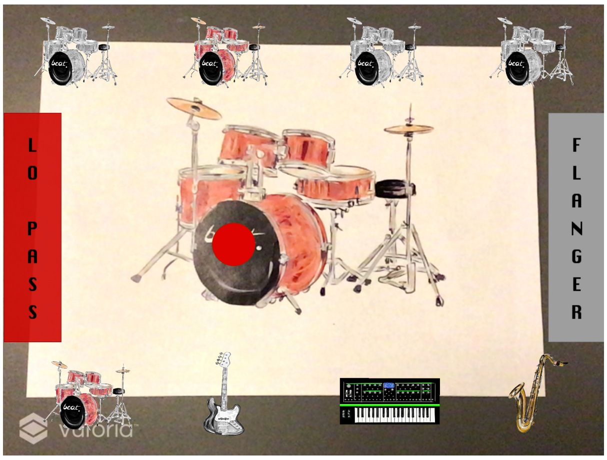

Figure 4. Screenshot of the *Drum Station* with the low pass filter activated. The red cursor controls the effect

4. IMPLEMENTATION

The application was entirely built using the Unity Engine. This tool was chosen as it offers various tools to create state-of-the-art augmented reality applications. Vuforia was also integrated into the project: its engine utilises cutting edge machine learning algorithms to extract essential features from a set of images into a downloadable database. In this work five different image targets were used. The database is compilable as a *unitypackage* file for the Unity engine. This file contains the set of converted images which has to be added to Unity's Vuforia *Image Target* object. This object comes with a series of C# scripts which can be modified. Five different scripts were customised and attached to the five different "Image Target" objects. Each script was written so that once a target is recognised by the program, the corresponding station UI becomes active and visible on the screen. If the image target is lost, the UI disappears and the sound stops. However, all changes made by the player are saved internally. This distinction is key in understanding the difference between the types of interaction and quality of user experience that changes if the UI is triggered by a movable image versus a stationary one. A script stores each of the player's changes, triggering the audio files to play or to stop. To handle all interactions between the user interface and DSP effects, a series of scripts are attached to the UI.

Unity does not offer much customization regarding digital signal processing. Custom DSP plugins that could be easily integrated into Unity were then needed. To do so, different approaches were explored, encountering different problems and solutions along the way. At first, JUCE framework was inspected: this was the first choice as it provides many state-of-the-art tools for signal processing plugins development, and because JUCE's *Unity native plugin support* was recently released. Unfortunately, this tool does not integrate with mobile-built Unity applications: therefore, JUCE was no longer used for development. As a second choice, FAUST was explored: a domain-specific functional programming language for implementing signal processing algorithms, which can be exported and integrated into different software. While exploring this tool some difficulties with Unity integration were discovered, for this reason FAUST could not be used. Given these issues, the natural choice fell on the *Native audio plugin SDK* that Unity provides, which consists of a set of libraries that allow to develop plugins with native Unity code. The system is divided in two parts: the *native DSP* part, which is written in C++, and the *GUI part*, written in C. The GUI section was not pertinent to our project, so it was not used. The DSP libraries consist of a framework that provides tools for creating a custom audio processing unit: while a powerful system, it is also a restricted framework, thereby making it difficult to customize. The plugin is built to be automatically recognized by Unity when correctly included into the project. Different plugins can be added to different *mixer* objects inside the Unity application, so that each plugin gets access to a different audio stream inside the software. The plugins were developed with classic audio DSP techniques, and are not related to any commercial audio effect.

5. TESTING METHODOLOGIES

We conducted a qualitative study based on the *Likert* scale as well as open questions and a quantitative study to evaluate whether augmented reality can be used to enhance a museum experience while teaching audio mixing concepts. The aim of the qualitative study was to analyse the efficacy of the user interface design, comprehend the general level of engagement towards the application and to understand whether the application helped in enhancing the museum experience for visitors. The objective of the qualitative study was to analyse how long it would take for the testers to comprehend the overall game functionalities.

6. TECHNICAL CHALLENGES

The greatest challenge in implementation arose when transferring the application to mobile devices. The DSP plugins' architecture seems to clash with ARM processors, which were integrated in the development hardware. This problem demonstrates that Unity's development team is still in its early stages of opening up part of the sound system to third-party developers [11]. This major issue forced a change in the application's presentation. Because mobile devices could not be used, a different approach had to be found in order to maintain museum navigation as a core part of the experience. Instead of images on walls, portable cardboard targets were used. Rather than processing the audio at the instrument station, players had to search for the targets within the museum's collection and bring them to the stationary laptop's camera, where the application was running. This configuration, however, 'shed light' on another problem. The low lighting of the museum, combined with the low quality of the computer's camera, and the fact that the latter lacked a flashlight, made it more challenging for the app to recognise the image targets.

A pre-test at the Music Museum was conducted to observe how users would react to the app on a mobile device, despite the audio processing part of the game was not working. The application was installed onto an IPad 7 and a pair of AKG K240 headphones were used – a semi-open pair of headphones. Testers enjoyed being able to select their sounds and hear them come together in the mixer, but there was some intangible lack of purpose, which caused confusion. Additionally, the UI simply was not optimized for the restructured experience. Therefore, it was decided to prioritize the ability for the user to interact with the effects. As mentioned, this entailed radically pivoting the hardware setup and design of the experience within the space. In order to preserve the ability to mix using the effects, a laptop had to be used.

6.1 The participants and the equipment

The test took place in the music museum of Copenhagen, *Musikmuseet*, with a total of ten subjects between the ages of 3 to 45 taking part in the study.

6.2 Preparation

Cards with the AR image target printed on them were placed around the museum, strung with ribbon so that the user could walk around with the AR image target on their neck. The cards were placed in strategic positions, so that the image would have a symbolic association with the surrounding instruments. Players could walk around the museum to collect these 'medallions' and then go to the stationary laptop to play the game. Fig. 5 represents a map of the museum with the cards positions.

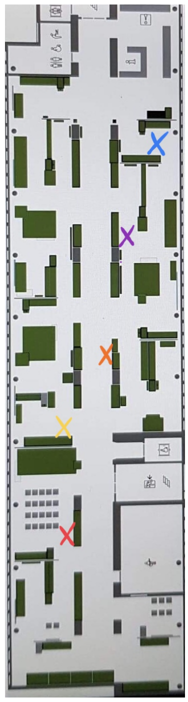

Figure 5. A map of the *Musikmuseet* with the locations of the cards. From the nearer to the entrance: blue cross represents the drum card, purple cross represents the synth card, orange cross represents the bass card, yellow cross represents the saxophone card, red cross represents the laptop station.

6.3 Test procedure

Before starting the test, users were asked to complete a questionnaire to collect data regarding their age, as well as their computer music and augmented reality background. Additionally, they were asked whether they had been to the museum before and if so, whether they had enjoyed the interactive instruments available. The testers were then asked to start playing the game with minimal instruction.

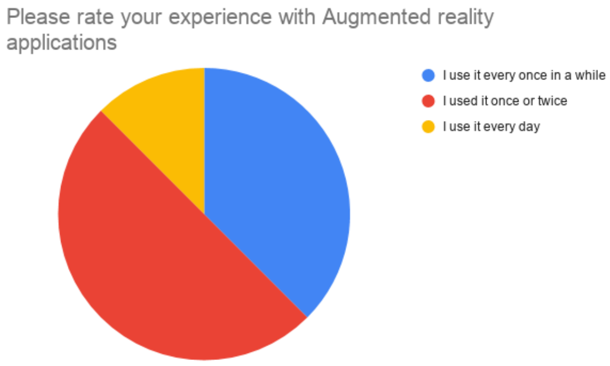

Figure 6.

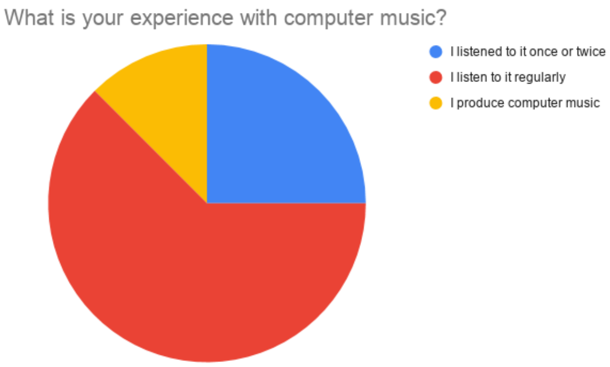

Figure 7.

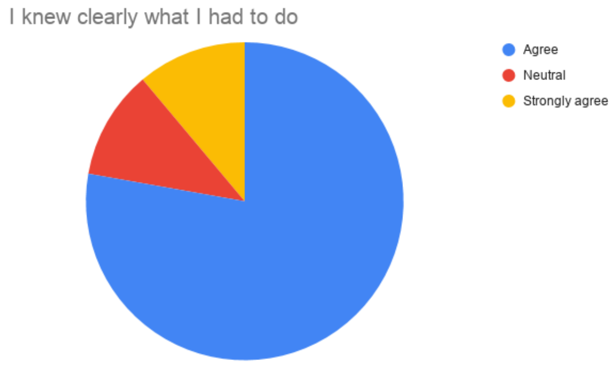

Figure 8.

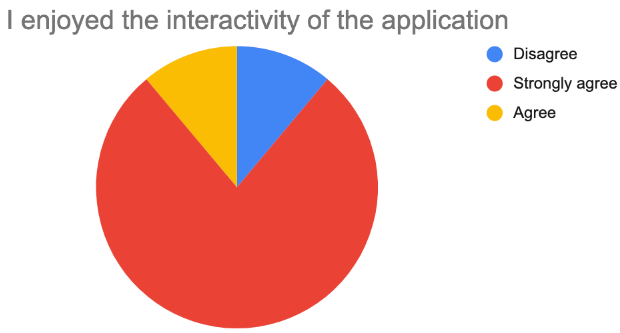

Figure 9.

Once the subjects finished playing the game, they were asked to answer questions concerning their experience with the application and whether they had become more aware of the collection in the museum.

6.4 Results and discussion

The average age of the participants was 24.5. Only three out of ten testers had previously visited the *Musikmuseet*. Additionally, all participants affirmed that they had already used the interactive instruments present at the museum and enjoyed them. Visitors were asked to evaluate their experience with Augmented Reality applications. All participants were already acquainted with this technology, stating that they use it regularly. In addition, one subject claimed daily use (Fig. 6). The last question of the pre-experience questionnaire asked the subjects to describe their computer music background. All testers were familiar with computer music and 75 % of the testers reported listening to it regularly (Fig.7). Once they finished the game, the subjects were asked to complete the second part of the questionnaire. The majority of them agreed with the statement: *"I clearly knew what to do without any indication"*; only one subject remained neutral (Fig. 8). These results indicate that the design of the application is simple and intuitive to use. All participants agreed that it was easy to maintain concentration while completing the tasks and the majority strongly agreed with this statement (Fig. 9). Only one tester did not enjoy the interactivity offered by the application. They justified this choice by writing: *"Not optimal with cards around the neck that you had to change, while having headphones on"*. As previously stated, the application was initially designed for mobile devices and the cards were not intended to be part of the final product. These results indicate that the application has the potential to be a fun way to experience museum. The responses to the statement *"Time slipped away while experiencing the application"* were generally positive (Fig. 10). This indicates that the game creates an immersive environment for the player. The aim of the question *"The experience has made me more aware about the different musical instruments"* was to address whether this work could integrate successfully with the museum collection, creating an interactive experience that could entertain visitors while bringing attention to the collection. Mixed answers were given, as the graph shows (Fig. 11). One explanation could be that the application was not rendered for tablets, making the experience less entertaining and not synergizing with the museum. When testers were asked if they would like to have this type of experience again, they all answered positively (Fig. 12). In addition, when asked to compare this application to similar augmented reality apps, an overall positive response was given (Fig. 13). This shows that the application has the potential to be an interesting feature inside a museum

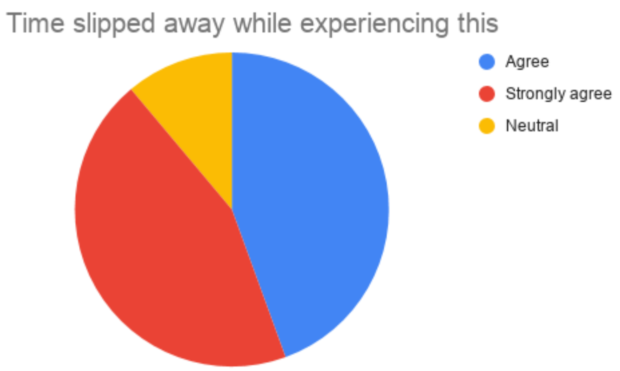

Figure 10.

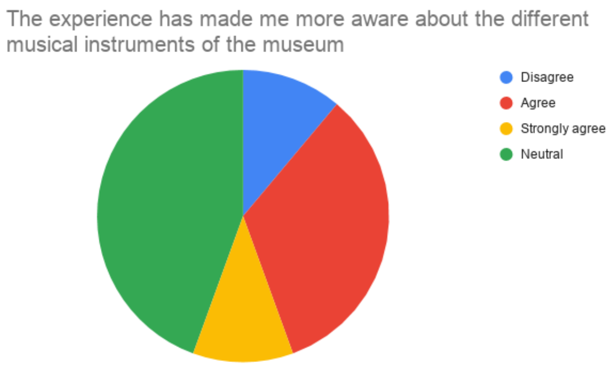

Figure 11.

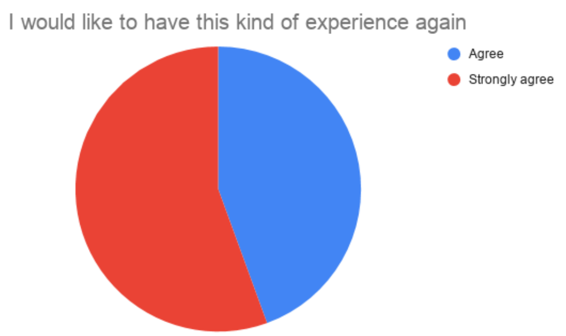

Figure 12.

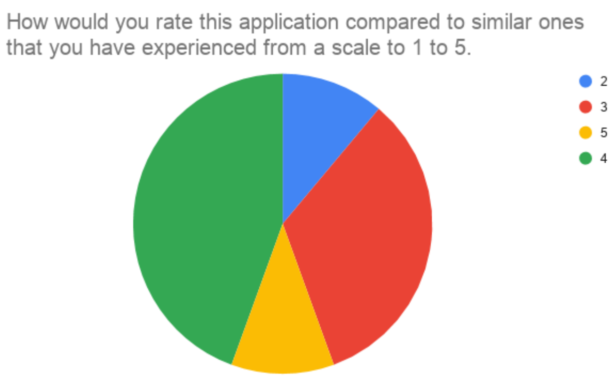

Figure 13.

7. OBSERVATIONS

Upon observing the testers, we also noticed an interesting social component evolve. Most of the museum visitors we tested were couples or families, who engaged with the application both collaboratively and competitively.

8. ADDITIONAL FEEDBACK

One of the main informal observations we received from users concerned UI feedback – we could have used more visual feedback, for example with animation of UI components. It was also suggested that we could have kept the UI visible after the image target was detected once, even if the image was no longer in the camera's field of view. Additionally, there was a proposal to let users hear the previously selected loops at each 'instrument stage' before the 'mixer' stage. There was also an expressed desire to save the completed tracks, so that users could compare their creations with those of their friends/partner/family members.

9. FUTURE USE CASES

This application is currently a prototype for the ways in which one can mix music using augmented reality. Alternative features can be added, such as laser targets, sensors to detect distance, different visual and auditory feedback mechanics, advanced hardware, spatial audio, different locations, physical modelling of acoustic spaces, additional effects, and so on. The potential use cases are widespread in the sectors of education, music technology and creation, experience design, accessible art, LBE (location based entertainment), and more.

10. CONCLUSIONS

In creating an application that enables one to mix music with AR technology and after testing it at the Music Museum, we have found promising outcomes as well as challenges. Mixing music in AR involves several technical challenges, indicating that more work needs to be done to enable easier access for the creation of audio-based AR, and sound processing for mobile devices. Mobile devices are by far the most accessible point of entry for AR technology but may not be the most adept for complex AR experiences. Within the context of museum experience design, the tool shows promising results. Interactive AR experiences for location based entertainment is a powerful educational tool, and can go far in terms of engaging and instilling a sense of agency for museum visitors. Since museums attract couples and families, we find a lot of potential in experiences such as Beat Painter, which enables competitive as well as collaborative interactivity. The pursuit of mixing music in AR is far from futile – as the technology develops, so will robust creator tools. The tool itself is promising – exciting testers as well as the creators, and can be seen in development by others around the world, and will continue to grow as large companies incentivize the creative development of AR technology.

The source code and Unity project for this application can be found on GitHub at: `https://github.com/Rickr922/Beat-Painter`

11. REFERENCES

[1] T. Loose. (2019) A walk on the frontier of art, where the sky is the limit. Accessed: 2019-10-15. [Online]. Available: https://www.nytimes.com/2019/11/27/arts/augmented-reality-exhibitions.html

[2] S. Rogers. (2019) Audio ar hits the right note at south by southwest. Accessed: 2019-10-12. [Online]. Available: https://www.forbes.com/sites/solrogers/2019/03/26/audio-ar-hits-the-right-note-at-south-by-southwest/#19c08e3125d3

[3] L. Stinson. (2019) An artist uses an iphone to visualize sounds in a.r. Accessed: 2019-10-10. [Online]. Available: https://www.wired.com/story/an-artist-uses-an-iphone-to-visualize-sounds-in-ar/

[4] A. Savona. (2019) At aes: the realities of mixing in virtual, mixed, and augmented reality. Accessed: 2019-10-9. [Online]. Available: https://www.prosoundnetwork.com/post-and-broadcast/at-aes-the-realities-of-mixing-in-virtual-mixed-and-augmented-reality

[5] S. Milne, S. Wilson, E. Jones, R. Boyer, D. Magleby, E. T. Dias, and K. Baranov, "Augmented reality audio mixing," Patent 20 190 303 090, 2019.

[6] "Crossing the spatial divide: Bringing tònadi's sound spirits to life," accessed: 2019-10-11. [Online]. Available: https://www.magicleap.com/news/for-creators/magic-leap-studios-tonandi-q-and-a

[7] N. Gallucci. (2019) The hear app makes trippy sounds, but it won't probably help you concentrate. Accessed: 2019-10-9. [Online]. Available: https://mashable.com/article/hear-app-review-advanced-listening-sound/?europe=true

[8] "Abbey road red hackathon 2019 - "the power of immersion" - winners announced!" accessed: 2019-10-7. [Online]. Available: https://www.abbeyroad.com/news/abbey-road-red-hackathon-2019-the-power-of-immersion-winners-announced-2629

[9] H. Suhr, "The audience and artist interactivity in augmented reality art: The solo exhibition on the flame series," *Critical Arts*, vol. 32, pp. 111–125, 05 2018.

[10] E. Law, *Augmenting the Experience of a Museum Visit with a Geo-Located AR App for an Associated Archaeological Site*, 02 2018, pp. 205–224.

[11] "Unity documentation," accessed: 2019-10-15. [Online]. Available: https://docs.unity3d.com/Manual/AudioMixerNativeAudioPlugin.html