

Effects of audio and visual text modalities on learning in an augmented reality museum application

Project video: <https://vimeo.com/386790516>

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ABSTRACT

Augmented Reality (AR) technology is getting more popular in various fields. It is not only popular in the entertainment business but also some museums have implemented AR in their exhibitions, which allows more interactive features or visualisation. A study was conducted where use of AR in a museum setting was explored along with the alternatives of receiving information from the exhibition through the modalities visual text and sound. An interactive AR application was created using Unity and Vuforia and a model of a museum was created in which eight objects (half with information through visual text and the other half through audio). A user test was conducted with 8 participants and the results indicate that it was easier for the participants to remember the information given through the modality of visual text, while finding the auditory modality to be more engaging.

1. INTRODUCTION

The use of Augmented Reality (AR) environments are becoming more frequent. Commonly used for purposes such as entertainment, retail and education [7]. Due to not necessarily needing advanced equipment the uses of AR can be introduced not only to high levels of research but also in the everyday life of people. Practically anything with a camera and a display could

be used with an AR environment. From advanced glasses to everyday items such as a regular smartphone; AR can be used to create a kind of alternate reality. Combining the real elements of the surroundings with computer generated information; AR can create an interactive experience that passes the boundaries of what should realistically be possible.

In 2016 the game of Pokemon Go was released, featuring AR elements and taking the world by storm. However, video games are not the only way to implement AR technology. More and more museums are implementing AR features into the exhibitions, allowing more interactive features or visualisations. In this study, one aspect of the use of AR environments in museums will be explored: the use of AR to present additional information on the exhibits. A model of a museum was constructed, in which information on the exhibits could be received through an AR application. The information was presented through either visual text or audio. The participants were then allowed to freely move around in the museum, and afterwards filled in a quiz to examine how much they learned by the exhibition.

The aim of the study is to examine the following research question:

In an augmented reality museum guide, what is the difference between the modalities audio and visual text for receiving information?

Previous research on AR in museum has regarded learning through interactions [1, 2] or enhancements [6], and we wish to add to that field of research.

To answer the research question an application was developed using Vuforia and Unity. Furthermore, a model museum was constructed which 8 participants visited while using the application which had both modalities. Afterwards, participants were quizzed on information regarding the objects in the museum in order to investigate the different modalities effects on information retention.

2. BACKGROUND

There is ongoing research in the matters of implementing AR as a tool for learning by experience in a museum environment. In [3] they performed an experiment which aimed to find out if AR improves the ability to retain and transfer information. They made an art museum consisting out of 6 different paintings that should be experienced with AR to uncover changes over time within the paintings. They investigated if the participants could remember aspects of the paintings after 24 hours and they concluded that AR can assist the learning process in a museum context. Conditionally, the exhibition should not contain elements that can imply interference for the participants in the scene, which they experienced through physical text descriptions that interfered with the use of AR visualization in the

artworks. We will keep these findings in mind when designing the AR application used for this study.

The effectiveness of AR interactions in museums was evaluated in [4] and the effect they had on how a group of schoolchildren learned. In the experiment the children where freely exploring a museum, and interacted with the exhibits through an AR application. The application also quizzed the children on each exhibit. In their experiment they evaluated the results based on Kolb's Experiential Learning cycle: (1) concrete experience, (2) reflective experience, (3) abstract conceptualisation, and (4) active experimentation. Of these four we cover concrete experience and abstract conceptualisation in this experiment. The study by Moorhouse et al. contributed with new sub-themes to the research area of AR and learning, including themes such as new knowledge acquisition and identification of preferred learning style.

In [6], they investigated how AR affects learning in a museum environment. They did this by letting participants perform the same test before and after visiting a museum where some exhibits were enhanced with various AR technologies and some weren't. Furthermore, they designed questions which answers were dependent on information from both AR as well as the traditional visual aids provided by the museum; a method that we intend to partly employ in our study. The test scores for the questions related to the AR-enhanced exhibits increased significantly in comparison to the questions related to the traditional exhibits, indicating AR's effect on learning.

Further studies have been conducted within the field of learning and AR. In a paper describing the state of the art of AR learning [2], the authors say that it's clear that AR can “provide immersive, compelling and engaging learning experiences” and that they believe that AR will prove to be a powerful tool in the future. Furthermore, the paper also states the AR could be distracting in learning scenarios, much like in [3].

However, in a comprehensive literature review of AR in education [8] the authors found some conflicting conclusions in their review. For instance, some papers had found that AR could increase cognitive load as in [3], but others found that it could decrease cognitive load. There was also some discrepancy in the conclusions of the usability of AR. This literature review states that research in AR for education is still relatively young, which means that it could take a few years until educational AR research has matured enough to make better conclusions.

In [5], an experiment showed that AR can promote learning and motivate young students to engage with the material. This was also shown in [8]. The same study also showed that AR can also be a good collaborative learning platform which has been further explored in [1] that concludes that AR is a useful learning tool where users can develop their own collaborative learning contexts.

3. METHOD

In this section, we will present the experiment that was conducted to test different modalities text and audio in a

museum setting as well as the process of designing that experiment.

Pilot study

To ensure the quality of the application as well as the validity of the study, two pilot studies were performed; one before the development of the application and one before the study took place (which will be discussed later).

The aim of the first pilot study was to decide what synthetic voice would be used for the application. The study included 13 participants who were asked to listen to four different synthetic voices, all different versions of Apple's virtual assistant Siri; male and female voices with british and american accents were chosen for the pilot study. These voices then read the same text (an excerpt from the Wikipedia article on the Mona Lisa¹) to the participants who were asked to rate each voice on three different qualities: the *pleasantness* of the voice, the *suitability* of the voice for the context of a museum and finally, how *natural* the voice felt.

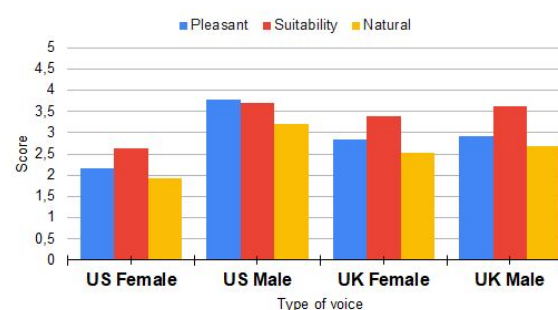


Figure 1. Results of the pilot study showing the participants rating of the four different voices on a 5-point likert scale.

The results of the first pilot study were

¹ https://en.wikipedia.org/wiki/Mona_Lisa Paragraph 1

compiled and presented in Table 1 above. The numerical values are as follows: (Pleasant; Suitability; Natural; **Average**) UK Male: (2.92; 3.62; 2.69; **3.08**) UK Female: (2.85; 3.38; 2.54; **2.92**) US Male: (3.77; 3.69; 3.21; **3.56**) US Female: (2.15; 2.62; 1.92; **2.23**). US Male got the highest average score and was therefore chosen as the synthetic voice to use in the application.

Application

The application was developed using the Vuforia AR engine in the program Unity. The application allows the user to look at an object through the camera of their smartphone and be presented with various elements in 3D-space around said object through AR. For the study, the application displays the title of the object as well as a button which the user could press to receive more information about the object; half of the objects presented this information through the synthesized voice and half through traditional text (See Figure 2 below).

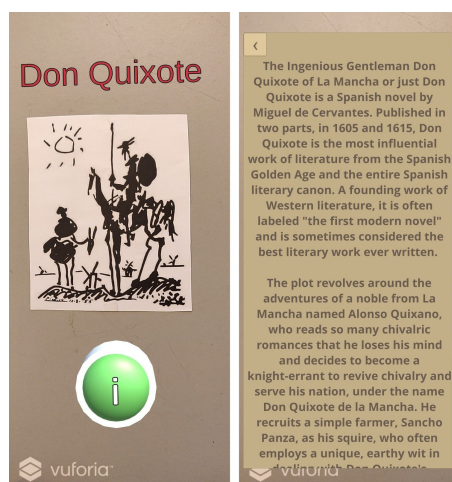


Figure 2. A screenshot of the application displaying the title, button and information text about the object.

The objects included had been chosen at random as to avoid the museum having an overlying theme as we felt this might cause problems for the study. The information about each object was excerpts from Wikipedia and slightly edited for the convenience of the reader or the speech agent.

Museum²

The Museum was constructed in a group room in the library at KTH Campus. Inside the room, the four sculptures were placed on tables and three of the paintings were hung on the walls to simulate a museum. One painting was placed on a table as opposed to hanging on a wall. This decision was made as the application had difficulties determining what was up and down on the painting, which made tracking difficult. We opted to place the painting on the table as opposed to choosing a different painting in hopes that it would make the museum more interesting and interactive for the participants.

At the day of the study, participants were greeted outside the room and presented with instructions. The participants were informed that they were to stay in the museum at a minimum of 8 minutes and at most 15 minutes. This was done in hopes that the participants would look at each object at least once and still have plenty of

² Video of the application and museum:
<https://vimeo.com/386790516>

time to go back and look at the objects multiple times, if they wished. The participants were also informed that it was important for them to retain the information presented regarding the objects and that they would answer a survey after their visit.

Participants were then given a smartphone with the application installed along with a pair of headphones which they could use to listen to the information about the object which used the synthesized voice. The headphones were important as we allowed up to three participants inside the museum at the same time. Furthermore, one member of the group was inside the museum at all times in case the participants had any issues with the application.

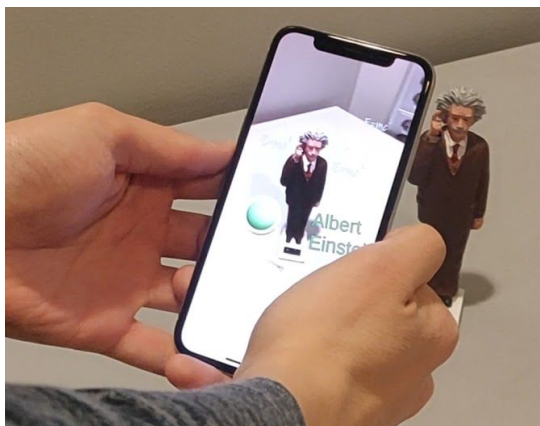


Figure 3. Example of a person using the application inside the museum.

Questionnaire

Upon exiting the museum, the smartphones were taken away and participants were given a questionnaire which consisted of two parts: a quiz and a reflective survey. The quiz consisted of 8 multiple-choice questions related to the

objects inside the museum, the answer to which could be found in the information given by the application. The purpose of this quiz was to test the participants' ability to retain information and investigate any differences between the two modalities employed by the application. The latter part of the questionnaire were 4 questions which were added to get the participants' opinions on the two different modalities as well as some general thoughts on their experience.

It was important that the quiz was of appropriate difficulty for the study. We wanted to construct a quiz with questions that could only be answered if you had taken part of the information provided by the application. After creating the first draft of the quiz, we sent it out to six people who were not going to attend the actual study to investigate the difficulty level. Upon discovering that some questions were too easy, tweaks were made to the quiz and after sending this revised version, we observed an average score of 2 out of 8 possible, which, given the 4 options on each question, would suggest that the users were guessing. This told us that the quiz was of suitable difficulty and ready to be used in the study.

The complete questionnaire can be found in the appendix (A).

4. RESULTS

The study had eight participants who attended the AR museum guide and they were contacted through various social media

channels. All of the participants were students from KTH Royal Institute of Technology.

The study found that the results were very even; four of the participants preferred visual text and three preferred the information by sound meanwhile one participant preferred neither of the modalities used for information output.

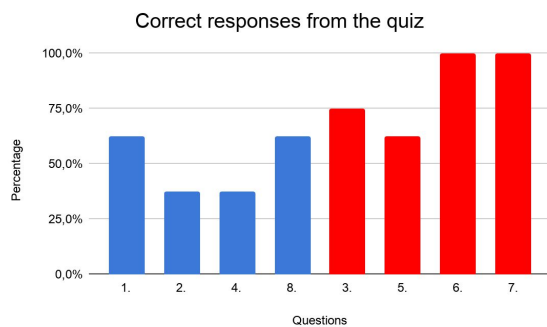


Figure 4. Results of the study. The blue bars represent the exhibits with sound modality and the red bars represent the visual text modality. The questions (shown in numbers) are in numeric order from the quiz (see appendix A).

Out of all the questions from the quiz the participants had an average score of 5.375, the questions with sound modality had an average score of 4 and the questions with visual text modality had an average score of 6.75. The question with the lowest score was question number 2 and 4 (See *Figure 4*) which had sound modality as an information source. Two of the questions had all the participants full score on, which was question number 6 and 7. All questions, except the two questions with the lowest score, more than half of the participants answered correctly.

Participants had the opportunity to give opinions of their experience with the two

different modalities sound or visual text as information in an AR environment. Most of the participants thought that the visual text was a more effective way of receiving information as well as the possibility to go back and forth in the user interface for the text. Meanwhile, the sound modality had more mixed responses. Some participants thought that sound gave a better and more pleasant experience and that it made it possible to look around while you listen on the information, but some thought it was a bit hard to memorize by only having the sound modality.

5. DISCUSSION

The average score for the overall participants was 5.375 out of the 8 possible questions, and while the amount of participants prevents us from saying anything statistically relevant, a claim can be made that the museum did raise the overall score on the quiz. However, as we did not compare information through the application and a more classical form of information (i.e. physical signs in the museum), we cannot say how much of an impact the introduction of AR had on participants.

While the impact of AR as a modality was not examined through the experiment, the difference between audio and text as a complementary modality to AR could be spotted in the replies to the survey. Visualisations contributed to better recognition and led participants to having a better experience. One participant noting: *“The best was when you got some audio and visual info. Like for example with einstein. It was easy to hear about the $e=mc^2$ equation, although I may have missed what it did”*.

This may imply that visual cues and effects could have an impact on learning, a claim that also is supported by [6]. These seem to be better paired with sound, as the visual cues are still visible when listening to the sound, correlating with the findings in [3]. Given this, along with other positive comments observed in the survey, it would seem that the AR consistently improved the participants' experiences.

Furthermore, the results seem to imply that the text modality seems to be superior when it comes to retaining information as the difference between the two modalities is 2.75 points. What causes this is unknown and could form a basis for a future study of similar nature. Another possible area of further research is the collaborative qualities of AR. Through the responses from some of the participants in this study it is clear that the collaborative aspects of AR in museums is quite important. *"I usually visit museums together with other people and I don't know how that would work when using an app, especially when listening to information segments. Maybe there is something that could be done to encourage people to use AR apps together?"* Some of our background research [1][5][8] stated that AR could be useful in collaborative learning situations. Therefore it could be interesting to repeat our experiment and focus on the interaction between people in an AR museum to see if a collaborative learning aspect could change the results.

Method discussion

We have identified two main concerns with the way that this study was conducted: the *scale* and questions regarding the *quiz*.

The scale of this project was quite small given the area it regards. Firstly, the museum was quite far from a real museum. It had only 8 exhibits and users were only there for up to 15 minutes; ideally a study of this nature would be performed in a real museum. Furthermore, we feel that our selection of participants was neither large or diverse enough. Only using 8 participants is not enough to conclude anything statistically significant and it is barely enough to discover a pattern. The participants were all students from the same school, generally around the same age. A more thorough experiment would have a more diverse set of participants of different educational backgrounds, ages, etc. These issues with scale are mainly a product of the limited amount of time we had for the project.

The second issue with the method employed regards the quiz. First of all, it is quite hard to know when the quiz is appropriately difficult and that the participants do not know the answer to the questions before exploring the museum. We did try to circumvent the former problem by testing the quiz and performing adjustments but we should have done more thoroughly, if we had the time. Perhaps the final quiz we used for the study was too easy as every participant answered correctly on question 6 and 7. The latter issue regarding the previous knowledge of the participants is very difficult to circumvent as we cannot possibly know what participants already knows going in to the study. We did try to prevent this by not having certain theme in the museum that participants may already be interested in, although this solution is not perfect.

Finally, the way you inform participants about the quiz at the end may impact how much they learn. For example: if we did not tell them about the quiz, they might have scored lower and conversely, if we had given them an incentive to score higher, we probably would have seen different results. We decided to take a middle ground and not specifically mention the word “quiz”, instead saying “survey” as well as underlining the importance of taking in the information given about the different objects.

The choice of the exhibition objects was made depending on what the group members had available. All the objects were very small in proportion to the room we used for the user test which could have impacted the participants experience of the AR museum. Perhaps different sizes of artwork or larger sizes of objects could have given a better impression to the users and it draws more attention to the object itself.

6. CONCLUSION

Overall, the participants had more correct responses from the information given through visual text rather than through sound which seems to indicate that information given through text may be optimal for information retention. Furthermore, the introduction of AR in a museum seemingly increased all participants' experiences, indicating that AR is a suitable modality to use in a museum.

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Appendix A: Questionnaire

Museum questionnaire

Please fill out this questionnaire about what you experienced in the museum and your experience.

* Required

What did Albert Einstein receive the Nobel Prize for? *

☐ Developing the IQ test

☐ Discovery of the photoelectric effect

☐ Developing the theory of relativity

☐ The world's most famous equation

What family of beetles does the Rhinoceros beetle belong to? *

☐ Jewel beetles

☐ Earth-boring dung beetles

☐ Scarab beetles

☐ Metallic wood-boring beetles

How low can green sea turtles slow down their heart rate to? *

☐ 1 beat per 9 minutes

☐ 1 beat per 1 minute

☐ 1 beat per 5 minutes

☐ 9 beats per 1 minute

Which of these traditions is NOT part of the inspirations for Santa Claus? *

☐ Western Christian culture

☐ Hindu gift giving traditions

☐ Pagan traditions

☐ Greek mythology

During which period of time was the Modern Art era? *

☐ 1860 to 1970

☐ 1890 to 1930

☐ 1920 to 2010

☐ 1960 to current date (we are still in the Modern Art era)

What does Don Quixote try to be? *

☐ A baron

☐ A squire

☐ A king

☐ A knight

Which geographic area is the Hippopotamus native to? *

☐ West Sahara

☐ Egypt

☐ Sub-Saharan Africa

☐ Algeria

From which museum was the Weeping Woman by Picasso stolen? *

☐ Centre George Pompidou in Paris, France

☐ The Louvre in Paris, France

☐ Tate Modern art museum in London, England

☐ National Gallery of Victoria in Melbourne, Australia

Which did you prefer? *

☐ Audio information

☐ Text information

☐ Neither

What did you think about the text information? *

Your answer

What did you think about the audio information? *

Your answer

What are your general thoughts on AR in a museum environment? *

Your answer

I hereby give my consent for the answers in this questionnaire to be used to analyze for research. I am aware that my answers will be securely stored, and deleted at the latest on February 1. *

☐ Yes