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No Longer Stuck (IST) in Two Dimensions: Evaluating Augmented Reality Art Experiences

Christopher Wypyski[1], Ronald Throop[2], Damian Schofield[3]

ABSTRACT

The aim of this study is to explore how bringing art to life using Augmented Reality (AR) technology can affect viewer engagement and interest compared to the viewing of traditional static artwork. To measure these properties this study uses a combination of surveys: The User Engagement Scale (UES) and a slightly modified version of the Museum Experience Scale (MES). The results from both questionnaires were aggregated to obtain a more accurate measurement of engagement, as the UES questionnaire is specifically focused on interactive systems while the MES is focused on an overall view of an exhibit. Using both questionnaires a more accurate measurement of "engagement" can be reached for the purposes of this study.

Keywords: Augmented Reality, Interaction, Engagement, Art, Painting, Stuckism.

1. Introduction

Art has been with mankind since the first cave paintings. Whether it was for recording the locations of wild animals, spreading religious ideologies, expressing personal emotions, or inspiring others; art has always been an important piece of the human experience (Clowney, D., 2011). As mankind has moved forward and progressed throughout history, art too has advanced and evolved. More complex tools, methods, and techniques have been created and developed over time to create and explore varying styles, genres, aesthetics, and themes in art. In the 20th and 21st century digital technology has become more prominent and commonplace, which has allowed for the creation of a range of new types of artworks.

Augmented Reality (AR) originally dates back to the 1950s (Carmigniani, J., Furht, B., Anisetti, M., Ceravolo, P., Damiani, E., & Ivkovic, M., 2011) but only in recent years, has the technology become

[1] Masters Student, Department of Computer Science, State University of New York, Oswego, New York, 13126, USA. Email: cwypyski@oswego.edu

[2] Artist, Owner, and Curator, Fuel Gallery, Oswego, New York, 13126, USA. Email: throop4@verizon.net

[3] Full Professor, Department of Computer Science, State University of New York, Oswego, New York, 13126, USA. Email: schofield@cs.oswego.edu

pervasive due to advancements in smartphone technology. AR allows digital elements such as images, animation, or audio to be connected to static physical images or objects and can allow for some forms of interaction between the audience or observer with a particular artwork.

This study aims to explore how the use of Augmented Reality (AR) technology can affect viewer engagement and interest compared to the viewing of traditional static artwork, in this case paintings.

AR technology is becoming more popular, and there are many examples of its use in a number of modern museums, creating more dynamic experiences for the museum visitors. The Museum of London and the Van Gogh Museums are good examples of institutions that have embraced this new technology to create unique exhibits (Van Der Vaart, M., & Damala, A., 2015; Wojciechowski, R., Walczak, K., White, M., & Cellary, W., 2004, April).

AR allows museum visitors to freely observe, and interact with, virtual 3D models, text and video that is superimposed over the artwork in the 'real' world. This enhancement to the normal way of viewing an artwork using AR provides a new way for artwork or artifacts to be explored by the viewer; and also, be used to increase engagement and attention (Jung, T., tom Dieck, M. C., Lee, H., & Chung, N., 2016).

Little work has been undertaken to measure the quality of experience provided by AR in museums. This paper reports on an experiment undertaken to quantify the experience of the museum visitor. To achieve this, the study uses a combination of surveys: The User Engagement Scale (UES) and a slightly modified version of the Museum Experience Scale (MES). The UES is a questionnaire created to measure engagement when using an interactive system (O'Brien, H., & Cairns, P. , 2015). The MES is a scale created to measure the overall experience of visiting a museum (Othman, M. K., Petrie, H., & Power, C., 2011, September).

Analysis of the data from the experiments described in this paper illustrate that the addition of the AR to the paintings had a significant positive effect on the participants viewing of the paintings. This in turn increased the viewer engagement and created an enhanced experience. The statistical difference between the groups is quite pronounced, suggesting that the AR had a very strong effect on the participant's viewing experience.

This paper begins with an explicit statement of the research goals of the project, followed by a literature review, and a description of the experimental methodology. The final sections provide the reader with the data from the experiment, analysis, discussions and conclusions that can be drawn.

2. Research goals

Little work has been undertaken to measure the quality of experience provided by AR in museums. The aim of this study is to explore how bringing art to life using Augmented Reality (AR) technology can affect viewer engagement and interest compared to the viewing of traditional static artwork. To measure these properties this study uses a combination of surveys: The User Engagement Scale (UES) and a slightly modified version of the Museum Experience Scale (MES).

The UES is a questionnaire created to measure engagement when using an interactive system (O'Brien, H., & Cairns, P. , 2015); the UES breaks down engagement into four key attributes (Focused Attention, Perceived Usability, Aesthetic Appeal, and Reward Factor) with certain parts of the questionnaire measuring each attribute. The questionnaire combines the score of all the attributes to create a score or measurement of engagement.

The MES is a scale created to measure the overall experience of visiting a museum; it breaks down the experience into four elements (Engagement, Meaningful Experience, Knowledge/Learning, and Emotional Connection). This scale measures each element to gain an overall perspective of visiting a museum; although for this experiment we're more interested in the engagement section, the other information collected could provide other helpful insights (Othman, M. K., Petrie, H., & Power, C., 2011, September).

The results from both questionnaires were aggregated to obtain a more accurate measurement of engagement, as the UES questionnaire is specifically focused on interactive systems while the MES is focused on an overall view of an exhibit. Using both questionnaires a more accurate measurement of "engagement" can be reached for the purposes of this study.

3. Augmented reality

Augmented Reality (AR) can be defined as using technology to supplement the physical world with virtual elements, so they appear to coexist (Azuma, R. T., 1997). AR technology creates the illusion that virtual or digital elements/objects exist in the physical world and are interacting or taking space in the physical realm.

Perhaps the most famous example of AR is the Augmented Reality game Pokemon GO. This game runs as an app on a suitable smartphone and uses the device's GPS and camera to show Pokemon (virtual creatures) appearing in real world locations (Rauschnabel, P. A., Rossmann, A., & tom Dieck, M. C., 2017).

Although Pokemon GO is the most famous, and disruptive, example of AR technology, there is an array of other useful applications for this technology. Due to the advent of smartphones making AR more accessible, AR has recently been used as a new form of advertisement. AR technology has been used to make advertisements more interesting and engaging to consumers. The interactivity of AR allows for more dynamic ads that could potentially be more impactful than traditional static ads that create a more passive experience (Singh, P., & Pandey, M., 2014).

A number of modern museums have implemented AR among their exhibits creating more dynamic experiences for the museum visitors. The Museum of London and the Van Gogh Museums are good examples of institutions that have embraced this new technology to create unique exhibits (Van Der Vaart, M., & Damala, A., 2015). The AR systems implemented allowed visitors to observe artwork and items through a different lens, presenting different effects and novel information to the visitor. Often, museums only have a finite amount of space, and may be unable to present all of the items in their collection to the public, or certain items might not be presented to the public due to their fragile nature. Additionally, many items might present a limited view to visitors who are unable to view an item at all angles or observe all sides of an object. AR can be a solution to these problems as it allows guests to freely observe, and interact with, 3D models (Wojciechowski, R., Walczak, K., White, M., & Cellary, W., 2004, April). Hence, AR can provide a cost-effective mechanism to present additional information or visuals, increasing the exhibited content without taking additional floorspace.

4. Engagement

In addition to creating software that is easy to use, it is also important to create a product that is captivating and engages the intended audience. Given the abundance of web sites, streaming services, and apps created to gain people's attention; any novel product needs to be created with usability and engagement in mind, or it could be easily forgotten. Due to the abstract nature of the concept, there isn't a universal definition for engagement. However, one widely accepted definition is given below (O'Brien, H. L., Cairns, P., & Hall, M., 2018):

> *"Engagement is a quality of user experiences with technology that is characterized by challenge, aesthetic and sensory appeal, feedback, novelty, interactivity, perceived control and time, awareness, motivation, interest, and affect."*

In other words, to create something that is engaging, it needs to be pleasing or interesting aesthetically through visuals, or audio, or both. An engaging interface needs to provide immediate and helpful feedback to the user and be able to create a novel experience with a certain amount of interactivity. The level of engagement will also be related to the user's own interests or motivations. An engaging system should also provide the correct amount of challenge or difficulty to the user without frustrating or boring them. Lastly, interacting with something that is engaging can distort a user's perception of time; for example, undertaking an engaging activity can make time fly by, while doing a boring or not engaging activity can make time feel very slow. For something to be engaging it does not need to contain all of the above characteristics; however, having the more of these attributes that are present, the more engaging the system will be.

The User Engagement Scale (UES) is a tool created to measure user engagement, specifically engagement with digital systems (O'Brien, H. L., Cairns, P., & Hall, M., 2018). The UES divides user engagement into four components:

- Focused Attention, feeling absorbed in the interaction and losing track of time.

• Perceived Usability can depend on negative effects experienced by the user as a result of the interaction, and the degree of control and effort expended.

• Aesthetic Appeal is the attractiveness and visual appeal of the interface.

• Reward Factor relates to the enjoyment of using an application and willingness to use it again or recommend it to others.

5. Measuring engagement in museums

Museums and galleries are collections of artwork and historical artifacts that can help us view and understand different cultures and societies. Museums often create different exhibits to present artwork and artifacts in a collective way to understand past or foreign cultures for modern audiences. Besides putting related pieces together to create more context for them, the museums often provide textual descriptions of the exhibits to help audiences understand them or to provide additional information for a piece.

In the past museums have employed personal audio devices (such as a Sony Walkman) to provide audio tours for exhibits; the devices would play relevant audio descriptions for specific exhibits. This was a way to provide more information and content for an exhibit via a different modality – other than the visual experience of the artifact itself. Although this information-transfer method may seem somewhat simplistic today, it is an example of how museums were concerned with enhancing their exhibits using innovative technologies or mediums. Hence, this example can also be seen as a precedent for museums being willing to explore the use new technologies to expand exhibits.

Using recent technology, such as AR, is a potential way to enhance museum exhibits even further. AR provides a new way for artwork or artifacts to be enhanced, altered, expanded, or explored in a new way; and also, be used to engage tourist attention (Jung, T., tom Dieck, M. C., Lee, H., & Chung, N., 2016).

6. Methodology

The goal of this project is to measure the effects of AR technology, with respect to viewer engagement. The project aims to assess if viewing artwork, with the additions of AR animations, could potentially make viewing the artwork more engaging. A number of paintings were provided to the project by Ron Throop, from the Fuel Gallery. Animations were created for each painting, based on the artist's ideas and wishes. The AR system created was triggered to activate when a painting was viewed through a smartphone camera, using the Artivive AR application.

To get an accurate measurement of engagement from the painting viewers, two different data collection metrics were used; the User Engagement Scale (UES) which provides a Human Computer Interaction (HCI) oriented measurement of engagement and the Museum Experience Scale (MES) which focuses on engagement in relation to museum exhibits. The use of two different scales provided a more accurate measurement of engagement and to determine whether perhaps this painting AR application could be engaging in an HCI sense, but not a museum exhibit sense, or vice-versa.

6.1 Design

This study was an experimental between-subjects study. The independent variable of the study was to view the paintings with or without the AR animations. One group of participants viewed the paintings with the AR animations and then completed the MES survey, while another group of participants viewed the paintings without the AR animations and then completed the MES questionnaire. The dependent variable was the level of engagement while observing the paintings; and that engagement was measured via the MES survey. The participant group that did not view the AR animations was then allowed to see the animation. Both groups of participants then completed the UES survey.

6.2 Procedure

Before beginning the experiment, participants were given a consent forum to read over and state that they are consenting to participate in the experiment. The consent form explained that the purpose of this experiment was to study AR technology and the effects it may have on engagement.

The participants were also told what to expect, and what they would experience during the experiment. This included a short briefing session explaining AR technology and how it works, introducing the participants to the Artivive App on a smartphone. The participants were told that during this experiment they would be observing artwork normally, as well as using the Artivive app to view AR animations added to the artwork, and then they would answer questions about their experience.

A number of participants undertook the experiment online, these participants were given additional instructions on how to download and install the Artivive app and any additional steps they needed to set up on the Artivive app to access the AR animations for this study.

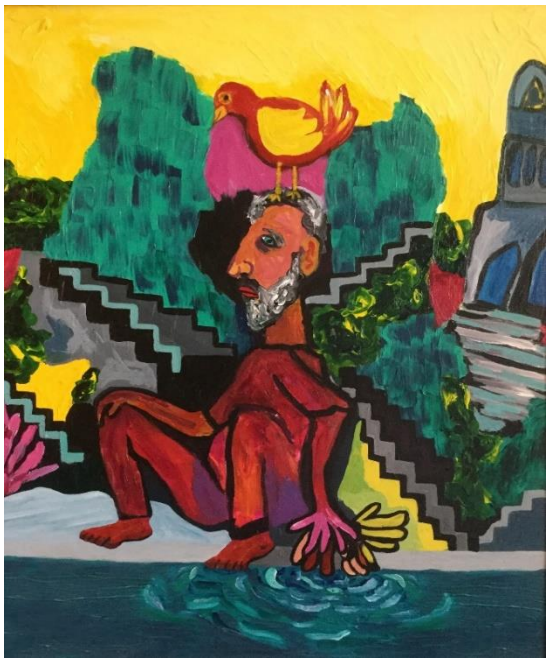

Figure 1. You'd Go Sit by the Ganges Too if Your Country Was Warping into a Pharmaceutically-induced, Armed Camp of Imbeciles.

Figure 2. Painting 2, If I Knew Then What I Know Now About Avarice in the Arts, I Would Have Stayed Home and Played with My Balls.

Figure 3. Painting 3, The Cosmological Playoffs - Ascendance of Mankind: 1, The Rest of Respirating Life: 0

Figure 4. Painting 4, Yes Minik, I Will Avoid the MoMA Like Tuberculosis.

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The tutorial on how to use the Artivive app, was intentionally kept simple. Participants had to open the app and then point their phone camera at the painting. The Artivive app then scans and recognizes the image, so that the appropriate animation can be played over the top of the painting. A tutorial was also available, to allow the participants to familiarize themselves with the app by practicing using Artivive to view AR content on a painting.

The participants were split into two goups, base don whether they were online or in-person participants. Online participants initially viewed the paintings with the AR animations while the in-person participants were assigned to initially observe the paintings without the AR animations. Both groups of participants were shown the same images.

During the experiment, each participant was sequentially shown four paintings (Figures 1-4). The paintings were each shown with their title, and in the same order, for all the participants. They could observe the paintings for as long as they wanted to (although a minimum 10 second time period was imposed). The group assigned to view the AR animations used the Artivive app while observing the paintings and were asked to watch the animation loop play through completely at least once.

After viewing all the paintings both groups answered a few demographic questions to get a general understanding of each participant's background and their familiarity with AR technology.

Al participants then answered the MES survey (Table 1) based on their experience of observing the paintings. Each question is on a Likert scale, this is a score scaled from 1 – 5, with 1 representing that the participant strongly disagrees with the statement and 5 meaning that the participant strongly agrees with the statement on the survey. The questions are divided into 4 sections based on their topic:

- Engagement
- Knowledge/Learning
- Meaningful Experience
- Emotional Connection

After completing the MES survey, the participant group that did not view the AR animations was then allowed to watch the animations for each of the four paintings. Both groups of participants then completed the UES survey (Table 2). The UES survey also uses a Likert scale of 1 – 5. The questions of the UES survey are again divided into 4 sections based on the topic they pertain to:

- Focused Attention
- Perceived Usability
- Aesthetic Appeal
- Reward Factor

After completing the surveys, there was an optional section where participants could leave open ended comments about the experiment. Participants were then debriefed, the experimental goals were explained, and any questions from the participants were answered.

Before beginning the experiment, participants were given a consent forum to read over and sign. The age range for in-person testing was 25 - 60 years, and the average age was 31 years old; however, there were two 60-year-old outliers, if these were excluded then the age range was 25 - 30 years old, and the average range was 26.5 years old (Figure 3).

Table 1.

Museum Experience Scale (MES).

Engagement	Knowledge/Learning
1. I enjoyed visiting the exhibition. 2. I felt engaged with the exhibition. 3. My visit to the exhibition was very interesting. 4. I felt I was experiencing the exhibition rather than just visiting it. 5. My visit to the exhibition was inspiring.	1. The information provided about the exhibits was clear. 2. I could make sense of most of the things and saw and did at the exhibition. 3. I liked graphics associated with the exhibition. 4. My visit enriched my knowledge and understanding about specific exhibits. 5. I discovered new information from the exhibits.
Meaningful Experience	**Emotional connection**
1. During my visit I was able to reflect on the significance of the exhibits and their meaning. 2. During my visit I put a lot of effort into thinking about the exhibition. 3. Seeing rare exhibits gave me a sense of wonder about the exhibition. 4. After visiting the exhibition, I was still interested to know more about the topic of the exhibition. 5. Seeing real exhibits of importance was the most satisfying aspect of my visit to the exhibition.	1. The exhibition enabled me to reminisce about my past. 2. My sense of being in the exhibition was stronger than my sense of being in the real world. 3. I was overwhelmed with the aesthetic /beauty aspect of the exhibit. 4. I wanted to own exhibits like those that I saw in the exhibition. 5. I felt connected with the exhibits.

Table 2.

User Experience Scale (UES).

Focused Attention	Perceived Usability
1. I lost myself in the experience. 2. I was so involved in this experience I lost track of time. 3. I blocked out things around me when I was using Artivive. 4. When I was using Artivive, I lost track of the world around me. 5. The time I spent using Artivive just slipped away. 6. I was absorbed in this experience. 7. During this experience I let myself go.	1. I felt frustrated while using Artivive. 2. I found Artivive confusing to me. 3. I felt annoyed while using Artivive. 4. I felt discouraged while using Artivive. 5. Using this Artivive was taxing. 6. This experience was demanding. 7. I felt in control while using Artivive. 8. I could not do some of the things I needed to do while using Artivive.
Aesthetic Appeal	**Reward Factor**
1. The Artivive app was attractive. 2. The Artivive app was aesthetically appealing. 3. I liked the graphics and images	1. Using Artivive was worthwhile. 2. I consider my experience a success. 3. This experience did not work out the way I had planned. 4. My experience was rewarding.

of Artivive. 4. The Artivive app appealed to the visual senses. 5. The screen layout of Artivive was visually pleasing.	5. I would recommend Artivive to my family and friends. 6. I continued to use Artivive out of curiosity. 7. The content of Artivive incited my curiosity. 8. I was really drawn into this experience. 9. I felt involved in this experience. 10. This experience was fun.

7. Participants

For this study there were a total of 31 participants, with a range of demographics. The participants were split into two groups: 16 participants for the in-person testing and 15 for the online testing.

7.1 In-person participants

For In-person there were 9 male participants, 4 female participants, 1 Nonbinary / third gender participant, and 1 participant that preferred not to say their gender. Participants were also asked how comfortable they were with using technology. The results were definitely skewed toward the participants being very comfortable with technology. Participants were also asked about their familiarity with AR technology. Most participants have some experience of the technology, only one participant claimed to use AR technology frequently (Figure 3).

Table 3.

In-Person Participants.

16 Participants	Age Range: 25 - 60years old	Average age: 31 years old	Age Range without outliers: 25 - 30 years old	Average Age without Outliers:26.5 years old
Genders:	Male: 9	Female: 4	Non-binary / Third gender: 1	Prefer not to say: 1
How comfortable are you with using technology?	I am somewhat comfortable: 1	Neither comfortable nor uncomfortable: 1	I am fairly comfortable using technology: 6	I am extremely comfortable using technology: 8
Do you know what Augmented Reality (AR) is?	I have heard the term but don't know much about it: 3	I somewhat understand what AR is: 4	I know what Augmented Reality is: 9	
How much experience do you have with AR technology	I have never used AR technology before: 3	I have limited experience with AR technology: 6	I have used AR technology before: 6	I use AR technology frequently: 1

7.2 In-person participants

The age range for online testing participants was 23 - 28 years old with the average age being 25 years old. There were 10 male subjects, 4 female subjects, and 1 subject that preferred not to say their gender (Figure 4). Online participants were also asked how comfortable they were with using technology. The results were again skewed toward the participants being very comfortable with technology. The online participants were also asked about their familiarity with AR technology. In a similar manner to the in-person participants, most online participants have some experience of the technology, and again only one participant claimed to use AR technology frequently (Figure 4).

Table 4.
Online participants.

15 Participants	Age range: 23 - 28 years old	Average Age: 25		
Gender:	Male: 10	Female: 4	Prefer not to say: 1	
How Comfortable are you with using technology?	I am fairly comfortable using technology: 1	I am Extremely comfortable using technology: 14		
Do you know what AR is?	I somewhat understand what AR is: 15	I know what AR is: 13		
How much experience do you have with AR technology?	I have never used AR technology before: 1	I have limited experience with AR technology: 6	I have used AR technology before: 7	I use AR technology frequently: 1

8. MES results

The MES was used to compare the experience of subjects who viewed the painting with the addition of the AR animations (Online group) with the experience of subjects who viewed the paintings without any additions (In-Person). The MES was also used to compare the experience of subjects participated int eh experiment online, with those who participated in-person. The results from the MES are shown in Figure 5.

It can be seen that there was a significant difference between the Engagement, Knowledge/Learning, and Emotional Connection sections of the MES; however, there was not a significant difference between Meaningful Experience section of the MES (Tables 5, 6, 7, 8, 9).

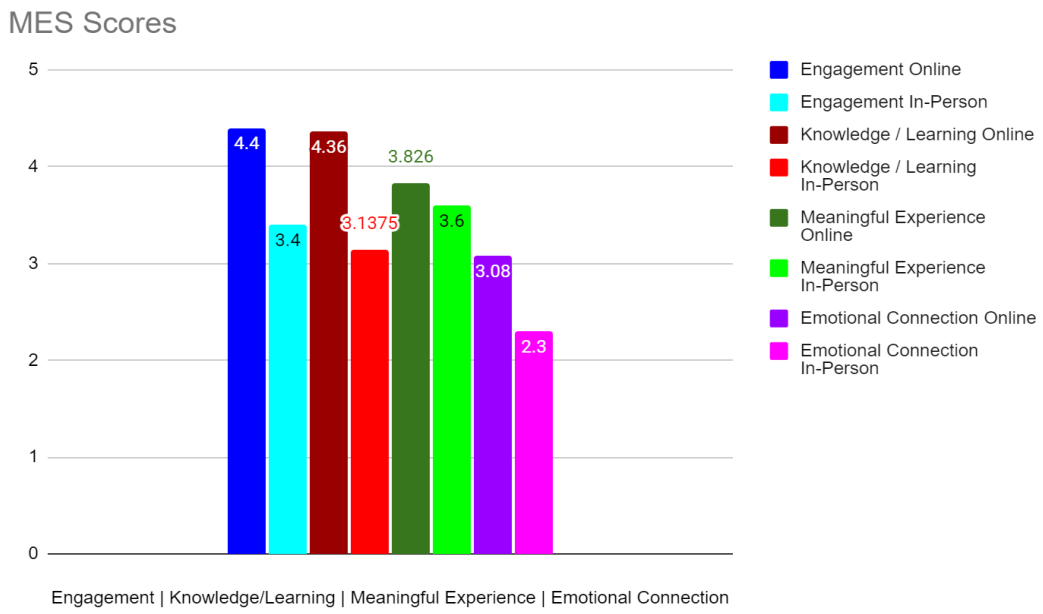

Figure 5. Mean scores of the four sections of the MES for online and in-person participants.

Table 5.
MES – Mean Score on Each Section | μ |

Section	Online	In-Person
Engagement	4.4	3.4
Knowledge / Learning	4.36	3.1375
Meaningful Experience	3.826	3.6
Emotional Connection	3.08	2.3

Table 6.
MES – Variance.

Section	Online	In-Person
Engagement	0.253	0.445
Knowledge / Learning	0.374	0.498
Meaningful Experience	0.393	0.205
Emotional Connection	0.830	0.550

Table 7.
MES – Standard Deviation.

Section	Online	In-Person
Engagement	0.503	0.667
Knowledge / Learning	0.611	0.706
Meaningful Experience	0.627	0.452
Emotional Connection	0.911	0.741

Table 8.
MES – Standard Error and T-Score.

Standard Error		T - Score	
Engagement	0.27426	Engagement	3.6461
Knowledge/Learning	0.29130	Knowledge/Learning	4.1967
Meaning Experience	0.26466	Meaningful Experience	0.8539
Emotional Connection	0.32717	Emotional Connection	2.3840

Degrees of Freedom = 29, Two tail, Alpha = 0.05, critical value = 2.045

Table 9.
MES – Hypotheses.

Engagement	3.6461 > 2.045	Reject Null Hypothesis	$p < 0.05$
Knowledge/Learning	4.1967 > 2.045	Reject Null Hypothesis	$p < 0.05$
Meaningful Experience	0.8539 < 2.045	Failed to Reject Null Hypothesis	$p > 0.05$
Emotional Connection	2.3840 > 2.045	Reject Null Hypothesis	$p < 0.05$

Figure 5 shows the mean scores of the four sections of the MES for the Online group (With AR) and the In-Person group (Without AR). This shows that the Online group that initially were exposed to the AR technology when viewing the paintings scored higher on all the sections than the In-Person group which didn't initially use AR system. All the sections of the MES were proved to demonstrate significantly differences between participant groups, except for the Meaningful Experience section. However, the online participant group still scored higher on the Meaningful Experience section, but not enough to prove it was significantly different.

Table 10.
UES – Section Results.

UES Section	Online	In-Person	Combined
Focused Attention	3.50	3.44	3.48
Perceived Usability	4.60	4.29	4.44
Aesthetic Appeal	4.28	3.73	4.01
Reward	4.16	4.00	4.06
Engagement/Overall score	4.13	3.87	3.99

9. UES results

The User engagement scale (UES) is a survey containing 30 questions; the UES is composed of 4 subsections: Focused Attention, Perceived Usability, Aesthetic Appeal, and Reward. All of the question scores from each subsection were averaged together to get a score for the attribute that each subsection represented. The scores from each subsection were also combined to calculate an overall, aggregated, engagement score (Table 10).

The chart (Figure 6) shows the score for each section for both the online group of participants and the in-person group. The chart clearly illustrates the differences between the groups.

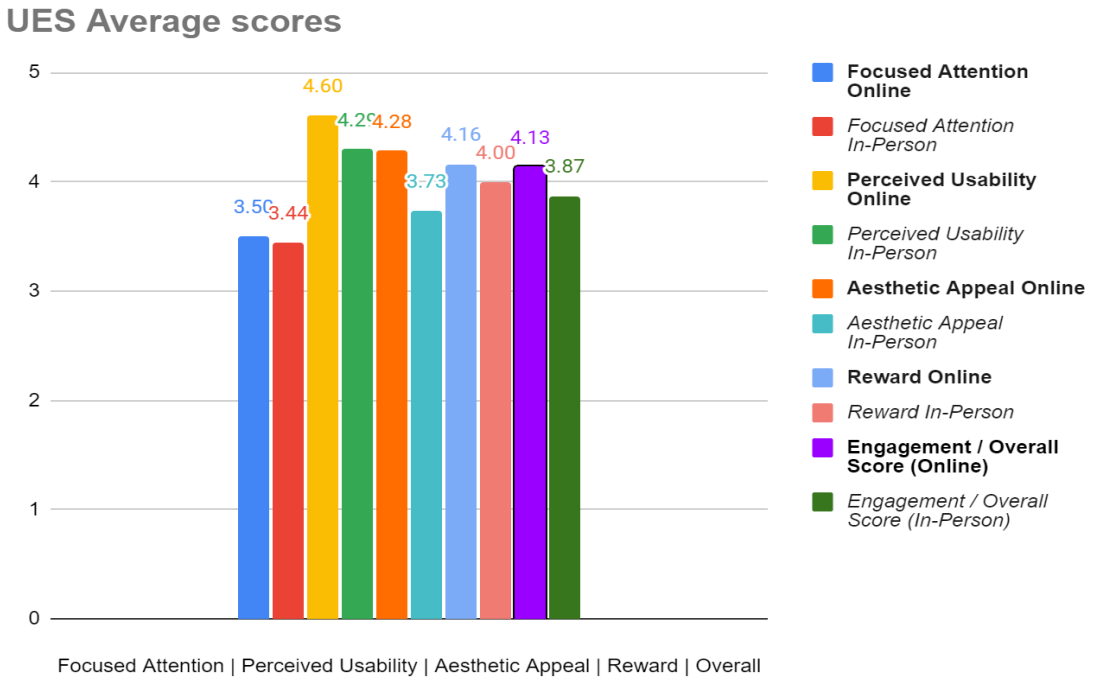

Figure 6. Mean scores of the four sections of the UES for online and in-person participants.

10. Discussion/ Conclusion

The purpose of this study was to see if the addition of Augmented Reality (AR) animation could change how artwork was viewed, and perhaps create a more engaging experience. The study used two different scales to measure viewer engagement: The Museum Experience Scale (MES), and the User Engagement Scale (UES). The MES was used to directly compare the experiences of participants who viewed the artwork with added AR animations, to those who viewed the artwork normally (without any added AR animations). The UES was used to get an overall general engagement score from all participants, based on their viewing the artwork with the added AR animation. Hence, the MES scores were more oriented to how participants would experience the artwork in a gallery/museum exhibit setting, while the UES score measured participant engagement through a more Human Computer Interaction (HCI) / usability / user experience lens.

The MES survey collected data from participants relative to four components: Engagement, Meaningful Experience, Knowledge/Learning, and Emotional Connection. Each category recorded higher scores among participants from the online group that viewed the paintings with the added AR animations, when compared to the in-person group of participants who viewed the paintings without AR. Each category recorded a statistically significant difference between the online and in-person scores except for the Meaningful Experience category.

The scores from MES survey demonstrate that the addition of the AR to the paintings had a significant positive effect on participants viewing the paintings, this in turn increased the viewer engagement, and created an enhanced experience. The statistical difference between the groups is quite pronounced, suggesting that the AR had a very strong effect on the participant's viewing experience.

The exception to this, where a significant difference was not recorded on the MES survey, was the category of Meaningful Experience. Since there was no significant difference recorded among the participants, it seems the AR did not increase the meaningfulness of the experience. Hence, it possible to conclude that the meaningfulness of the experience is derived primarily from the artwork itself, and not dependent on the view modality. This implies that the addition of AR animations had little impact on the meaningfulness of the artwork, and the impact of the change in view modality was not significant enough to affect the participant.

The UES survey collected data from participants relative to four components: Focused Attention, Perceived Usability, Aesthetic Appeal, and Reward; the results from these four these categories were aggregated to give an overall engagement score for each participant.

Each category received relatively high scores with Perceived Usability recording the most positive response the highest, and Focused Attention recording the lowest. Focused Attention refers to the participants being lost or absorbed in the experience; this score being lower than the other could potentially be due to the experimental methodology employed during this experiment. All participants viewed the paintings using a computer screen rather than interacting with the real painting physically, this could have indirectly created an effect that detracted from the experience and made it more difficult to be absorbed by the experience.

Perceived Usability scored the highest out of the categories; this high score suggests that using the AR application and viewing the AR animations was easy to do and did not hinder from the experience.

Aesthetic Appeal and Reward scored fairly well, each reporting similar scores. Aesthetic Appeal refers to the visual appeal of the AR app, the look of the animations, and the artwork. Due to the subjective nature of aesthetic interests in art this may be harder to judge because a different art style may be more or less appealing to each individual participant. Reward is a similar category, where it is possible that a different art style or AR animation style could have been more or less rewarding to each individual participant.

The aggregated scores from these four UES categories generated an overall engagement score of 3.99 out of a total of 5. This score suggests that viewing the paintings with the AR was able to create an engaging experience however there is still room to improve. Future iterations of this project could aim to improve these scores and explore the effects of other factors on the experience.

After the participants had completed the surveys there was an option to leave a final open-ended comment. The comments left supported the conclusions from the data, since most of the comments praised the AR modality, saying that it helped them understand the paintings better by providing more context and information about the paintings.

Although this project was able to explore the fundamental research questions of analysing if adding AR animations to artwork could make viewing the experience more engaging, it had several limitations. The main pool of participants covered a relatively small demographic of people in their mid to late 20's who were mostly very comfortable using technology, and a many of them were already familiar with AR. If this experiment were repeated, it could be improved by using a participant pool with a wider demographic range (a wider age range and more people less familiar with technology) to gain a broader perspective on this research question.

Due to constraints caused by the global pandemic every participant had to view the artwork through a screen instead of in-person, ideally it would have been better to have everyone view the paintings physically in its original state, and perhaps in a museum like setting, as opposed to viewing it digitally.

Another limitation of the experiment was that all the art came from a single artist. Due to the subjective nature of taste, the art style may have strongly resonated with people or perhaps affected the scoring negatively – this, in turn, may have affected the results collected. To deal with this effect it may be better in future experiments to use art from several different artists, with many different art styles.

Despite all the limitations described above, the experiment was able to provide evidence that the AR animations provided a positive effect on participant engagement and the overall art viewing experience. Future studies could adjust a number of the experimental variables to further explore and understand the effect reported in this study.

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