Effects of Mobile AR-Enabled Interactions on Retention and Transfer for Learning in Art Museum Contexts

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ABSTRACT

In this paper, we describe an experiment to study the effect of mobile Augmented Reality (AR) on learning in art museum contexts. We created six original paintings and placed them in a mini art museum. We then created an AR application on the iPad to enable the artist to visually augment each painting by introducing animation. We then measured the ability of the visitors to remember the appearance of the paintings after 24 hours, as well as their ability to objectify the paintings. Experiment results show that while AR does improve retention and transfer of such art information, the benefits of AR are mediated by other factors such as interference from other elements of the exhibition, as well as subjects' own prior art experience and training. The use of AR may also produce unexpected benefits, such as providing users with a new perspective of the artwork, as well as increasing their curiosity and encouraging them to experiment with the technology. Such benefits may potentially improve the chances for learning and analytical activities to take place.

Keywords: Evaluation, Learning, Museums, Software.

Index Terms:H.5.1 [**Information Interfaces and Presentation**]: Multimedia Information Systems—*Artificial, augmented, and virtual realities*; H.1.2 [**Models and Principles**]: User/Machine Systems—*Human factors*

1 INTRODUCTION

The use of Augmented Reality (AR) to enhance indoor museum experiences is an emerging application area [8]. Many papers have focused on museum tour guidance [2, 4, 5, 9], collaborative problem solving [13, 17] and experience personalization [7] in museum contexts. Researchers have also focused on the technological implementation issues and user acceptance aspects of the applications [5].

However, there seems to be a lack of work focusing on the effect of AR on learning in such contexts [17]. In this case, the definition of learning is the ability of the learner to commit information to memory (retention) and to use that information to solve new problems (transfer) [10]. Learning in museum scenarios is important, especially if the exhibition is meant to have a pedagogical outcome. Hence, it is our intention to study the effects of AR on learning in order to evaluate the benefits or disadvantages of deploying AR in museum exhibitions.

Specifically, we would like to investigate whether or not the use of handheld magic-lens-type AR [1] will enable art museum visitors to remember details of the artwork's appearance and use those details to objectify the artwork, 24 hours after the museum visit. The definition of objectification is the process whereby the subject "distinguishes elements which permit connections to be made between the work of art...and a specific field [related to the visitor's] interest" [12]. In the following, section 2 discusses the related work on using AR in museum contexts for learning. Section 3 describes our study methodology and experimental protocol. Section 4 presents the results of the data analysis. Section 5 provides a discussion for the interpretations and findings of the results. Section 6 concludes the paper and suggests future work.

2 RELATED WORK

Two papers are important for forming the foundation of our investigative framework. The first is the paper by Yoon et al. [18]. In this paper, a study was conducted to examine the effect of learning science concepts with AR in a science museum. By using a prototype exhibit device called "Be the Path" that illustrated electrical conductivity and circuits, students from 6th and 7th grade classes participated in the study by attempting different configurations of component arrangements to complete a virtual circuit. Once the circuit was completed, a projected visualization of electrons flowing around the complete loop appeared. The experiment conditions were formulated to represent increasing use of digital augmentations (Projected AR) and physical knowledge-building scaffolds (such as printed captions on physical labels) for learning.

The students were then asked after the experience to complete a survey that tested their conceptual understanding and recall (retention) of scientific information, as well as a worksheet which tested their higher-order reasoning, which was akin to demonstrating transfer effects, as students had to integrate multiple sources of information and reasoning to solving the problem. The results of the study showed that although digital augmentations without physical scaffolds had the highest impact on conceptual understanding, scaffolds were required for the improvement of higher-order thinking.

Another closely related paper is that of Tillon et al. [12]. In this work, the authors studied how an AR application affected the activity of visiting an art museum. First, a model of the activity of visiting a museum was presented in the paper. In this model, analytical activity was defined as a process which enabled visitors to retain the precise description of an artwork, as well as have the ability to objectify the artwork, and generate questions regarding the artwork. The paper reported an experiment to measure the impact of AR on such activities. The results suggested that AR may be well suited for the analytical activity by directing visitors' attention through magnification, modelling and superimposition.

Our paper complements the previous two papers [12, 18] by focusing on how AR interactions can be used to improve learning in art museums. In particular, we focused on how AR may affect the retention and transfer in the

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Figure 1: Six orginal paintings arranged and displayed on a white wall in the art museum.

analytical activity of the visit, as the retention of the precise description, as well as the transfer in the form of objectification and emergence of questions.

The motivation for this paper is based on the theory that introducing interactivity to a learning activity will enable kinesthetic learning [19]. In this case, the definition of interactivity is the manipulation of the medium, to allow for multidirectional communication to foster learning [10], and kinesthetic learning is facilitated by interactivity because interactivity with the content enables a form of "learning while doing", which has been shown to improve learning outcomes [19].

Traditionally, learning experiences in museums have been facilitated by the use of scaffolds, such as labels and descriptions, to accompany the exhibits [18]. While informative, such scaffolds afford little interactivity. A common way of increasing interactivity in the museum would be to create objectives for the visitors to complete, such as an investigative activity which requires visitors to explore the museum to gather clues to answer a question. Such an activity may be implemented as a worksheet exercise.

However, besides motivating visitors to seek out as many descriptions and labels as possible to find the clues to the worksheet questions, could there be other ways of engaging visitors in the learning content? For example, AR affords the ability for additional associated content to be attached to the exhibit in an interactive way. Could such a method be applied to improve learning of art museum exhibits as well? In this case, we refer to specific aspects of museum artworks, such as the information about an artwork, and the overall theme of the exhibition.

Our research question for this study is: "Does the use of AR improve a learner's ability to retain and transfer information (as a result of analytical activities [12]) related to artworks in a museum, even after 24 hours?"

3 Methodology and Experiment Protocol

We formed two hypotheses:

H1: AR interactivity improves the ability of the subject to retain information regarding an exhibit, as compared to the use of physical labels and descriptions, after a period of 24 hours.

H2: AR interactivity improves the ability of the subject to transfer the information to solve a problem (that requires the integration of multiple information sources), as compared to the use of physical labels and descriptions, after a period of 24 hours.

We combined and modified the study method of the previous works [12, 18] to address the research question, and created an iPad application called AR-muse (pronounced "Ah-Muse") to test the hypotheses. Using AR-muse, we conducted an empirical user study.

3.1 Experiment Apparatus and Venue

In terms of the artwork, we commissioned an artist to create six original paintings (Figure 1). As they were original and had never been published or exhibited before, it was very unlikely that the test subjects would have had prior encounters with the paintings. We then placed these paintings in a mini art museum and removed all other artifacts from the wall. Referring to Figure 2, each full exhibit consisted of the painting, its title label, as well as a physical label with a textual description of the painting. The description contained the artist's visions about the

Figure 2: Sample painting "Cocoon" with the associated physical labels for titles and descriptions. Descriptions were removable to cater for experiment conditions.

Figure 3: Snapshot of ARMuse in action. As shown, the augmented animation is displayed on the iPad when the painting is recognized as a marker.

painting and its contents. The text labels were removable to cater for experiment conditions, as will be described later in the paper.

Using the game engine Unity for iOS [15], coupled with Qualcomm's Vuforia AR engine [16] through an extension framework [14], we created AR-muse. AR-muse is a magic-lens [1] type video-see-through AR application on the iPad 4. AR-muse utilizes the back-facing camera of the iPad, along with each painting as a unique AR marker, using Vuforia's natural feature tracking (NFT) capabilities, to augment additional visualizations and animations on the artwork (Figure 3).

Our artist then developed animated visualizations to augment the artwork. Specifically, the visualizations were embodied representations of the artist's visions as written in the descriptions. In other words, the artist, in her mind's eye, imagined the content in the paintings to be animated and lively scenes. The artist then conveyed her visions in two ways: through the words in the descriptions, and by animating the artwork through AR-muse

From our experience, the Vuforia NFT library uses edges discerned from greyscale contrasts that create sharp features. Hence, the artist iterated multiple designs in order to ensure robust tracking. We ran paintings through Vuforia’s image analyzer at each of the iterations (Figure 4), and modified the paintings until they fulfilled a trackable marker profile. To verify that the images were functional as markers in practice, we loaded each image into the AR-muse application, and measured the time taken for registration to begin. On average, it took less than a second for registration to start with a good image as a marker, as compared to a poor image, with which it could take more than five seconds, or not register at all. Based on Vuforia’s image analyzer, and our application’s time for registration, we iterated the designs of the paintings with the artist until the registration and tracking performance was ideal for the study.

AR-muse introduced interactivity in two ways. First, the magic-lens metaphor required subjects to use the iPad as a handheld lens, thereby enabling subject to engage in embodied participation in the experience (as opposed to just a simple fixed perspective playback of the animations). Second, the user could touch the virtual artwork (by tapping on the screen) to toggle between playing and pausing the animation. These interactions were in accordance with the artist's visions and intentions for the artwork. Selected animation frames are shown in Figure 5.

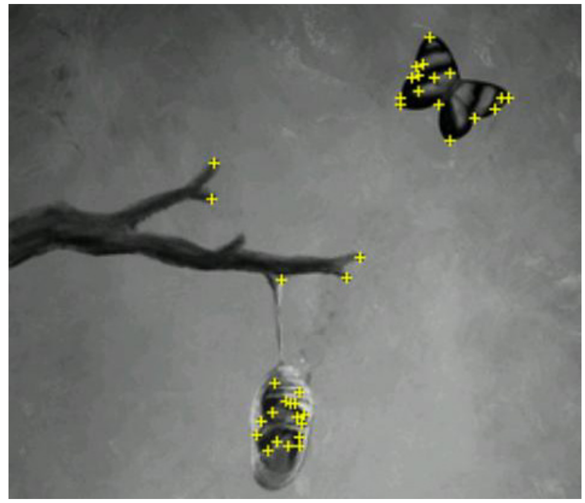

Figure 4: Vuforia’s image analyzer tool showing the features used for registration and tracking as yellow crosses. Suitable features are produced from high contrast and sharp, well-defined edges.

3.2 Experiment Protocol

For the study, the independent variable (IV) was the information representation method. There were three media conditions:

1. Physical paintings + text title + text descriptions (Text-only)
2. Physical paintings + text title + text descriptions + AR (AR+Text)
3. Physical paintings + text title + AR (AR-only)

Condition 1 (Text-only) served as the control, as such a condition was typical of existing art museums.

Before the actual experiment was conducted, a small pilot study with three volunteers (Mean age = 24.7, SD=0.89, 2 female) was conducted to determine how long each experiment session should last. The protocol for the pilot studies was exactly the same as the actual experiment (described later in the paper), only that each pilot study session had no time limit. From the pilot study, we determined that the volunteers spent an average of ten minutes in the experiment area, with a maximum time of 15 minutes and a minimum of five minutes. This result was then used to determine the maximum time allotted to each subject in the actual experiment. The data from the pilot studies were not used for the computation of results in the actual experiment.

In all, 30 subjects (Mean age = 24.5, SD = 3.31, 11 female) were equally and randomly separated into three groups, one group per condition, ten subjects per group. The subjects were recruited from the general student population in two universities, in a between-subjects study. The experiment was split into two parts: the visiting phase and the testing phase. All three experiment conditions used the same protocol, with additional steps for the conditions that required AR-muse.

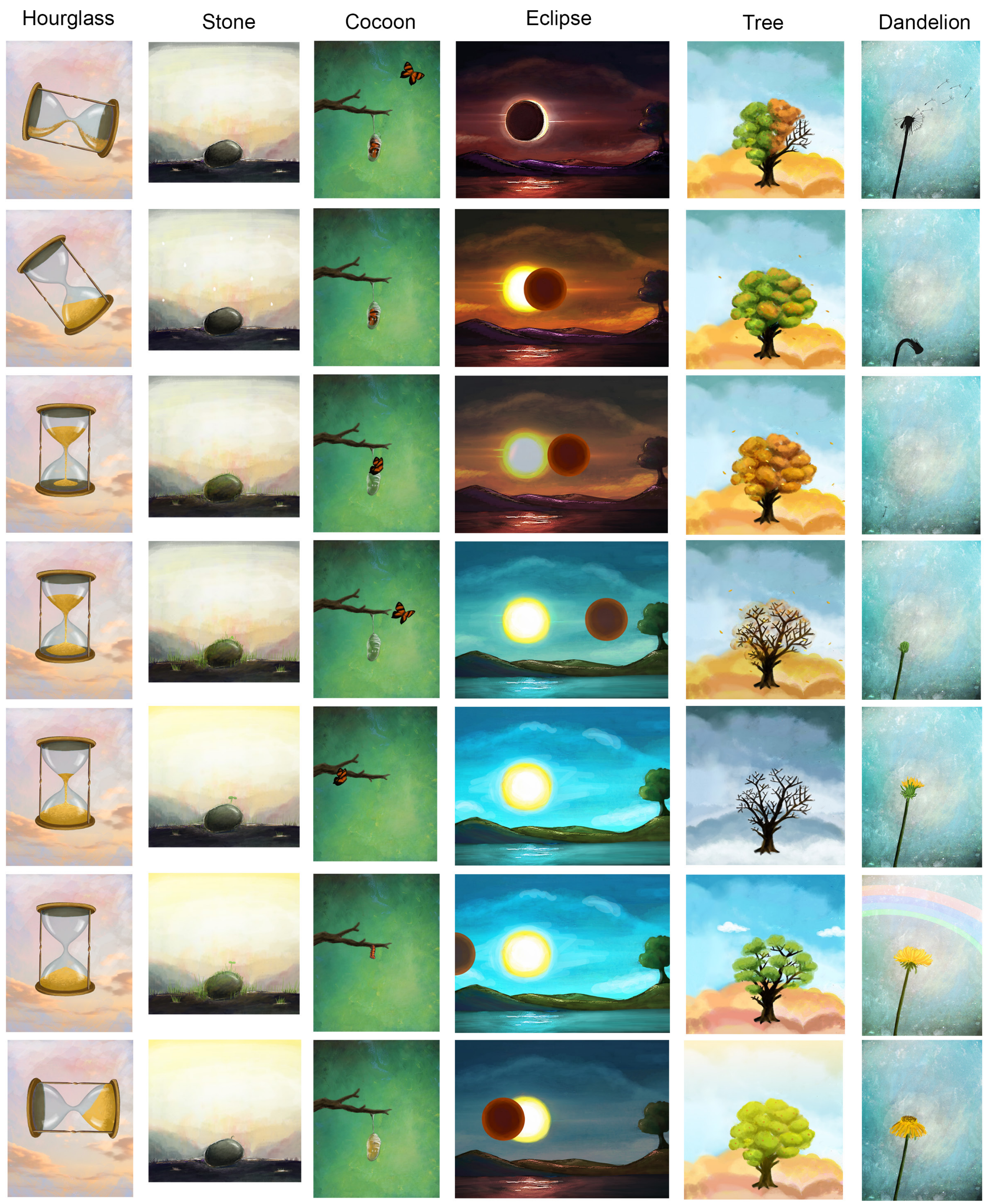

Figure 5: Selected samples of frames used to animate each painting. There were sixty frames per artwork, animated at 5 frames per second, arranged in an infinite loop. The artist's theme for the exhibition was "The Cycle of Time".

Experiment protocol:

1. Before the start of each trial, the subject was asked to fill in demographic information into a web-form on a computer. Age and gender information was collected. Also, the subject was asked rate his/her perceived experience with art on a 5-point Likert scale (1: No experience; 5: Expert), and to provide verbal justification for the rating. This verbal justification was provided in the form of a multi-line text input box that enabled subjects to type in freeform responses. The subjects were told that in the case of the experiment, “art experience” referred specifically to formal training in visual artwork creation or appreciation, such as drawings and paintings.

2. After the subject provided this information, the experimenter then told the subject that s/he was going to visit a mini art museum. The subject was then told to “do whatever you [the subject] do in an art museum. Spend as much or as little time as you want”. This was done so as not to unintentionally bias or prime the subject. For the conditions that included AR, here were the additional steps:
    a. The experimenter gave the subject a short training session in the use of AR-muse. A photograph (not a painting) was used for this training, and the subject was told that the photograph was not part of the museum.

    b. Only when the subject demonstrated sufficient competency in using AR-muse did the experimenter enable the experiment to proceed with the iPad. The subject would have demonstrated competency if s/he could aim the iPad camera at the photograph, see the animation, and pause and play the animation by tapping on the image of the photograph in the iPad.
3. The subject was then led into the museum and left alone to freely explore the artworks (Figure 6). No time limit was imposed for the visit.
4. After viewing the artworks, the subject then exited the museum. On exiting the museum, the subject was told by the experimenter to return 24 hours later for the testing phase of the experiment.
5. When the subject returned 24 hours later, s/he was brought to a different room outside the museum and was seated at a computer terminal. The subject was not allowed to re-enter the museum, and therefore had no further exposure to the paintings. The subject was then told to answer the questions asked by the computer. The subject then typed the answers using a keyboard into the computer, and the responses were recorded in a database.

After the subject had answered all the questions, the experimenter thanked the subject, and the experiment session ended.

The visiting and testing phases were each completed within 30 minutes per subject.

3.3 Experiment Variables and Parameters

As the study was measuring a subject's ability to retain (remember) and transfer (apply to a new problem) information about the painting, the dependent variables (DVs) were:

3.3.1 Precise description (DV1 and DV2)

As stated by Tillon et al. [12], the ability to accurately recall the appearance of the artwork is one measure of analytical activity. This also corresponds to our model of retention in learning [10]. Hence, we provide two DVs to measure this.

DV1: Number of paintings remembered; The subject's ability to recall the number of paintings is measured by asking the subject how many paintings did s/he see. The number was recorded.

DV2: Appearance of painting; The subject's ability to recall the appearance of each painting is measured by asking the subject to describe each painting in detail. The response was recorded, and later coded.

3.3.2 Objectification (DV3)

In Tillon et al., objectification is the process whereby the subject “distinguishes elements which permit connections to be made between the work of art...and a specific field [related to the subject's] interest”. Hence, to measure the subject's ability to objectify the painting, we asked the

Figure 6: Views of the experiment space from the side camera (left) and the top camera (right).

subject whether or not s/he could relate to the content of the painting, and if so, describe this thought. We then counted the number of subjects that had a relevant response, forming DV3. The relevance was later judged according to a coding scheme, and used as a measure for transfer effects.

3.3.3 Emergence of questions (DV4)

According to Tillon et al., when a subject is "confronted with a work of art, some questions [would] arise...". Therefore, we counted the number of questions that the subject asked for each painting. The number was then recorded.

3.3.4 Identification of theme (DV5)

According to Moreno et al. [10], the ability to use retained information to solve a new puzzle is a sign of learning. Hence, we asked the subject to identify common the theme of the artworks (as specified as a list of keywords by the artist). The theme was never told verbally to the subjects, and therefore required additional thinking by the subjects in order to give an answer. The response was recorded, and the relevance of the responses to the artist's intended theme was coded.

3.3.5 Dwell time (DV6)

Similar to Tillon et al., we recorded footage of the museum from an overhead camera, as well as from a side camera (Figure 6). The overhead camera enabled us to measure the dwell time of the subject on each painting.

3.3.6 iPad Use time (DV7)

The side camera enabled us to determine if the subject was looking at the exhibit directly, or at the iPad. The time spent on each viewing method was recorded.

The responses were then recorded using a simple web-based form, and stored in a database for analysis. Demographic information such as age, gender, perceived art experience (5-point Likert scale [1: No experience; 5: Expert]) was also recorded. A post-experiment interview was conducted to gather subjects' opinions.

3.4 Coding of Subject Responses

Three independent volunteers (Mean age = 26.4, SD = 1.07, 1 female) were recruited and trained for the coding. For DVs that were direct inputs from the subjects (DV1, DV4), no further coding was required. For the DVs that required coding (DV2, DV3, DV5, DV6, DV7), the coders followed the following schema:

3.4.1 DV2: Appearance of painting

The coders were provided a list of keywords for each painting by the artist. They were instructed to score the subject responses according to a binary rating, either "0" for no relation, or "1" for a response that was exactly or related to the keywords, using an online thesaurus [11].

3.4.2 DV3: Objectification

The coders were given instructions to "determine if the response was relevant to the keywords or appearance of the painting as specified for DV2, and that it was logical and made sense." The coders were then instructed to give a binary rating, either "0" for irrelevant, or "1" for relevant.

3.4.3 DV5: Identification of theme

As in DV2, the coders were provided a list of keywords for the theme by the artist. They were instructed to give a binary rating, either "0" for no relation, or "1" for a response that was exactly or related to the keywords, using the online thesaurus [11].

3.4.4 DV6: Dwell Time

Coders were instructed to keep track of the amount of time subjects spent viewing each artwork.

3.4.5 DV7: iPad Use Time

Coders were instructed to keep track of the amount of time the subject spent on each viewing method (direct viewing of the artwork or mediated through AR-muse on the iPad).

For all coding tasks, intercoder reliability was $r > 0.9$.

4 RESULTS

We focused our analysis on determining the relationship between the amount of time spent on viewing the artworks, and the learning outcomes, between the three media conditions (Text-only, AR+Text, AR-only).

Using paired-sample t-tests, we analyzed the data from the between-subjects study.

In terms of Dwell-time (DV6), Text-only vs. AR+Text ($t[9] = -2.287$, $p < .05$), Text-only vs. AR-only ($t[9] = -2.67$, $p < .05$) were significant. AR+Text vs. AR-only (t[9]

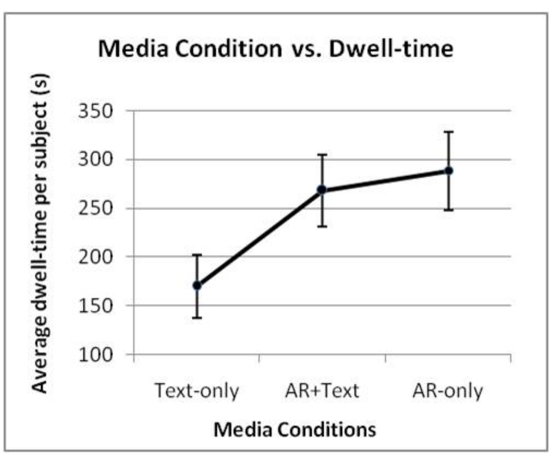

Figure 7: Average dwell-time refers to the total time that the subjects spent on viewing the exhibits, averaged across all subjects, for each of the three media conditions.

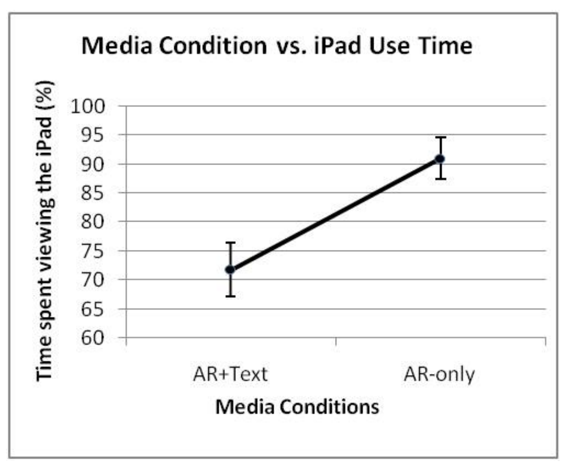

Figure 8: The % time spent viewing the iPad was calculated by taking the total time subjects spent using ARMuse, divided by the total time spent viewing all the artworks.

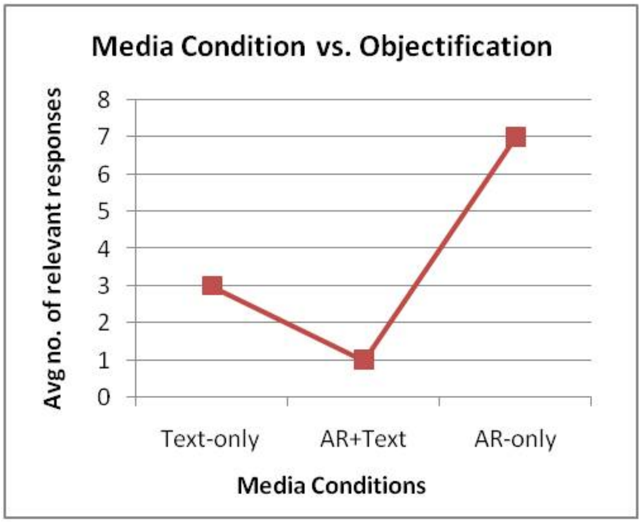

Figure 9: Average no. of relevant responses is an average of the number of responses (rounded to closest integer) deemed as relevant (explained in section 3.4.2) per subject, per condition.

= -.443, p =.668) was not significant. Refer to Figure 7.

As depicted in Figure 8, in terms of the percentage of time spent on looking at the iPad (over the total dwell-time, as opposed to looking at the exhibit directly; DV7), AR+Text vs. AR-only ($t[9] = -2.78$, $p < .05$) was significant. For AR+Text, subjects spent only 71.8% of the total dwell time looking at the iPad, compared to AR-only condition, which saw subjects spend 91%.

Using Chi-square analysis on DV3 (objectification) averaged across the six paintings, we found significant associations between the media condition and objectification (χ^2 [2] = 8.038, $p < .05$) as shown in Figure 9, as well as art experience and objectification (χ^2 [2] = 8.828, $p < .05$) as shown in Figure 10. The results involving the other dependent variables (DV1, DV2, DV4, DV5) were not significant.

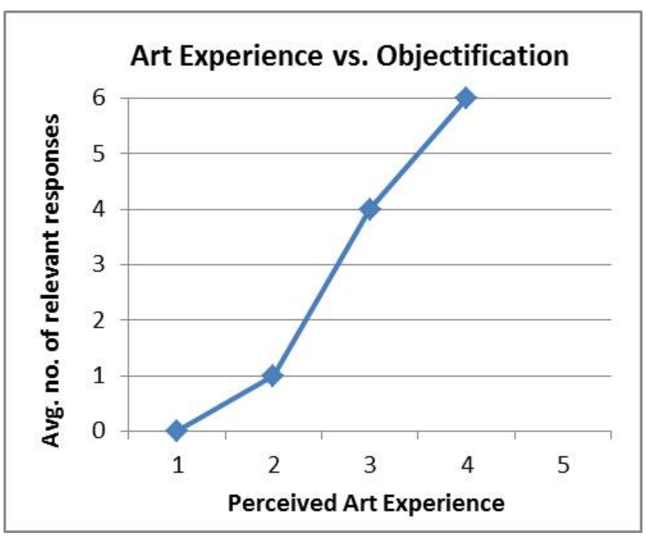

Figure 10: Similar to Figure 9, except that now the classification is based on subjects' self-reported art experience level collected as demographic information (section 3.3). As none of the subjects scored themselves with a "5" for perceived art experience, the results were tellied for scores 1-4.

Results of the post-experiment interview found that 50% of the subjects that experienced the AR conditions were very interested in the technology. 80% of the AR subjects felt that the AR was a distraction from the physical artwork.

5 Discussions and Implications

The results of the data analysis paint an interesting picture about the use of AR in art museum contexts for retention and transfer.

5.1 Addressing the effect of AR on retention and transfer

First, there was significant increase in total dwell-time caused by the use of AR (Figure 7). This meant that AR was effective in increasing the subject's voluntary exposure to the artworks.

However, this increased exposure only resulted in a very particular type of long-term learning. Specifically, the ability of the subjects to objectify the artworks was significantly higher in the AR-only condition than the other conditions (Figure 9).

As objectification required the subjects to form associations and relationships between the artwork and their own domains of interests, the subjects had to retain at least the gist or meaning of the artwork in order make those conceptual connections, thereby supporting hypothesis H1 (AR interactivity improves the ability of the subject to retain information regarding an exhibit as compared to the use of physical labels and descriptions, after 24 hours).

Also, the ability to make such conceptual links between different concepts was a sign of transfer, thereby supporting hypothesis H2 (AR interactivity improves the ability of the subject to transfer the information to solve a problem [that requires the integration of multiple information sources], as compared to the use of physical labels and descriptions, after a period of 24 hours). Therefore, learning was improved by AR.

5.2 Unraveling the interaction effect between AR and Text descriptions

Referring to Figure 9, it was interesting to note an interaction effect between the AR and Text descriptions. This suggested that although AR seemed to be beneficial when used alone, it was detrimental when coupled with the text descriptions. To uncover the reasons for this phenomenon, we examined the subjects' use of the iPad.

Referring to Figure 8, we found that subjects spent more time using the iPad (91%) in the AR-only condition, as compared to the AR+Text condition (71.8%). This suggested that in the AR+Text condition, the subjects were allocating time to view the physical painting and descriptions, as opposed to using AR-muse exclusively.

While this did not solve the mystery of decreased objectification ability, it did give us a clue about the type of information presentation required. The post-experiment interview gave another clue, in that 80% of the subjects in the AR+Text and AR-only conditions felt that AR was a distraction. This information, coupled with the evidence in the AR-only condition, suggested that this "distraction" quality of AR actually enhanced objectification ability.

The variable missing from the AR-only condition was that of the text descriptions, meaning that the text descriptions somehow impeded objectification ability of the subjects. It was possible that the presence of the text descriptions could have primed the subjects to think in a certain way, and when coupled with the augmentations from AR-muse, resulted in cognitive dissonance [3], possibly in the form of the Stroop effect [6] or otherwise, thereby decreasing performance. This would explain why performance was slightly better in the Text-only condition, as the exhibit artifacts were complimentary or consonant with one another.

Despite the evidence that suggests the benefit of AR in enhancing objectification ability, this expectation may require adjustments according to the subjects' prior experience with art. As shown in Figure 10, with increasing art experience comes an increased ability to objectify the artwork. As we could not find evidence to suggest that there was a significant difference in objectification ability between subjects of the same art experience level with or without AR, this could mean that an individual's art experience plays an important role in the learning process. Therefore, it might be important for the AR designer to consider the general art experience level of the target audience before deciding on the intended benefits to any specific group of learners.

5.3 AR-muse-ing "distractions", unexpected benefits

Diving deeper into the "distracting" quality of the AR, we wanted to understand the components that created this amusement. We obtained several insights by examining the data from the post-experiment interviews.

Several of the subjects mentioned the visualizations created a situation of "paintings within paintings". Since each of the paintings was animated with up to sixty frames per painting, and each frame was hand-drawn and painted, a user could essentially view up to sixty different sub-paintings, within each painting in AR-muse (see Figure 5 for more information). The ability to pause and play the animation afforded users control over this viewing process. One subject even said "I was smiling when I saw the paintings, because every single change was potentially a new idea, and a relationship between these ideas started to form in my mind...". This feature could have enhanced objectification ability, as now the users had more (and potentially different) things to relate to.

Another unexpected benefit from the AR "distractions", was that it made subjects curious about the exhibition and the technology. From the post-experiment interviews, we know that 80% of the subjects felt curious, and from the video footage, we observed that some subjects tried to understand how the technology worked, and what it could do. For example, many of the subjects tried to determine the limits of the AR tracking capabilities, either by viewing the paintings from extreme angles, or by viewing very close (or from far away). Some subjects even tried to see if interesting interactions could be done by waving their hands in the camera view (Figure 11).

While such interactions had little to do with the actual content of the paintings, they may have contributed to enhancing subjects' objectification ability by supplying additional stimulation into the experience, thereby increasing chances for learning to take place.

6 Limitations, Conclusions and Future Work

There are several limitations of this study. First, the interactions through the AR-muse application were deliberately kept simple so as not to introduce too many confounding variables to the study. Specifically, users

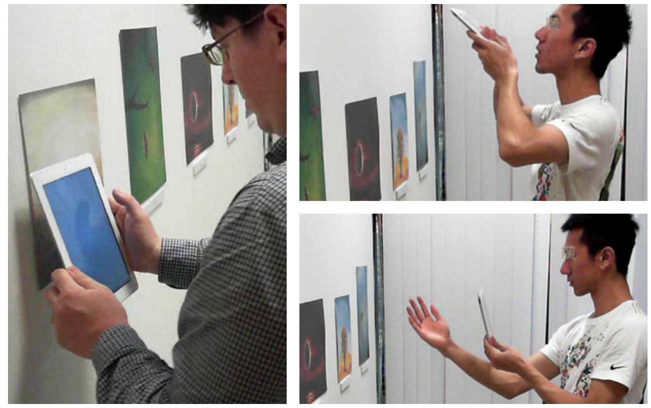

Figure 11: Viewing close-up, at extreme angles, and waving in the camera view.

could tap the screen to pause or play the augmentations, and this was implemented for every painting. In a way, one could argue that this interaction is more than just exploring and appreciating form and aesthetic choices, and has become hypertext or interactive storytelling. While it may be interesting to examine whether or not this changes the fundamental art-form, the study shows that it does improve learning of art regardless. Hence, while more complex interactions could potentially stimulate additional enhanced kinesthetic learning opportunities, this hypothesis will be a topic of future research with consideration for the evolution of the fundamental art-form.

Second, this work focused on paintings, which have different qualities from other forms of artworks, such as sculptures. Hence, future work should focus on these other forms of artwork. One could also argue that it may seem odd for an artist to present a work of art that is intended to have an AR dimension, yet compare the non-AR dimension of a still image. However, such an argument assumes that the artist would need to have full knowledge of the properties of AR, so as to design an artwork to intentionally take advantage of those unique properties. In our study, the primary focus was to study learning in art contexts, with or without AR, and not specifically to study of the properties of AR.

Furthermore, previous literature does not mention the actual measured effects of AR on the learning of art content, so it was necessary to establish the status quo first (paintings with physically labeled captions), and then compare the effect of AR on the status quo.

This also explains why there was no fourth experiment condition of paintings with title only and no AR, since the status quo would consider the painting to have at least a title (in art museum contexts), thereby considering the title as part of the standard presentation of the artwork. Future work will be to uncover the specific properties of AR that the artist can use for intentional artistic effect.

Third, the number of paintings exhibited was still a small number (six), so future work will be required to see if the results can be generalized to exhibitions of other sizes.

In conclusion, this study has found that AR does improve learning in art museum contexts. Specifically, we found that AR improves the ability of a visitor to remember the gist of a painting even after 24 hours, and objectify the artwork. However, the condition for this benefit is that there should not be elements in the exhibition that would interfere with the AR experience. In our study, the presence of physical text descriptions interfered with the use of AR visualizations, resulting in a decreased ability of the user to objectify the artwork.

In addition, the visitor's prior experience or training in art is an important factor in determining the ultimate benefit of AR, as visitors with less art experience would be less capable of objectification as compared to visitors with more art experience, regardless of the use of AR. However, the use of AR affords unexpected benefits to the user, such as the ability to view “paintings within paintings” thereby gaining a new perspective on the artwork, or by increasing the curiosity of users, thereby encouraging experimentation with the AR technology, potentially increasing the chances for learning or analytical activities to take place.

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