Pointfo: The Impact of Pointing-Triggered Projection on Interest in Art

LAUREN HILL, University of Bristol, UK
MANAMI NAKAGAWA, University of Bristol, UK
HIROMICHI YANO, University of Bristol, UK
XIAOXIAO LIN, University of Bristol, UK
WARINTORN PALARIT, University of Bristol, UK

At museums, visitors typically engage in passive experiences such as viewing artworks, reading explanatory texts, and listening to audio guides. As these traditional approaches take an individual's attention away from the art itself, visitors have to connect the information they received with the relevant part of the artwork by themselves, potentially leading to misinterpretations of the information given, which is a frustrating disruption in what is meant to be a relaxing experience. To enhance visitors' art experience, more interactive approaches, including using Augmented Reality (AR), have been suggested. However, these interactions involving a machine may impose burdens on visitors due to setup requirements and technical comprehension, potentially leading to user fatigue. Additionally, studies have highlighted potential accessibility issues with certain AR and Virtual Reality(VR) interventions. In this paper, we propose Pointfo, which uses a projection triggered by a pointing hand gesture to convey information, aiming to provide a more intuitive approach. Our findings suggest that Pointfo offers increased time spent at the exhibit, improved cognitive load, and increased surprise and curiosity levels. These findings lead the discussion, including long-term interest levels. Pointfo offers a more interactive experience at the museum and also highlights possibilities for applying pointing interaction outside the museum.

1 INTRODUCTION

In traditional museum settings, visitors can learn about the background of a work of art through the descriptive text displayed next to the artwork. However, the act of reading the text next to a work of art does not occur without a certain level of interest, and the visitor may be missing an opportunity to learn about the work and its history. Creating an initial engagement in art history can lead to people gaining insights into the changed historical, religious, literary, and cultural backgrounds of art pieces [40], thus, leading them to understand why the work is admired. Overall, this improves engagement with the museum exhibits themselves [40]. Through this experience, people can also develop their powers of observation, critical thinking, and expression [35]. Therefore, it is significant to know the background of art history that it is actively incorporated into an individual's education [35, 39, 40].

One approach to trigger interest in the art background is to make the art-viewing experience more interactive, and several previous studies have explored implementing such methods. For example, Yoo's research (2019) [43] proposes an application that uses Augmented Reality (AR) and 3D models to enhance the experience of viewing a painting, by making parts of the painting, such as the human figure, float above the actual painting and display information on it. In terms of information display, there is also research on the use of a torch-type device to project the information [8] partially onto exhibits. However, the introduction of 'uncommon in daily life' devices, such as AR or torch-type devices, might cause psychological barriers and cognitive load during the viewing experience.

We propose Pointfo, which displays information on a painting by a user's pointing motion in a hands-free manner, to engage people interested in the background of the art. Pointfo uses a pointing as the input so it is intuitive. When the user makes a pointing motion to a mark projected onto distinctive parts of a real painting such as a person, Leap

Authors' addresses: Lauren Hill, University of Bristol, UK; Manami Nakagawa, University of Bristol, UK; Hiromichi Yano, University of Bristol, UK; Xiaoxiao Lin, University of Bristol, UK; Warintorn Palarit, University of Bristol, UK.

Motion [1], a hand gesture recognition device, detects the motion and displays information according to the object to which the user points.

In our research, we designed Pointfo based on the findings from a formative questionnaire, we evaluated whether Pointfo can trigger people's interest in the art. Participants underwent two conditions in random order: the baseline, in which traditional descriptive text was displayed next to the artwork, and using Pointfo, a viewing experience with our prototype. For each condition, we measured the time the participant spent looking at the painting and interacting with it. Moreover, we asked participants' interest levels and cognitive load—the amount of working memory being used—by using a questionnaire after the experience. Through this research, we found a significant difference in the time spent in the viewing experience in Pointfo compared to Baseline. This suggests that Pointfo may increase the amount of information users gain by increasing their time spent looking at the art and interacting with it. This paper also discusses the long-term impact based on the practical findings of data on interest levels and cognitive load.

We aim to contribute to the development of real-world applications of pointing-triggered interactions through Pointfo. Pointing interactions can be applied not only to museums but also to other situations, including maps, where textual and visual information intersect. Pointing interaction could improve not only the user experience due to its intuitive operation to trigger interest, but also its inherent hygienic nature, as users can operate it without touching an object, increasing the acceptability of interaction in a world where hygiene concepts have become widespread in the wake of the COVID-19 pandemic [13]. This study suggests the potential for such a development, as it improves accessible interaction in museums.

2 RELATED WORK

This section introduces the pre-existing research surrounding how technology can influence interactions in museums, and thus improve museum experiences. We discuss the traditional museum experience, what previous insights have been gathered through the use of technology to portray information in museum settings, and pre-existing research and products involving the technologies we chose to use in this study.

2.1 Traditional Museum Experiences

Firstly, when analysing data on art history engagement, in particular general viewing times and the use of audio. Undoubtedly it is an important activity for the development of a variety of transferable skills in users [35]. However, it is also recognised that literacy levels and economic background can be a barrier that prevents certain demographics from visiting museums [27]. Additionally, analysis of the behaviour of museum visitors shows that more can be done to increase the amount of time spent engaging with art at museums.

Furthermore, researchers have thoroughly studied *how* people spend time at museums [9, 37]. Smith et al(2001)[37] found the average duration of the actual museum viewing experience was about 30 seconds, ranging from 13.2 to 44.6 seconds[37]. In contrast, the research on time spent in art exhibitions by Carbon [9] illustrates the average duration of spending time on artworks was roughly 27 seconds, ranging from 26 to 41 seconds [9]; with this maximum duration deemed an adequate time to grasp the concept of the art. It must be noted however that Wolz and Carbon (2014) argued that when artworks are displayed on a computer monitor in a laboratory environment, can produce results that do not reflect real-world contexts [42]. Therefore, based on this data, this study considers that the maximum time for

[1] https://www.ultraleap.com/leap-motion-controller-overview/

interacting with exhibits in the traditional manner was roughly 40 seconds, although environmental differences have to be taken into account.

2.2 Technical Insights from Interactive Museum Experience

Museums provide a unique, educational environment for visitors[24] with the potential for interactive exhibitions. For example, instead of just displaying the collections in the traditional sense, Yoshida et al. (2015) [44] created a projection exhibition for interactive learning and engagement about fossils, called 'Live Biblia'. This incorporated real fossils into its design, asking users to place the fossils near a sensor, causing a creature associated with the fossil would then be displayed on a screen. The use of real artefacts improved engagement, as it grabbed the learner's attention; and research into the importance of kinesthetic learning activities[14] supports this, where people learn through doing.

Augmented Reality (AR) technologies have also been shown to enhance the real-world environment, by adding additional virtual details [31]. However, there are issues when introducing unfamiliar technology to users. A project by Yoo and Foster (2019) [43] utilised Augmented Reality (AR) to highlight figures and visualising the corresponding information around them. This approach can enhance the interactive experience, by providing information, directed by the users' individual choice, about the features in the artwork. However, there are several barriers to this technology, including if people have to download new apps for AR or use their own smartphones, WiFi and battery power issues, as well as psychological barriers to using new technology. Our research proposes an interaction that does not require the user to bear the burden of preparing for the technology, utilising the idea of displaying their information close to the object.

In addition, there was an example of the use of technology as a means of teaching the background and philosophy behind the painting. A project by Huang and Lioret (2013) [20] introduced an interactive art installation with a digital Chinese ink painting reflecting the user's thoughts. The project aimed to make a connection between technology for brain wave detection and traditional arts, to facilitate a deeper understanding of the art. Traditional philosophical and cultural art concepts and spirits were introduced using a variety of novel technologies. Although our study did not use learning effectiveness as a measure of evaluation, Huang and Lioret provide a noteworthy example of utilising technology to help users understand the background of a painting.

Furthermore, employing audio in learning media, also increases the interest level in the learning context. A project by Suyitno et al. (2020) [38], using the audio material in the learning media, successfully increased the interest level in learning [38]. This research indicates the influence of using audio in the learning material to enhance educational interest.

2.3 Hand gesture

Using a device which is wearable is increasingly becoming popular in recent years, such as Ego-vision [1], a project by Serra et al. (2013) [33]. It is a framework to integrate human and wearable devices, utilised to enhance vision capabilities through an automated system to process videos captured from a first-person camera. Detecting hands and gestures with the system was essential in this context since they were replacing physical control devices with wearable devices that work the same as physical control devices. In this system, random forest classifiers were employed [33] to ensure an effective and speedy implementation[6]; using this technique to analyse colours and gradient features to achieve recognising gestures. Furthermore, temporal smoothing and spatial consistency were used to enhance detection accuracy. Segmented images were utilised to optimise the algorithms rather than whole frames in the testing stage.

This system was effective in improving the accuracy of recognising gestures. However, there was a limitation in that pointing had a lower 'Mean Average Precision' compared to some of the other hand gestures in this project.

2.4 Leap Motion

Existing practical applications and studies of Leap Motion confirmed that it is a user-friendly hand gesture recognition device that does not require a lot of learning. A project by Chakravarthi et al. (2023) [10] offers an analysis of hand gesture recognition through the use of a Leap Motion controller (LMC) [2]. Leap Motion was highly demanded in a variety of fields that need accurate hand gesture recognition, such as robotics and healthcare [5, 11]. The LMC allows users to use their hands to interact with virtual or augmented reality, so the user no longer needs to learn how to use complex controllers to operate systems.

A project by Koo et al.(2014) [23] utilised a pencil to act as a stylus, pausing and playing the video based on writing patterns; instead of an extra device such as a mouse or keyboard, which might distract from concentrating. This research showed that using Leap Motion makes it faster to complete the task than the traditional approaches, such as using a mouse task to pause and play the video.

Research by Vamplew et al. (2013) [29], also used a variety of different methodologies. The first methodology was Sign language recognition (SLARTI) which used a Cyber glove and two sensors to detect hand gestures. The second methodology was Power glove, which use a neural network to identify Australian sign language (Auslan) that is being portrayed through the hand gestures. As a result, SLARTI with Cyberglove obtained a 94% detection percentage for signers trained on how to operate the system and 85% for signers who have not been trained. This indicates Leap Motion has a high proficiency in accuracy with the integration of technology [41]. Additionally, Leap Motion was reasonably accurate and user-friendly [4, 16] as it can be seen from the result above, non-trained signers even achieved high proficiency. Language communication has been facilitated with the use of gesture recognition technologies for deaf and hard-of-hearing people.

2.5 Summary

To summarise, literature indicates that the use of genuine exhibits, instead of replicas, is beneficial for getting more people's attention but recognises that technology can enhance the users' experiences of museums [44]. Despite advancements in technology being demonstrated, the introduced research studies have limitations, such as inconsistency of accuracy, non-suitability to use a variety of gestures due to the complexity, or two adjacent fingers that are prone to error when using the Leap Motion technology. We proposed Pointfo which tracks the finger movements consistently. Moreover, it only utilises one finger to point at the painting, which is intuitive as it is a natural part of communication [12]. Using complex hand gestures is likely to result in low accuracy; however, it can be mitigated by using one finger. Additionally, our current product has integrated text and audio to provide a more active and immersive experience (discussed in subsection 4.1).

Therefore, the literature [44] indicates that the use of genuine exhibits, instead of replicas, is beneficial for getting more people's attention.

[2] https://www.ultraleap.com/leap-motion-controller-overview/

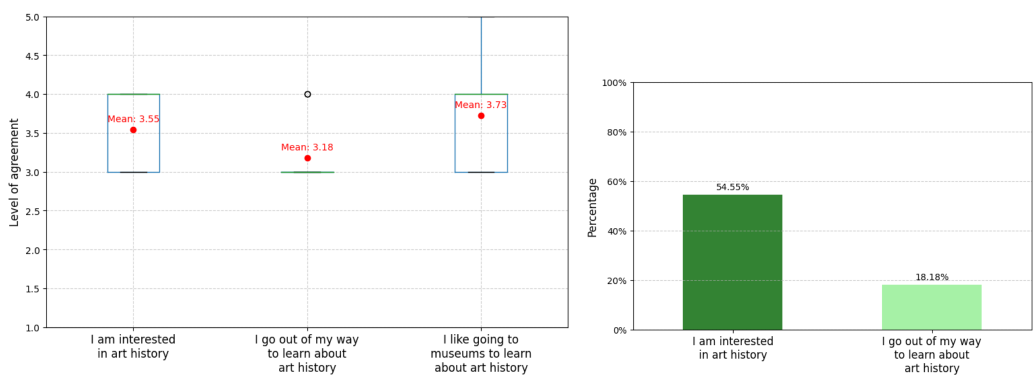
3 FORMATIVE STUDY

For designing the prototype and research, we conducted a survey on general art experiences as a formative study. 12 participants (Male=2, Female=9 , Other=1) answered a questionnaire online. Participants were gathered by word of mouth, and their mean age was 31.9 years.

3.1 Questionnaire Design

In our formative study, we aimed to gain fundamental insights into participants' attitudes and experiences concerning their interaction with art. This questionnaire included demographic information about the participants, including any disabilities they may have. This information was crucial for ensuring diversity in our research project. Additionally, we enquired about the frequency and reasons for participants' museum visits to obtain an overview of their exposure to traditional art exhibitions and their levels of familiarity with these environments, as well as their perspectives on engaging with art. Following this, we investigated participants' preferences in art regarding specific geographic regions and periods of art, such as Medieval, Renaissance, and Modern. Finally, participants rated their levels of interest in various features used in a museum setting, for example, sound, smell, and lighting on a five-point Likert scale (1 being Strongly Disagree, 5 being Strongly Agree).

3.2 Findings



(a) Interest and Engagement with Art History (b) Comparison of Proportions Responding 4 or Above

Fig. 1. **Questionnaire results from formative study**: People are generally interested in art, but the proportion of people actually taking action is low.

In the result on interest and engagement in art history, it was observed that while people generally show interest in art history, the proportion of those who are motivated enough to visit museums decreases.

The average responses for 'I am interested in art history', 'I go out of my way to learn about art history', and 'I like going to museums to learn about art history' are 3.55, 3.18, and 3.73, respectively (Figure 1a). The Figure 1a also indicates that all participants rated their interest at or above 3 (Neutral).

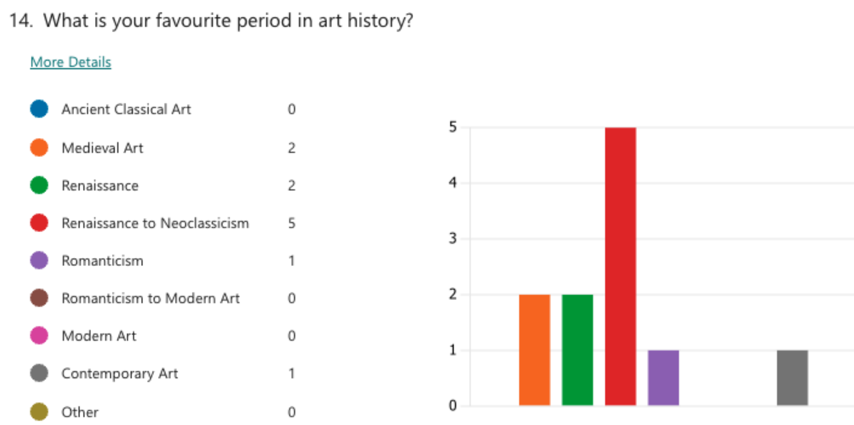


Fig. 2. **Favourite periods of art**: Romanticism to Modern Art was the most popular

Moreover, we found Romanticism to Modern Art was the most popular among the favourite period choices of paintings, as Figure 2 shows. The following section (section 4) describes the process by which this finding was used in the design iteration.

4 DESIGN AND IMPLEMENTATION

The design of Pointfo has iterated based on the findings from the formative study for the study design. This section describes the implementation iteration.

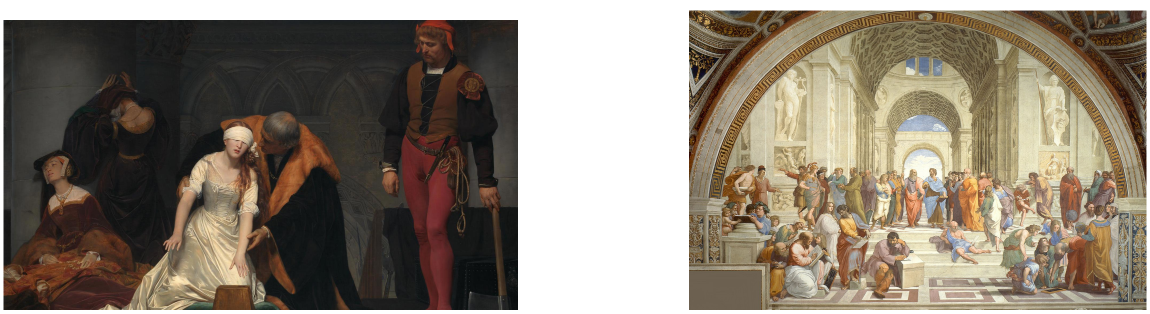
4.1 Prototype Design

The Pointfo prototype is composed of a projector, a Leap Motion controller [3], a Windows laptop, and a physical printed painting: 'School of Athens' painted by Raphael between 1509 and 1511. The integration of these components creates an interactive exhibit that allows users to explore the art. The projector is used to display digital information onto the physical painting, enhancing the user experience with additional content. The reasons why we chose 'School of Athens' will be explained in Section 4.1.1. The Leap Motion controller detects finger gestures, allowing for a hands-free interaction with the digital content. It is a contact-free pointing device with some advantages that track the quite small differences in accuracy for pointing movements[2]. The Leap Motion keeps tracking the finger positions to identify the motion and captured motion is quickly translated into digital input in real-time to take further actions[10]. These features of Leap Motion suitably fit into our project because quick recognition is needed with pointing movements. The Windows laptop acts as the central processing unit, running the software that manages the content display, gesture recognition, and user interaction logic.

[3] https://www.ultraleap.com/leap-motion-controller-overview/

Fig. 3. Initial sketch of Pointfo

4.1.1 Painting Selection. The initial selection of ‘The Execution of Lady Jane Grey’ painted by Paul Delaroche in 1833, was an example to demonstrate the concept of Pointfo (see Figure 4a). Due to its simple character relationship, it allowed individual exploration of each figure within the space. Because Pointfo was designed with the assumption that participants would have a certain interest in paintings and would point to them, we selected ‘School of Athens’ from the most popular Renaissance Art periods for our research 3.2. The total of 21 figures inside ‘The School of Athens’ painted by Raphael between 1509 and 1511 were in almost horizontal distribution, which was another reason this art piece was chosen for the final design (Figure 4b). Whilst most people are familiar with the historical context of the ‘School of Athens’ because plenty of visitors come to Vatican City to see it every year, they may not recognise all the figures depicted inside. This gap in knowledge presents an opportunity to engage users’ exploratory instincts, leading them to learn more about each philosopher, artist, or scientist featured in the masterpiece.



(a) Lady Jane Grey

(b) School of Athens

Fig. 4. Painting Selections

4.1.2 Painting Size and Projector. We printed ‘School of Athens’ in 594 x 841 mm, generally called A1 size with a resolution of 4966 x 7026 pixels. This clarity and size enabled individuals with normal vision to distinguish characters in the image from within a distance of 2-3 meters. High-quality Epson EB-L730U projector [4] allows for better creative

[4]https://www.epson.co.uk/en_GB/products/projectors/installation/eb-l730u/p/31704?pid=31704

presentations that can adapt to different spaces and lighting conditions. We tested it in a large, dark room to enhance the visibility of text projected onto paintings, which accurately replicates the atmospheric conditions typically experienced by visitors in museum settings.

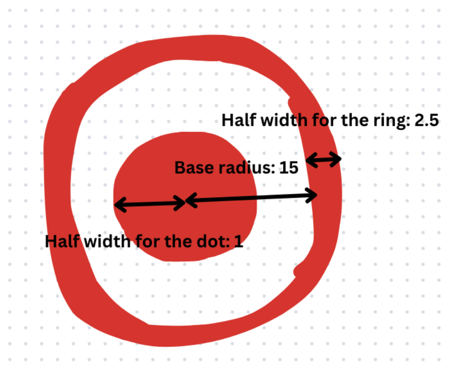
4.1.3 Text design. Considering that two-thirds of museum visitors are inclined to read information extensively, and the remaining people engage with at least some portions of the content [25], there is a significant demand for textual information to be made available. Based on this condition, we printed an A4 paper with figures and related descriptions for the 'School of Athens' and acted as a museum label for the traditional cases. For Pointfo, the texts projected above the characters were kept the same as the museum label, which was also designed for comparisons. Meanwhile, to avoid obstructing the view of relevant characters, the location of the projected text was designed to be directly above each individual. This adjustment is reflected in the CSV file by setting the info_left value to match the marker_left value, while only changing the info_top value to 1450 px. 1450 px was chosen to ensure that the projected text is positioned near the 'School of Athens' inside the dome, preventing any obstruction of the visuals.

Fig. 5. Text description with painting

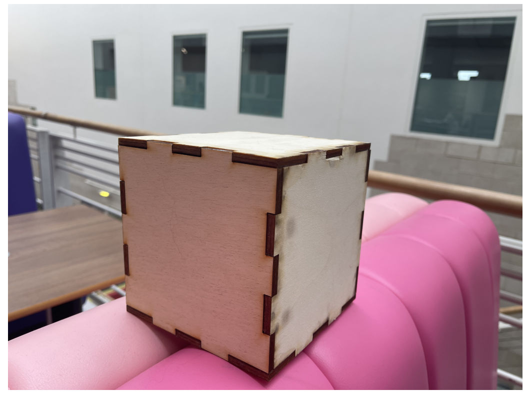
4.1.4 Audio design. The common examples of output devices are monitors, speakers, headphones, etc. Although playing audio through headphones is a common approach in museums because museums want to maintain a quiet exhibition space, we decided to incorporate Pointfo with open-air sound. We chose this because we wanted people to feel included in the interactions, regardless of if they are able to point over the sensor at that time. Furthermore, the use of headphones might lead to users feeling isolated from fellow users. We made use of text-to-voice online generators for the audio content. With the exception of the background and two scene introductions, which are around 30 seconds each, all individual introductions were strictly kept within 10 seconds.

4.1.5 Cursor, Fabrications for Leap Motion table, Squares. We did not set a specific width value for the cursor but separated it into two components: the ring and the dot in Figure 6a. The attributes and styles influencing the size are primarily related to the radius and the stroke width of the circle elements within the SVG. The colour we chose for the cursor is black/RGB (0,0,0) and enlarged the cursor to provide better visibility on a dark-coloured surface. The responding time for pointing was 1 second.

The overall fabrications for the Leap Motion table contained a table, a supporter, and text instruction. We used laser-cutting technology to produce the Leap Motion table in 15*15*15 centimetres like Figure 6b. We designed support to assist users by stabilising their hands and suggesting the appropriate height for the Leap Motion sensor to better detect finger movements. We suggested users hold their elbows near their side and keep their forearms parallel to the floor and at a right angle to their body. The text instruction included how to use Leap Motion and indicated the general range of finger movements.



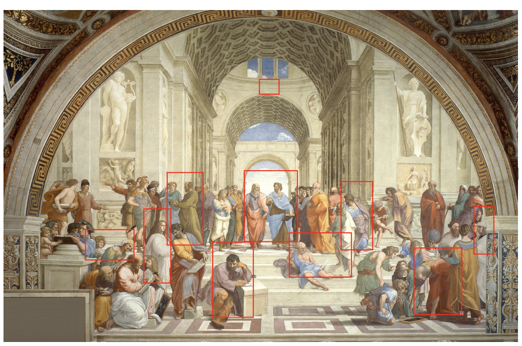
(a) Cursor: dot and ring



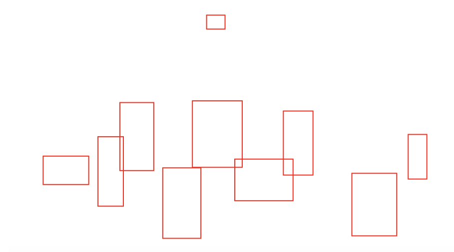
(b) Leap Motion table

Fig. 6. Cursor and Fabrications for Leap Motion Table

To improve the procedure of using Pointfo, we transitioned from using dots to squares to outline information points. This change allows users to identify and interact with the specified elements more easily. The squares are positioned using a CSV file and styled using CSS with absolute positioning relative to their parent container, named 'painting-container'.



(a) School of Athens with red squares



(b) Red squares with white background

4.2 Information flow from finger detection to text and audio outputs

Leap Motion can detect a wide range of gestures, including pointing and the procedure begins with capturing finger movements from this hardware. The input is then processed by the TouchFree application, which operates smoothly over the existing screen and user interface, running discreetly in the background. This Application Programming Interface (API) identifies a user's hand movement in the air and translates it into an on-screen cursor. Once the translated cursor is detected within the red box, corresponding commands inside script.js (JavaScript file) will read the Comma-Separated Values (CSV) file to locate each figure and trigger the generation of sound and text output. This involves playing pre-recorded audio files through the laptop's speakers, in parallel with projected text on the painting 'School of Athens' by the projector. Direct feedback from audio playback and visual display provides confirmation of the executed command, which enhances the user experience by offering informative responses to right finger pointing. The user interacts with the system by observing the generated feedback and adjusting their gestures accordingly.

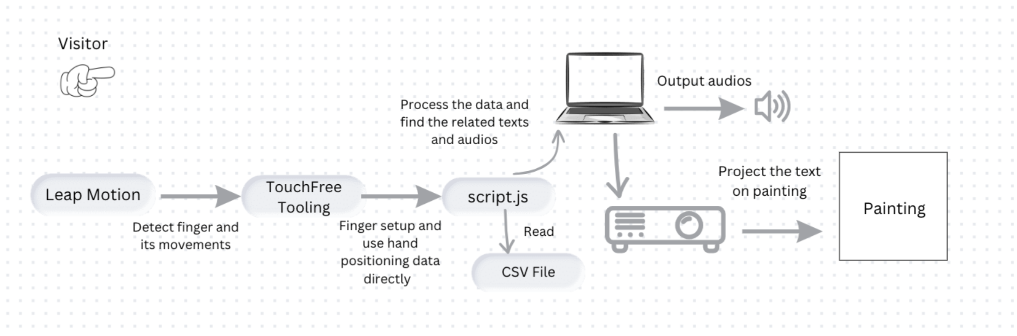


Fig. 8. Information flow of the procedure

4.3 Prototype Testing and Improvement

4.3.1 TouchFree: JavaScript vs Unity: C#. To simplify the operation of Pointfo for museum staff, it is essential to make related software and hardware as simple as possible. Unity, despite its robust capabilities, is not suitable for Pointfo for the following reasons:

(1) Unity does not support Leap Motion on macOS, and the version of Unity that can be used with Windows is strictly limited to 3.1.5 based on our test.
(2) Unity requires a lengthy loading time before use, which is much longer than the loading time for the TouchFree [5] API. As said before in 4.1, quick recognition and responding are needed with Pointfo design.
(3) Unity is not user-friendly for individuals without some computer knowledge, making it difficult to adjust outputs. However, by using Touchfree, staff can simply modify the relevant data in the CSV file without altering the existing JavaScript code.

4.3.2 Audio Pause. In the early stage of Pointfo, we experienced audio conflicts if another marker was triggered before the previous audio finished playing. To manage interactions across multiple markers, we added an event listener to the document to detect clicks outside the markers and made a global variable to track the current audio and ensure that any previous audio is paused before a new one starts. Originally, we intended to design the system to immediately stop the audio when the cursor was outside of boxes. However, considering that long time finger movements could lead to user fatigue and during the time users are trying to point to the exact box, disappeared background audio would potentially generate negative feedback. Therefore, we decided to remove this feature and make Pointfo more encouraging.

[5]https://leap2.ultraleap.com/touchfree/

4.3.3 Square Highlighting, Animation Feedback. Initially, we used red squares to distinguish each character in the painting. During the testing procedure, participants said they were willing to get more direct feedback from the screen to indicate which character they pointed to. According to that, we updated the squares' default colour to black and created a feature where the square changes to red when the cursor hovers over it; otherwise, it remains black. Moreover, to enhance user interaction with Pointfo, we considered adding feedback mechanisms. For instance, upon pointing at a square, a popup box might display messages like 'You've found someone...', or sound effects such as a 'ding'. Additionally, we could animate the corresponding character's border to enlarge or become transparent and add dynamic effects to the cursor, such as a meteor trail.

4.4 Further design

We divided the further design into the following sections to resolve two main problems based on the feedback given by lectures and Teaching Assistants (TAs) on the mock exam day. Section 4.4.1 corresponded to the prototype design, which lacks variation in voices and materials at the current stage. For further square patterns and finger gestures, see Section 4.4.2 and Section 4.4.3 respectively.

4.4.1 Language Diversity, Audio Diversity, Speaker Materials. Diversity is a crucial aspect of our design considerations with the responsibility to ensure fundamental freedoms of users and media outlets [19]. In the current stage, the default language for Pointfo is British English. In future designs, we plan to integrate Pointfo with an online translation API, which will enable users to select their preferred language, thereby promoting a more comprehensive understanding of the 'School of Athens' artwork. In terms of audio output, the content will be delivered in the user-selected language. We aim to expand beyond just using laptop speakers for output and explore a wider range of materials for the open-air speaker. These could include utilising sound-proofing and sound-absorbing materials and directional speakers, which are all effectively interactive exhibition elements [3].

4.4.2 AI detection for Square pattern. For future improvement, we plan to use AI detection to precisely outline each person, which is similar to how Scalable Vector Graphics (SVG) files assign unique IDs for activating individual characters so that we could roll out the technology over a wider range of paintings with minimal setups. It can avoid conflicts if there are abundant squares projected on the painting and ensure that individual characters within artworks are identified more accurately.

4.4.3 More Gestures in the air. For Pointfo, the use of Leap Motion extends beyond only recognising hand movements. Through the integration of TouchFree, it is possible to set up some specific hand gestures with corresponding commands. For example, assigning the swipe action to the function of the 'space' key, such as a left swipe displaying Figure 7a or a right swipe showing Figure 7b. We can implement the feature 'close tab' for index moving along a circle and the circle direction of hand gestures can also be implemented whether it is clockwise or counterclockwise [34].

(a) Swiping

(b) Circling

5 STUDY DESIGN

To examine the impact of Pointfo, this study compared two conditions, *Baseline* and Pointfo, within-subject. In the *Baseline* condition, a printed description was placed away from the painting, as in a general museum setting. In the Pointfo condition, a Leap Motion, a device that recognises the position of the hand, was placed in front of the painting. To simulate the museum environment, the research took place in an empty classroom at a university with many people coming and going, and participants took part in the research in person. We recruited 12 participants (Male=5, Female=6, Other=1) in the research by word of mouth. Participants ranged in age from 18 to 24. More than half of the participants' first language was not English Figure 10.

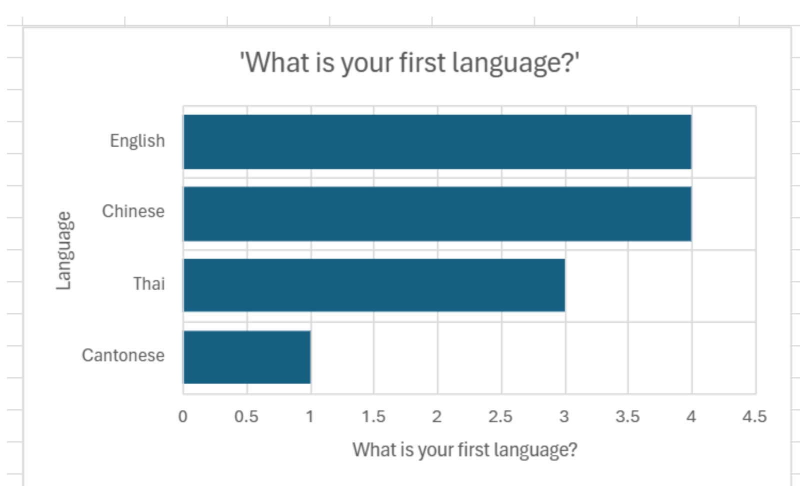


Fig. 10. **Participant's first language**: Over half of the participants were non-native English speakers.

5.1 Procedure

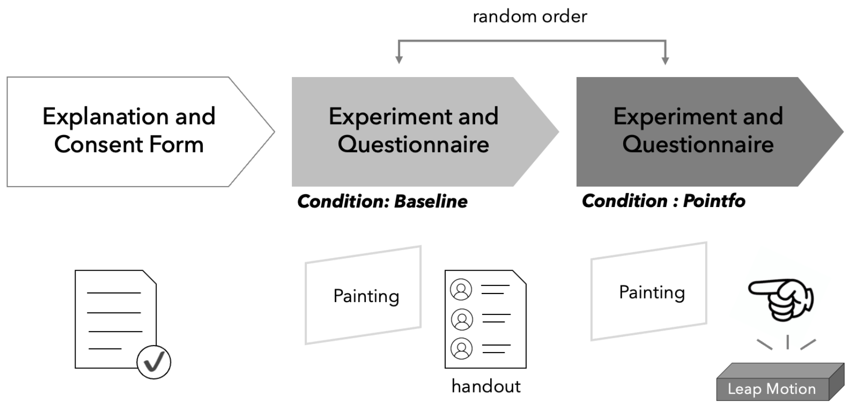


Fig. 11. **Procedure**: After agreeing to the research, participants perform the two conditions Baseline and Pointfo in a random order

The experimental procedure is shown in Figure 11. In a form for consent, participants first received an explanation of the research. Then participants their consent to the research through the form. Then, participants performed the research under both *Baseline* and Pointfo conditions, using the same painting and in a randomly assigned order. In the *Baseline* condition, participants viewed the painting on the wall as they would in a real museum. Under this condition, they had a handout with pictures of the faces of the people in the paintings with descriptions next to them. When participants viewed the painting for the desired length of time, they told the experimenter and filled out a Questionnaire. In the Pointfo condition, the experimenter first provided participants with instructions on how to move the Leap Motion, which tracks the position of the hand. During this time, participants were free to view the painting using Pointfo. They told the experimenter when they were satisfied with their viewing experience and completed a questionnaire.

5.2 Questionnaire Design

This study consisted of two distinct questionnaires corresponding to each structure to comprehensively analyse the impact of Pointfo on participants' interest in art and interaction dynamics. This can prevent participants from getting frustrated with flicking between sections. These questionnaires were structured into three sections: before, during and after. These questionnaires were both designed to inspect participants' experiences and perceptions within their respective experimental conditions. Similarly to the questionnaire in the formative study, we collected the participants' demographic information, including their first language, and their interest in art. Furthermore, we incorporate additional enquiries regarding participants' experience with the technology, focusing on its influence on their emotions and overall usage experience. With these supplementary questions, our aim is to capture a wide range of emotional responses, enabling us to evaluate how Pointfo affects the participants' overall emotional experience and interaction dynamics with the art. Prior research [21] highlighted the significance of users' psychological states in their task interactions. For instance, one's attention is drawn away from a primary task when being interrupted, leading to negative feelings such as stress, annoyance, anxiety and increased cognitive load. This can occur when there is a delay in the response of the

Pointfo to input, potentially causing the user to feel frustrated and increasing their mental workload, thus distracting them from the primary task of interacting with the art.

5.3 Measurements

5.3.1 Time. For each participant, we used a stopwatch to measure the time they spent on interacting with the art with and without Pointfo.

5.3.2 Cognitive Load. Participants were asked to answer a few questions regarding their cognitive load change level before and after each condition research. This was measured by the questionnaire using a Likert scale (1: Significantly Decrease - 5: Significantly Increase) based on NASA TLX [26] as it is commonly used to measure cognitive load [28].

5.3.3 Interest Level. Based on the findings from our formative study (subsection 3.2), we measured the change of interest level with the following statements:

- I am interested in art
- I want to know more about the painting
- I know the background of the painting
- I want to go to museums in my free time
- I enjoy looking at the art

Participants answered the extent of agreement with the statements on a Likert scale (1: Not at all - 5: Extremely Agreed).

5.3.4 Emotions. To measure the emotional change, we used a Likert scale (1: Significantly Decrease - 5: Significantly Increase) to allow participants to rank their emotions before and after each research. The following is the list of emotions:

- Excitement
- Curiosity
- Joy
- Surprise
- Appreciation
- Annoyance
- Anxiety

These emotions were selected to depict how Pointfo influenced the participants' emotions, thus potentially affecting their interest level. Silvia [36] refers to interest as the curious emotion and considers it a 'knowledge emotion', which also includes surprise and awe. Moreover, according to research [17], if an individual enjoys the task, they will experience high interest.

6 RESULTS

The analysis of the research employs the Wilcoxon signed rank test, as the study collects data with a Likert scale within-subject with two conditions. Additionally, in the field of Human-Computer Interaction, it is common to use Wilcoxon signed rank test over t-test [22]. We, therefore choose to run this form of analysis on time, cognitive load, interest level and emotion(see subsection 5.3).

Demand	Change
Mental	-41.66666667
Physical	25
Frustration	1.041666667
Performance	6.25
Effort	-20.83333333
Temporal	-41.66666667

Table 1. Cognitive load breakdown

6.1 Time of interaction

Figure 12 shows that the introduction of the Pointfo technology resulted in an average increase in interaction time of 63.76 percent. Only 1 participant interacted less with the art when the Pointfo was introduced than when we recreated the traditional museum experience. Upon performing, the Wilcoxon signed rank test, we got a p-value of 0.0015, which suggests that this result was not a coincidence.

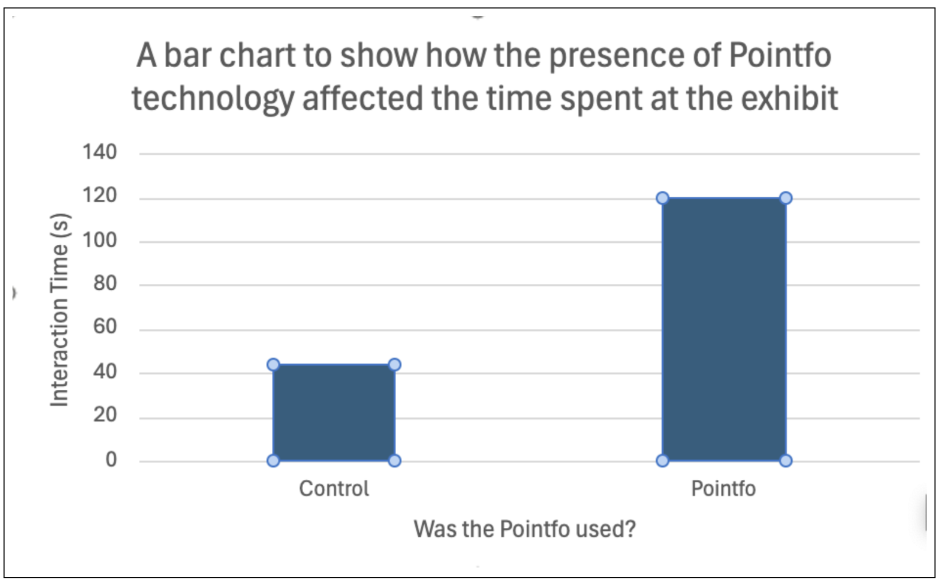


Fig. 12. Time Comparison

6.2 Cognitive load

A weighted NASA TLX was analysed as justified and expressed in the official NASA TLX guidance [26]. Research [15] shows that across the 2 trials, on average, the introduction of the Pointfo reduced cognitive load by 9.78 percent(2dp).

Figure 12 demonstrates how the introduction of our Pointfo technology resulted in a reduction in cognitive load. Although the physical demand and frustration evoked increased, the performance increased and the decrease in effort, mental load and temporal load were so significant that the overall cognitive load was reduced.

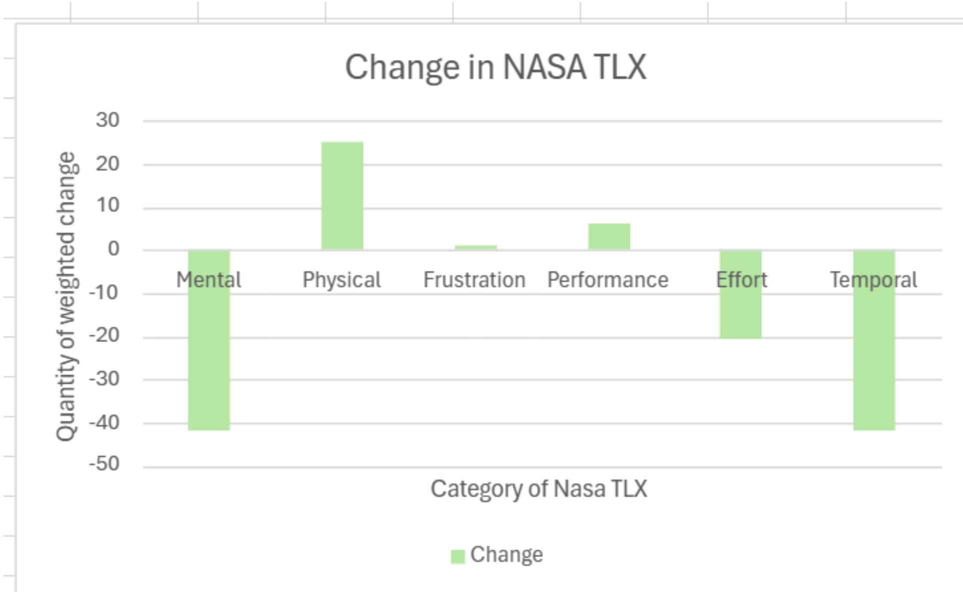


Fig. 13. Change in NASA TLX

6.3 Emotions Evoked

Each individual's emotion was analysed to see how the emotions evoked across the traditional museum experience compared to the emotional experience evoked through interacting with the Pointfo technology. When comparing the changes in excitement levels, it was found that the change in excitement when the Pointfo was introduced was positively skewed. Additionally, performing a Wilcoxon signed rank test gave a value of $W = 3$ and a p-value of 0.06(2dp), indicating that the change is not statistically significant. However, the change in curiosity when the Pointfo was introduced is negatively skewed and a Wilcoxon signed rank test gave a value of $W = 3$ and a p-value of 0.04(2dp) so this change can be deemed as statistically significant. In contrast, the change in joy experienced when the Pointfo was introduced is negatively skewed but the Wilcoxon signed rank test gives us $W = 2$ and $p = 0.09$(2dp), suggesting that any change was coincidental. Furthermore, the change in surprise when the Pointfo was introduced is negatively skewed and the Wilcoxon signed rank test gives us $W = 0$, p-value = 0.03(2dp), which shows that the change in surprise was statistically significant. Continuing on, the change in appreciation is positively skewed. Performing a Wilcoxon signed rank test found $W = 0$, p-value = 0.06(2dp) so we can conclude that any appreciation evoked is not statistically significant. In addition to this, the analysis determined that the change in annoyance is negatively skewed. Then, performing a Wilcoxon signed rank test gives us $W = 17.50$, p-value = 0.59(2dp) so it can also be concluded that changes in annoyance were not statistically significant. Finally, comparing users' rankings on anxiety when using the Pointfo to the anxiety felt in the traditional museum experiment found the difference in anxiety levels to be negatively skewed. Performing a Wilcoxon signed rank test on these differences gives us $W = 6$, p-value = 0.85, so we can conclude that this change is not statistically significant.

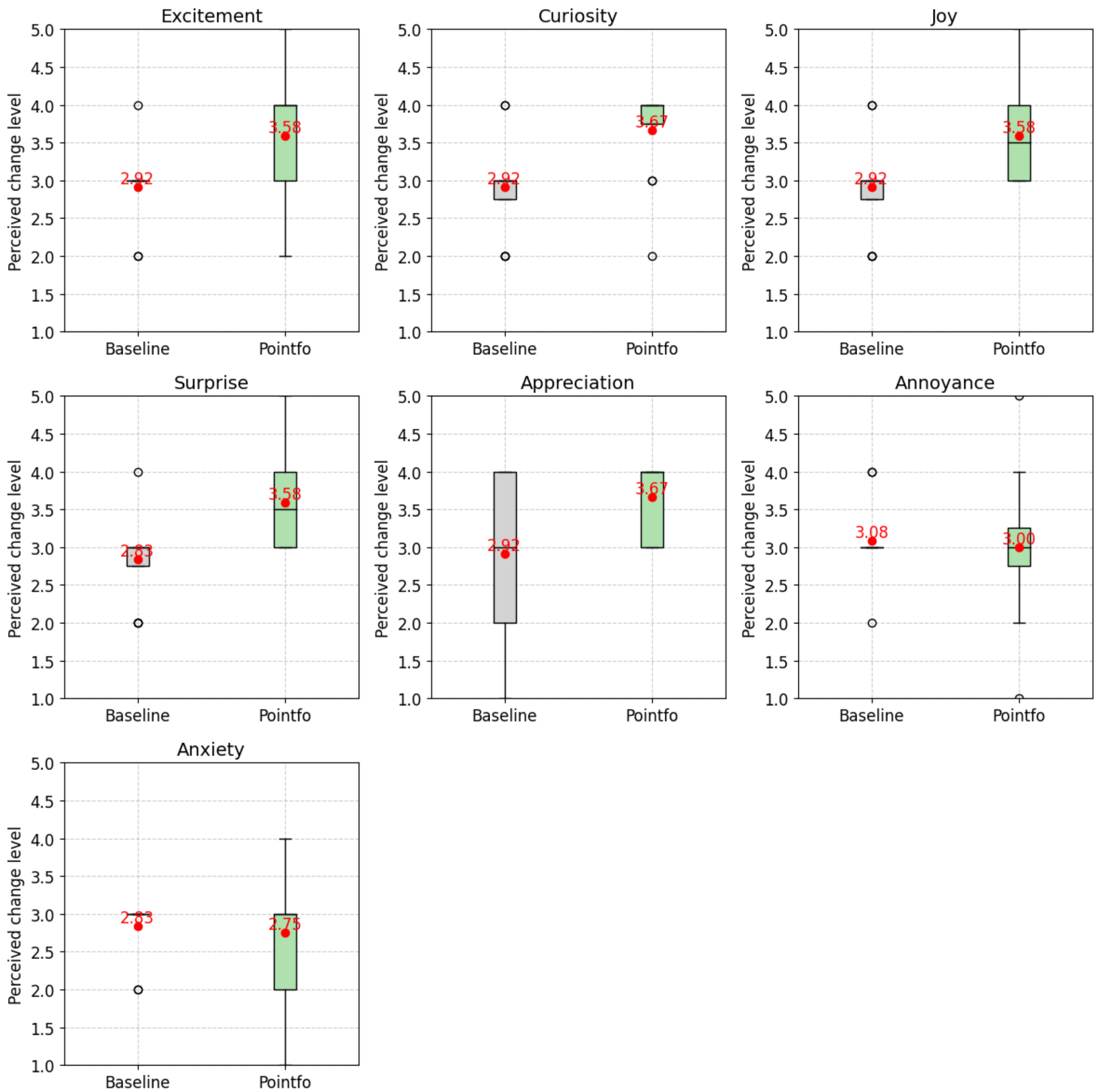


Fig. 14. **Change in Emotions**: Emotional changes before and after the Baseline and Pointfo research, rated on a 5 Likert-scale [1: Significantly decrease - 5: Significantly increase]. The analysis observed significant differences with items in Curiosity, Surprise (p<.05).

6.4 Interest

Using the Wilcoxon signed rank test to analyse a series of 5 questions relating to the user's interest in art history. This gave a W value of 0 and a p-value of 0.058, meaning we cannot say that an increase in interest is statistically significant.

7 DISCUSSION

The findings of this study indicate that Pointfo caused a change in the user's behaviour/interaction. For example, the introduction of the Pointfo technology resulted in an average increase in interaction time of 63.76 percent, which in the longer term could result in increased engagement in art history and longer interactions with the art exhibit. This could be because the technology is viewed as intriguing which then leads the user to uncover more information about art history that they wouldn't otherwise expose themselves to.

We hypothesised that this would happen and that this would result in the user becoming more interested in the art piece. However, despite increased interest in the artwork after they used the Pointfo being observed in some participants, further statistical analysis did not show that a change in art interest was statistically significant, as shown through a p-value of 0.058. This could be due to the subjective nature of qualitative data and Likert scales[18]. This could also be why the patterns in the emotional change between the user's experience in a traditional museum setting and their experience with the Pointfo were not consistent and thus did not result in statistically significant results for all the emotions recorded.

The overall reduction in cognitive load and increased interaction time suggests that the Pointfo did affect the user's interactions with the art. Some would argue that this implies that the user's experience of using the Pointfo was a positive one. However, it could also be proposed that throughout the interaction with the technology the novelty of the experience evoked negative emotions such as annoyance and confusion that would be different from someone who would visit museums and use the technology regularly, and thus the anxiety of the unknown would cause a user to be distracted from the art by the technology. More research would be needed to identify if the emotions evoked change after repeated use of the technology.

Furthermore, it could be theorised that the frustration caused by the lack of knowledge on how to use the technology could cause the user to disengage with the art and focus on the technology. Our questionnaire also found that participants wanted 'better' instructions. We were purposefully trying to give minimum instructions to analyse how intuitive our technology is. The results suggest that because the sensor is so novel, it might be worth incorporating some phenomenology and symbols into the setup to demonstrate how the technology should be used. These results would fit with the idea of Sweller's Cognitive Load Theory[32] which describes how the cognitive load of carrying an educational task can distract someone from the information. This theory would then suggest that the cognitive load shifted from linking the reading to the painting to figuring out how to use the technology. Therefore, even though Figure 12 demonstrates a reduction in mental load an increase in physical demand suggests that the extraneous cognitive load is shifting instead of disappearing completely.

Participants displayed frustration at the sensor's lagging accuracy and some suggested that more general hand gestures would be a better option to pointing. This frustration could be because of a resumption lag, where a delay in outputting the appropriate information interrupts the mental continuity needed to complete a task [7]. Moreover, the change in interest level could be prevented by the fact that some testers admitted to just not liking art. Therefore, when this is combined with the lack of instruction, it can be suggested that the interest level change would be more significant if they are already interested or are given a specific goal to use the Pointfo to achieve because the situational interest and intrinsic motivation would be greater [30] Therefore to summarise, the Pointfo shows potential to improve engagement with museum and art gallery exhibits but more research needs to be done to refine its design and determine its more effective setting.

Furthermore, when considering how a learning curve affects one's cognitive load, it is important to consider the demographic diversity of our participants. In our second study, only 33.33 percent of our percents said that English was their first language. Therefore, it could be argued that generalisations about how the Pointfo affects museum behaviours can't be made because the demographic diversity of our study might not affect the demographic diversity of certain museum/art gallery visitors. Further investigation would be needed to determine if more symbolism and phenomenology need to be incorporated into the setup to show elements such as the appropriate pointing height to investigate how this affects the learning curve and frustration levels experienced.

8 LIMITATIONS AND FUTURE WORK

More could be done to improve our ecological validity, which is the idea that we need to ensure that our research setup will reflect the real-life setup of our technology so accurate conclusions can be made and transferred to real-world context. For example, using actual art pieces instead of replicas would allow us to investigate how to stage the projection in a way that encourages engagement whilst preventing damage to the artwork. Additionally, we are aware of the effect that an environment's lighting can have on Pointfo's response time because some lighting from above can prevent the Leap Motion from detecting the users' hands. Therefore, we would need to ensure that the effects of the Pointfo translate to a museum/art gallery environment. Moreover, we also recognise the need to further develop the Pointfo technology so that it is applicable to a variety of museum contexts. For example, it is possible that the introduction of the Pointfo correlates to different behavioural changes, depending on the painting or exhibition. Further investigation would be needed to confirm this.

The reduced cognitive load and increased interaction time suggest that Pointfo positively affects the user's interactions with museum exhibits. It could be proposed that there was a learning curve when first learning how to use the technology that limited the reduction in cognitive load and prevented the increase in engagement in art history by distracting the user from the exhibit with the task of getting them to learn how to operate Pointfo. Further research would be needed to investigate if and how this manifests so we could better assess the long-term implications of this technology on interactions with museums. This would be done by investigating how cognitive load and emotional experience are affected by overcoming the learning curve. In addition to this, long-term studies could consider whether learning and art engagement improve over time or plateau once the novelty of the technology wears off.

It is also important to study group interactions with the Pointfo as implicit interactions were not addressed in this study. It can be proposed that the rise in curiosity would still occur, but would the frustration be observed in implicit interactions, and if not, how did that affect art engagement?

Finally, another obvious that has yet to be discussed is the accessibility of this technology. We chose pointing as an input because, to most individuals, this is easy and intuitive. However, it is important to remember that everyone's body functions differently, and there is the possibility that someone could have a physical or mental impairment such as paraplegia or Parkinson's disease, that could prevent someone from interacting with the technology or lead them from interacting with the exhibit in different ways. Future work would need to consider, how accessible this form of technology is and the implications of this on everyone's interactions with the art.

9 CONCLUSION

To conclude, we present Pointfo as a new interaction that shows the potential to make people more interested in the background of paintings, in museums. Pointfo projects a mark on a distinctive part of a painting, and information about the object is conveyed in text and audio formats when the user points over the Leap Motion sensor towards the mark on the projection. This approach allows the user to know information about the object by pointing, without having to carry a device around and provides a more intuitive way of learning about the history of the painting when compared to the traditional method of reading the explanatory text next to the painting.

Using the knowledge gained from the formative study, we created a prototype and evaluated the effectiveness and usability of Pointfo through a within-subject study. The within-subject study confirmed the effectiveness of Pointfo compared to the traditional method of displaying the text of the explanatory leaflet. Specifically, the use of Pointfo resulted in an increased interaction time by 63.76% on average, reduced cognitive load and increased surprise and curiosity levels compared to our recreation of the traditional museum experience. Based on these findings, we discussed how pointing interactions might lead to long-term behavioural changes in museums and increased interest in museums. Our findings are not limited to museum contexts but could also contribute to a wider cultural shift of more intuitive and potentially hands-free interfaces.

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A APPENDICES

A.1 Teamwork Diversity and Inclusivity

Fig. 15. Pointfo Group Image

We supported each other and appreciated every team member's skills from the beginning to the end of this unit. As a collaborative team, we discussed the expectations for the Pointfo in detail and respected everyone's unique ideas. We avoided assigning small tasks to one specific person as we regularly set up meetings to work together as a team. These meetings were usually held in the afternoon because four of our members preferred working in that time, but only one favoured the morning. We tried our best to meet in person as many times as possible to avoid miscommunications and to gain a better understanding of each other's perspectives. Four members are international students. As English is their second language, every member maintained patience and offered encouragement during every discussion. Moreover, we stayed connected via WhatsApp and uploaded the links of shared documents to GitHub. This helped us keep track of each member's work and be on the same page.

A.2 Video Link

https://youtu.be/jAT7k5Stfg4