ENVIRONMENT, ART, AND MUSEUMS: THE AESTHETIC EXPERIENCE IN DIFFERENT CONTEXTS

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ENVIRONMENT, ART, AND MUSEUMS: THE AESTHETIC EXPERIENCE IN DIFFERENT CONTEXTS

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EDITORIAL
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Editorial: Environment, Art, and Museums: The Aesthetic Experience in Different Contexts

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Keywords: aesthetic experience, environment, museum, art appreciation, landscapes

Editorial on the Research Topic

Environment, Art, and Museums: The Aesthetic Experience in Different Contexts

The aesthetic experience may be defined as people's interactions with, and reactions to, objects, places, but also to the environment. Most psychological perspectives on the aesthetic experience argue that it results from the coordination of different mental processes such as perception, attention, memory, imagination, thought, and emotion. Physiological and neurological responses are also involved. Aesthetic experiences can take place while we observe works of art in museums and galleries as well as in other contexts such as natural and built environments. Looking at a landscape, walking in a park, meeting people in a square, and walking into a building that is architecturally appealing are examples of natural and built environments where we can experience beauty, pleasure, attraction, and interest, among other aesthetic reactions.

Research on aesthetic experiences has a long history, and in recent decades, the field has experienced tremendous growth in the number of empirical studies conducted. One of the areas that researchers have yet to fully address is the influence of the context (natural and built environments) on aesthetic experiences. We refer to context according to three broad categories: *Context as natural environments, context as built environments,* and *environments for aesthetic experiences*.

CONTEXT AS NATURAL ENVIRONMENTS

People show a basic tendency to associate the natural environment with positive evaluations. According to an evolutionary explanation known as the *biophilia hypothesis* (Kellert and Wilson, 1993), human beings, who have evolved in natural environments, have developed an innate tendency to positively respond to nature as a consequence of an adaptation process.

CONTEXT AS BUILT ENVIRONMENTS

Urban environments, architecture, and buildings that have been systematically designed for both function and aesthetics can affect people's behaviors and social relationships (Mastandrea et al., 2009).

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ENVIRONMENTS FOR AESTHETIC EXPERIENCES

Museums can be considered as built environments, and some museums have even been designed so that they themselves could be seen as works of art, as aesthetic objects to be appreciated. These include specific elements of museums, from the halls to the artworks, from the arrangement of art in an exhibition, to the paths that visitors follow and the way that objects are displayed. These design elements can also influence visitors' enjoyment of the art collection (Tinio and Smith, 2014; Mastandrea et al., 2019).

We have received interesting contributions from scholars with different backgrounds, leading to a rich tapestry of offerings. We can synthesize the different topics into three broad categories: *Aesthetic experience in museums and art exhibitions*, *Art appreciation in ecological settings and different art contexts*, and *Environment and landscapes*.

AESTHETIC EXPERIENCE IN MUSEUMS AND ART EXHIBITIONS

Regarding this topic, Myszkowski and Zenasni, in "Using Visual Aesthetic Sensitivity Measures in Museum Studies," provide a history and an overview of visual aesthetic sensitivity as well as how it is measured and what it can tell us about individual differences in experiences and judgements of art. Importantly, the authors make a convincing argument of why visual aesthetic sensitivity measures should be implemented in research in museums.

Krukar and Dalton in "How the Visitors' Cognitive Engagement is Driven (but not Dictated) by the Visibility and Co-Visibility of Art Exhibits," asked participants to wear mobile eye-tracking while visiting an art exhibition with different spatial locations of the artworks. The exhibition's visual properties influenced the experience of museum visitors. More visible locations attracted more attention and the amount of attention improved the recognition and memory of pictures.

Annechini et al., in "Aesthetic attributes of museum environmental experience: a pilot study with children as visitors," highlighted the importance of the restorative aspect of a museum environment for children. They appraised the impact of museum environment on children during museum learning and experiential activities. In a case study, authors tried to understand and evaluate the museum impact on learning and experiential activities in children in the museum of contemporary art, MART, in Rovereto, Italy. Findings show that for most children, the MART museum (and for extension museums in general) provides a sense of relaxation and well-being during the museum visit and the aesthetic experience.

Bertamini and Blakemore, in "Seeing a work of art indirectly: When a reproduction is better than an indirect view, and a mirror better than a live monitor," used a survey and a set of hypothetical questions to explore three different alternatives of museum or exhibition: seeing an optical reflection (using a mirror), seeing a video screening (a closed-circuit camera) or seeing a reproduction. There was an overall preference for seeing a reproduction as opposed to an optical or digital image. Contrary to the idea that the original is always superior to a copy, many people felt that a direct view of a copy is a preferable experience than an indirect view.

Pelowski et al. in "Does Gallery Lighting Really have an Impact on Appreciation of Art? An ecologically-valid study of lighting changes and the assessment and emotional experience with representational and abstract paintings," presented a selection of realistic and abstract original artworks under three different lighting intensity/temperature conditions. Findings show that for both realistic and abstract paintings, the light changes in the gallery settings did not show significant effects on the evaluation and emotional experience within the artworks.

ART APPRECIATION IN ECOLOGICAL SETTINGS AND DIFFERENT ART CONTEXTS

Regarding the second topic we have three interesting articles. In "Communication and Meaning-Making are Central to Understanding Aesthetic Response in Any Context," Dolese and Kozbelt advocate for the use of a framework developed by Grice in helping us understand how to communicate via art, whether that communication is from artist to viewer, curator to visitor, or viewer to oneself. They discuss issues of what art means to individuals, and how they go about determining what that meaning is.

Estrada-Gonzalez et al. take a fascinating look at how we look at original artworks vs. computer reproductions of art in "Viewing Art in Different Contexts." They employ eye movement cameras to record fixations of works of art in a museum setting vs. computer reproductions that either used the same size image for all works, or a roughly proportional representation of the works. Their findings are complex, but generally indicate that the physical characteristics of the painting along with whether the image was in a gallery or on computer made a difference in viewing.

Carbon in "Ecological Art Experience: How we can gain experimental control while preserving ecologically valid settings and context," compared art experience in different art settings while participants observed paintings by Pollock and Rothko at different viewing distances. Liking of painting was correlated with farther distances, but insights of the artworks were not correlated to liking. Moreover, among the evaluative variables used by participants, interestingness, and powerfulness, were considered as predictors of how much people like paintings.

LANDSCAPES AND ENVIRONMENT

In this third topic, Law et al. in "Viewing natural landscapes is more stimulating than scrambled images after a stressor: a cross-disciplinary approach," show that viewing landscape paintings increased psycho-physiological responses (cortisol level, pupil size), compared to viewing scrambled images obtained from the correspondent landscape artworks. While viewing landscapes the

average pupil size was bigger compared to scrambled pictures; it is known that increased pupil size is related to augmented cognitive engagement, attention, and arousal.

Løvoll et al. in "Feeling at Home in the Wilderness: Environmental Conditions, Well-Being and Aesthetic Experience," conducted an original experience. Participants (47) undertook a 5-day, winter, wilderness adventure training with the aim to challenge wilderness and leadership skills under two different extreme weather conditions. Findings show that there was a correlation between the evaluation of the sentence "I felt at home in nature" and satisfaction with life and personal growth trait measures, mainly during sunny and cold weather conditions, and on the contrary not significant in stormy and wet weather in a mountain forest. The finding related to feelings and well-being are explained in term of relationship to self-awareness.

The studies presented took into consideration several different contexts: laboratory, museum, natural environment. These different approaches and settings can allow us to get more insight on the aesthetic experience while observing original arts, digital reproductions, nature and landscapes.

AUTHOR CONTRIBUTIONS

SM conceived the idea of this Research Topic. All authors listed contributed to the work and approved the submitted version.

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ORIGINAL RESEARCH
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Seeing a Work of Art Indirectly: When a Reproduction Is Better Than an Indirect View, and a Mirror Better Than a Live Monitor

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Visiting a museum and seeing an original artwork can be a special experience. We use a survey and a set of hypothetical questions to explore how such experience would be affected by changes in how the artwork is seen. In a first study, participants imagined that they had traveled to see a painting that they particularly like. They discover that it is impossible to directly see the original painting. Three alternatives are offered: seeing an optical reflection (using a mirror), seeing a video screening (a closed-circuit camera), or seeing a reproduction. In all cases, it is made clear that the size, brightness, and resolution will match that of the original. In addition, these options could be within the same room as the original, in the room next door, or in a different building. Results show that physical distance did not affect significantly the responses. However, there was an overall preference for seeing a reproduction as opposed to an optical or digital image. Contrary to the idea that the original is always superior to a copy, many people felt that a direct view of a copy is a preferable experience than an indirect view. The second study was focused directly on the comparison between a mirror and a monitor. Here we highlighted the fact that for the mirror light coming from the mirror originated from the painting. Data were collected in Britain and in China. In both cases, there was a clear preference for the mirror over the monitor.

Keywords: art, aesthetics, aesthetic experience, perception, museum

INTRODUCTION

Art plays an important role in society. We can see this by the production of artworks early in human history and by the large number of people that every day go to museums and exhibitions. Some even regard art as a pinnacle of human culture (Zaidel, 2010; Pelowski et al., 2017a), and Pelowski et al. (2017b) found a correlation between what was classified as a work of art and liking. The study of the aesthetics experience has also remained central to the interest of scholars in psychology and neuroscience over many decades (Arnheim, 1974; Kubovy, 1986; Ramachandran and Hirstein, 1999; Chatterjee, 2004; Leder et al., 2004). In a famous lecture in 1934 ("Art as Experience"), the philosopher John Dewey argued that what is important is not the material aspects of the work of art, but the process in its entirety, and in particular the experience of art (Leddy, 2016).

In this study, we asked participants to evaluate the impact of not been able to see a work of art (a painting) directly. It is accepted that the experience of seeing an original artwork depends on context. Some locations provide the expected home for art, and confer value to the experience, as in the case of theaters, cinemas, and museums. For paintings, a museum may create a quiet and thoughtful environment, sometimes characterized using the metaphor of a white cube (O'Doherty, 1986; Gartus and Leder, 2014). The popularity of art exhibitions and museums is strong in many countries. For example, in 2016, in the USA, museums were attended more than major league sporting events and amusement parks put together (as cited in Fingerhut and Prinz, 2018).

Another factor in the experience of art is the link with the artist through the material nature of the artwork. When people visit the Louvre and see Leonardo's *Mona Lisa*, they are present in front of the very canvas on which Leonardo worked for many years of his life (Lorusso and Natali, 2015). Similarly, when entering Leonardo's house in Amboise, France, visitors are aware that they are walking within the corridors and rooms in which the great artist lived during the latter part of his life. Newman and Bloom (2012) studied the special value of original artworks. They concluded that people assess art objects on the basis of the unique creative act (performance) and also in relation to the physical contact with the original artist (contagion).

To reflect on the role of knowledge about whether a work of art is the original, we consider the case of the Lascaux Cave. This cave was discovered in September 1940 by a teenager (named Ravidat) while looking for his dog (named Robot). The cave walls are covered with depictions of animals, and the complex was opened to the public after the war, in 1948. It was closed in 1963 when it became clear that the carbon dioxide, heat, and humidity were harmful to the images.

In 1983, Lascaux II was opened. This is a copy of part of the cave complex (the Great Hall of the Bulls and the Painted Gallery) a few hundred meters away from the cave location. Despite the fact that this is a copy, Lascaux II is the most visited Paleolithic site in the world. It is in itself a work of art, which took almost a decade to complete. The painter Monique Peytral used the same methods and materials as the original artists. She copied the original design by projecting photos of the drawings onto the walls and painting over them.

Lascaux III is an 800 m^2 exhibition and it has been traveling the world since 2012. More recently, in 2016, President Hollande inaugurated Lascaux IV. This is a replica designed by Norwegian architectural firm Snøhetta and located at the foot of the hill. To optimize the experience, this site includes a soundtrack of Ravidat whistling for Robot, and an environment in which temperature, air pressure, and damp smell are similar to that of the cave at the time of discovery.

Lascaux therefore provides a range of examples of how to experience art. The original (which we cannot see) is on rocks and these objects and images are shared with artists from the Magdalenian period (17,000–12,000 years ago). Lascaux II was created by an artist to be as faithful as possible and in proximity of the original. Lascaux III attempts to bring the cave around the world. Finally, Lascaux IV is a technologically state-of-the-art twenty-first century replica, possibly enhanced with respect to the original. A single work of art has now been multiplied into different experiences, which may be difficult to compare.

When discussing Lascaux with friends, we observed that some were enthusiastic about the experience of a visit to Lascaux II, while others felt that there was no reason to travel and see it as it was only a copy. This range of views (from a wonderful experience, to something worthless) is remarkable and was part of the motivation for our study.

IDENTITY AND AUTHENTICITY

Modern technology offers multiple ways of gathering sensory information about people and objects. For example, to what extent is having a conversation with a person over a videolink any different from a conversation in person? In the case of art, this opens up questions about how artworks are experienced and the importance of the physical presence of the object.

In philosophy, issues of authenticity overlap with issues of identity and ontology. In some cases, philosophers have resorted to thought experiments. The most famous such experiment dates back to ancient Greece, and is about Theseus ship (the best known version is in Plutarch, but the idea was debated by Heraclitus and Plato, and later by Thomas Hobbes and John Locke). Imagine that the ship is kept in a temple. Over time some parts need repair, so they are replaced. When all parts of the ship are removed and replaced by new parts, is the new object still the ship of Theseus? (Nozick, 1981; Pickup, 2016).

The philosopher Currie (1985) has suggested that there are conditions under which a copy is as aesthetically valuable as the original. This is called the transferability thesis. Writing in particular about paintings, the argument is clearly stated: "there is an aesthetically relevant difference between the two if and only if there actually is a perceptible difference between them" (p. 155). Currie also explicitly says he is not considering the complex issue of forgery and deception, and likewise we will avoid this additional aspect.

There are practical challenges in running a study that compares actual works of art with reproductions, but there have been some in the literature. For example, Locher et al. (1999) asked museum goers at The Metropolitan Museum of Art (New York City) to evaluate nine original paintings. Some participants rated instead slides of the artworks, and another group saw images on a computer screen. Some ratings were higher for the originals, but responses were largely similar for the three formats. Locher et al. (1999) concluded that this evidence lends support to the idea that art experience may be transferable, and that observers may make allowances for the limitations of a medium. In a subsequent study, this result was confirmed with untrained participants (Locher et al., 2001).

Several studies in the literature have demonstrated the importance of context in aesthetic appreciation, interest, and liking. The museum setting positively contributes to these aspects of art experience (e.g., Specker et al., 2017). Brieber et al. (2015) and Grüner et al. (2019) confirmed the museum effect (compared to a lab setting). In addition, they tested the effect of genuineness by comparing real artworks (paintings) hanging on walls with

reproductions of these artworks (PowerPoint presentation). They also found that the responses were similar.

In psychology, the term essentialism has been used to refer to the tendency to believe that categories (e.g., women, chairs, Picasso paintings) have an underlying true nature. Essentialism provides a reasoning heuristic in children and adults (Gelman, 2003). For example, children make different inferences about kids described as "kids who eat carrots" and those described as "carrot eaters" (Gelman and Heyman, 1999) and they are unwilling to accept an identical replacement for an attachment object (Hood and Bloom, 2008). Essentialism suggests that people may perceive a famous painting as having a true nature, and that this nature is lost in a copy. In 2017, the philosopher Jesse Prinz suggested that if the *Mona Lisa* burned in a fire, people may prefer to see the ashes than a copy (Prinz, 2017). This may be a case of essentialism as the essence of an object may remain within a physical object even when the qualities of the object change.

SURVEY ABOUT A HYPOTHETICAL MUSEUM EXPERIENCE

We studied self-reported preferences for different ways to see a painting. Using an online questionnaire, we presented participants with a scenario (**Figure 1**) and asked them to evaluate the impact of not been able to see a work of art directly. The methodology is similar to that of a philosophical thought experiment (as in Theseus ship) but with the difference that it allows the gathering of responses from a large sample. The survey was advertised on the university website and on social media and through personal contacts. Therefore, although in theory anybody could access the survey, a large proportion of participants are likely to have been psychology students and their friends and family. There was never any payment or reimbursement as part of the survey.

The study was approved by the Health and Life Sciences Committee on Research Ethics (Psychology, Health and Society) of the University of Liverpool (reference 0734).

Think of the most precious and famous painting you can think of. Something as important as the Mona Lisa by Leonardo da Vinci, although not that specific painting. We will call it Painting A instead. You are familiar with it and you consider it the most wonderful work of art.

You have decided to travel and see the painting in the museum. It is on a wall in a room of the museum, and there is a ticket to enter.

There is a difficulty. You discover that too many people want to go and see Painting A. Some options are explored to solve the problem. These will be described in turn in the next page.

Important: *Note that in the options described the images are always of equal size, resolution, brightness, contrast, and so on as the original painting. Please accept that the technological solution has been found and do not worry about how exactly it has been implemented.*

Participants were offered the option to see Painting A in three ways: in a mirror, on a live monitor, or on a reproduction (three columns of **Figure 2**). These three possibilities were presented in random order.

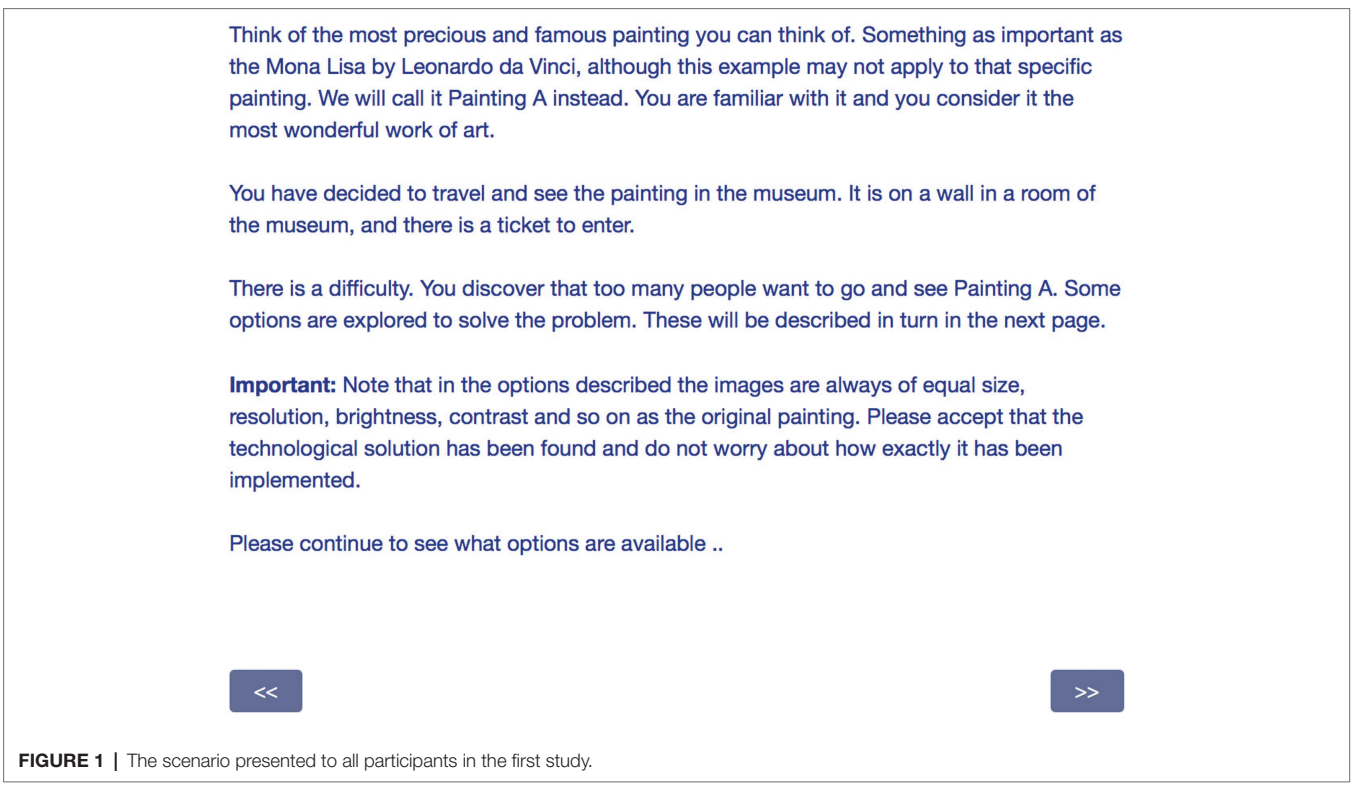

FIGURE 1 | The scenario presented to all participants in the first study.

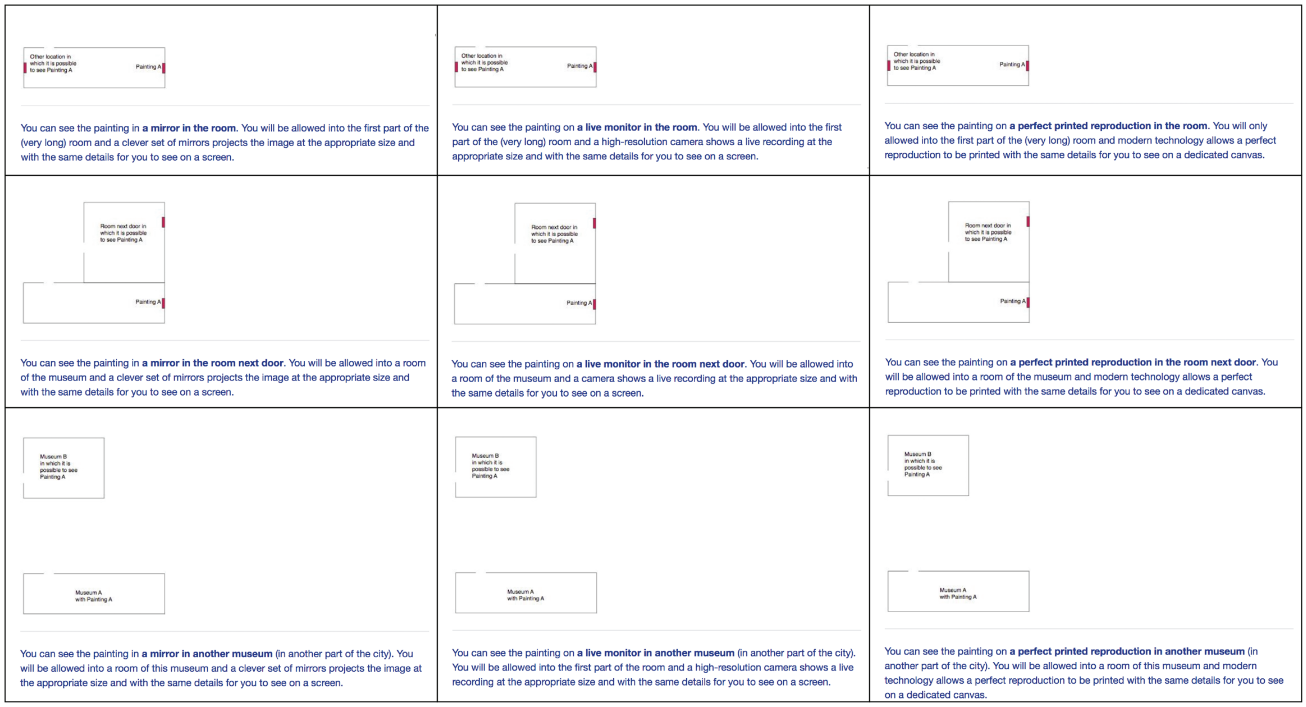

FIGURE 2 | The three columns show the three questions presented to an individual (in random order). The three rows show the three locations that were presented to different groups of individuals. Small maps were included in the survey to illustrate the locations. These were the same room as the original, the room next door, or a room in another building.

You can see the painting in a mirror in the room. You will be allowed into the first part of the (very long) room and a clever set of mirrors projects the image at the appropriate size and with the same details for you to see on a screen.

You can see the painting on a live monitor in the room. You will be allowed into the first part of the (very long) room and a high-resolution camera shows a live recording at the appropriate size and with the same details for you to see on a screen.

You can see the painting on a perfect printed reproduction in the room. You will be allowed into the first part of the (very long) room and modern technology allows a perfect reproduction to be printed with the same details for you to see on a dedicated canvas.

The three rows of **Figure 2** show conditions shown to different groups. The difference was the location, the painting (in a mirror, a monitor, or as a reproduction) was to be seen in the same room, in a room next to the room with the original, or in another building.

For each scenario and situation, participants were asked the following question:

> *The museum is considering what ticket price to charge in this case.*
>
> *In your personal case would you be happy to:*
> - *pay the same as the ticket for seeing the painting in the traditional way (no discount)*
> - *would not consider this alternative at all*
> - *pay a discounted ticket which is ___ % of the full ticket (for instance if you say 80% and the full ticket was 100 pound then the discounted ticket would cost 80 pound).*

In addition to what they would prefer, they were then asked the following similar question (with the same options):

> *In your opinion, most people would be happy to:*
>
> - *pay the same as the ticket for seeing the painting in the traditional way (no discount)*
> - *would not consider this alternative at all*
> - *pay a discounted ticket which is ___ % of the full ticket (for instance if you say 80% and the full ticket was 100 pound then the discounted ticket would cost 80 pound).*

It is already been found in the literature that people are more critical when evaluating according to their own standards (Leder et al., 2016).

Next, they were asked a question about the importance of knowing that the painting was not the original. The wording was as follows:

> *Despite the fact that the painting is not seen directly as an original object, imagine a slight variation to the situation described above. Suppose that the way the*

painting is shown (with a mirror) is such that it is impossible to tell the difference compared to the original.

In your personal case if you believed that you are seeing the original, do you think that your experience would be:

- *the same as seeing the original*
- *somewhat diminished because the original is not actually in front of me*
- *completely worthless because the original is not actually in front of me.*

The words in brackets in this example ("with a mirror") matched the scenario, and therefore could refer to a monitor or to a reproduction.

Finally, this question was asked with respect to other people:

In the case of most people, if they believed that they are seeing the original, do you think that their experience would be:

- *the same as seeing the original*
- *somewhat diminished because the original is not actually in front of me*
- *completely worthless because the original is not actually in front of me.*

Two-hundred and forty-six participants completed the survey (169 females). Average age was 30.7 years (SD = 13.87). We also asked about their experience with art. Few were professional artists (N = 6) and a minority said that they were artists although not at a professional level (N = 51). Other items at the beginning of the survey collected information about age, education level (Vocational, GCSE, High school or A-Level, University degree, Master's degree, Doctorate, None of the above), and when was the last time that they had visited a museum. Because the study was advertised online, the participants were not exclusively students. Indeed, approximately half (128) had an undergraduate degree (or above). We recoded this variable as dichotomous (University-educated vs. non-University educated).

RESULTS (MAIN STUDY)

Participants were assigned randomly to one of three scenarios (different locations). Therefore, the size of the subgroups was similar (same room = 81, next door = 89, other building = 76). The main question was about what people would do when offered the alternative options.

Overall, about half of the respondents said they would not consider the option described: 51.6% for the mirror, 60.2% for the monitor, and 49.2% for the reproduction. A minority said they were happy and did not need any discount: 14.6% for the mirror, 12.6% for the monitor, and 14.2% for the reproduction. The presence of these two large groups is interesting as it suggests a range of views, including both extremes (**Figure 3**). When the question was about what most people would say, responses were similar. In about half of the cases, participants predicted that other people would not consider the option as acceptable: 44.7% for the mirror, 50.0% for the monitor, and 42.7% for the reproduction. A minority predicted that most people would be happy and would not request any discount: 16.3% for the mirror, 11.8% for the monitor, and 17.9% for the reproduction.

Note a shift in the values in the case of a question about most people, as if the respondents were using a stricter stance for themselves and expected other people to be more willing to accept the option offered. The frequencies of the two responses (would not consider it at all, would pay the same amount) were different [mirror: $\chi^2(1) = 49.7$, $p < 0.001$; monitor: $\chi^2(1) = 75.1$, $p < 0.001$; reproduction: $\chi^2(1) = 46.3$, $p < 0.001$]. However, the association between type of response and whether the question was about the self or about most people was not confirmed [mirror: $\chi^2(1) = 0.66$, $p = 0.42$; monitor: $\chi^2(1) = 0.07$, $p = 0.79$; reproduction: $\chi^2(1) = 1.65$, $p = 0.19$].

To fully analyze the data, including the percentage of the price of the ticket, we created a new variable. We coded the choice as 0 if they would not consider at all the option (not willing to see the painting under those conditions). We coded it as 100 if they were happy to pay the original price, and we used the percentage to express their willingness to get a ticket. Therefore, we have a number between 0 and 100% that is our proxy for how much they valued that particular option. We call this Ticket value.

Overall, the mean values were 32.9% (SD = 38.9) for the mirror, 26.0% (SD = 37.3) for the monitor, and 34.1% (SD = 38.8) for the reproduction. For the question about most people, the values were similar: 36.6% (SD = 38.4) for the mirror, 30.3% (SD = 36.3) for the monitor, and 38.6% (SD = 39.4) for the reproduction.

We used a mixed ANOVA with the following within-subjects factors: Medium (mirror, monitor, reproduction) and Person (self, most people), and the following between-subjects factors: Location (same room, next door, other building), Sex (male, female), Art experience (not an artist, an artist), and Education (University educated or not). As there were only few professional artists we included professional and non-professional artists in a single group. We also included age as a continuous covariate. Average values are shown in **Figure 4**. It is evident that how much people were happy to pay increased with age; however, this was not the focus of our study and entering age as a covariate allows us to test for other factors controlling for age.

There was a significant main effect of Medium [$F(2,221) = 3.75$, $p = 0.024$, $\eta_p^2 = 0.017$] and of Person [$F(1,221) = 4.32$, $p = 0.039$, $\eta_p^2 = 0.019$]. The polynomial contrast for Medium confirmed that the value increased linearly from Monitor, to Mirror, to Reproduction [$F(1,221) = 7.80$, $p = 0.006$, $\eta_p^2 = 0.034$]. For Person, values were higher when the question was about the self. The continuous variable Age was also significant [$F(1,221) = 6.24$, $p = 0.013$, $\eta_p^2 = 0.027$].

There was an interaction between Person and Education [$F(1,221) = 5.37$, $p = 0.021$, $\eta_p^2 = 0.024$]. For non-university educated participants, responses were similar when the question was about the self and when it was about others. By contrast,

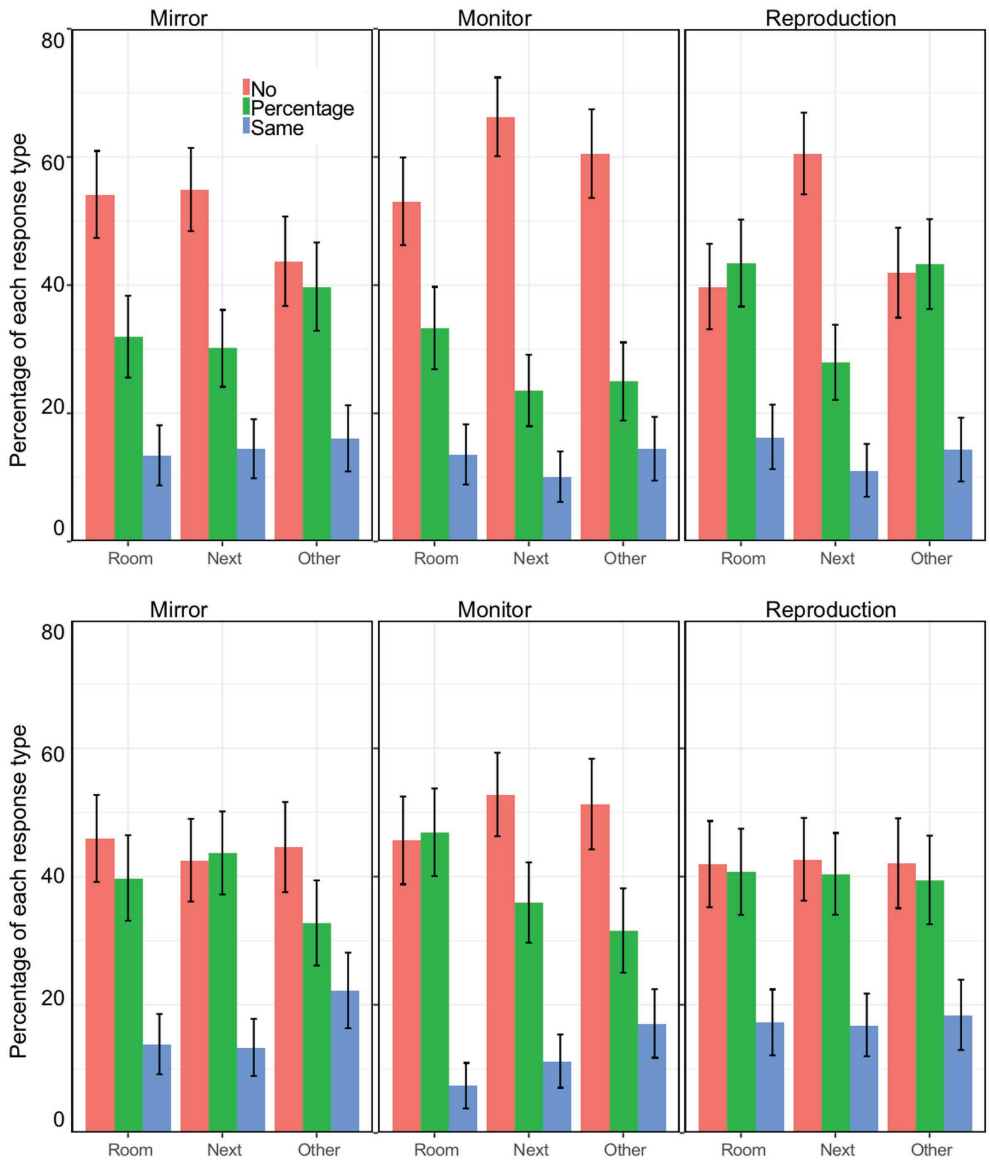

FIGURE 3 | Percentages for the three types of responses (no discount because it would be worthless, a discount, and the same as the original) as a function of location. The columns show the three media (mirror, monitor, and reproduction) and the two rows show the response when the question is about the person, and when the question is about what most people would do. Error bars are standard errors for the mean.

university-educated participants had lower value for what they were willing to pay themselves and higher value for what most people would pay.

No other effects or interactions were significant. Of the non-significant results, there was a trend worth mentioning for the interaction between Sex and Location [$F(2,224) = 2.88$, $p = 0.058$, $\eta_p^2 = 0.025$]. For males, it seems that scores increase for locations farther away from where the original painting is located (same room, next doors, other museum). For females, the highest score is in the same room as the original (**Figure 4**, right panel). We must be careful not to over interpret this; however, one possibility is that males feel more strongly about being in the same room as people who can see the original. This would create a form of public discrimination between groups: those who can and those who cannot see the original, something perceived as a source of humiliation.

We turn to the question of how people responded when asked to imagine that they believed that the object was the original. The most striking result is the range of views, many people thought that the experience would be worthless (21.1%), but a third thought that it would be the same (33.4%) (see **Figure 5**). The pattern was similar when the question was about how most people would respond (second row). In this case the belief that the experience would be worthless was expressed by fewer people (17.1%), and more people thought that it would be the same (37.4%). This trend is consistent

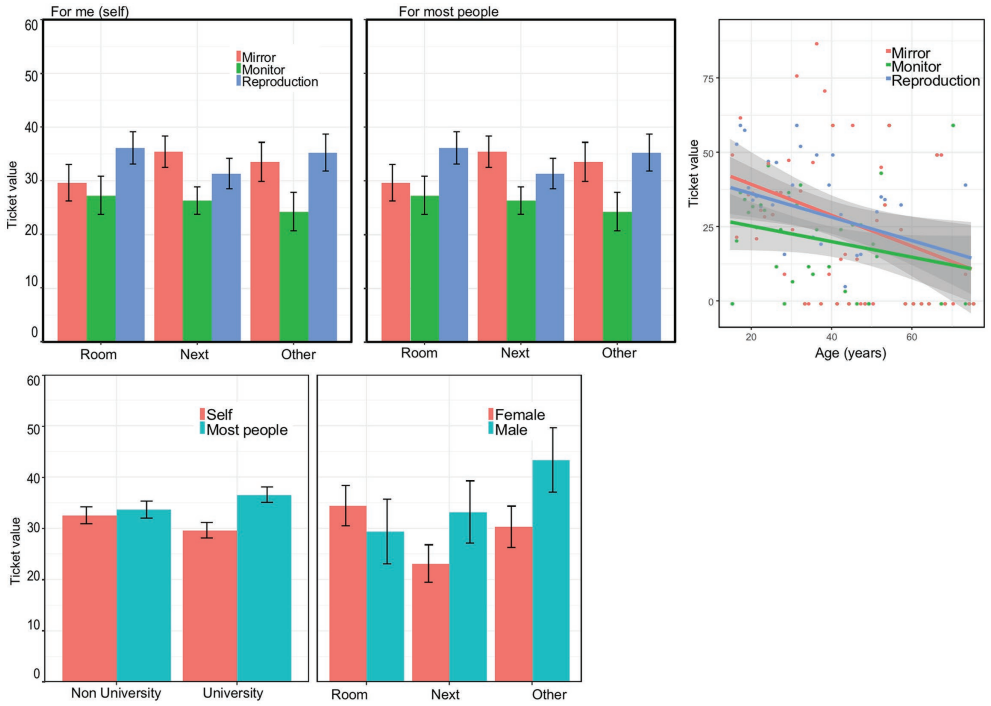

FIGURE 4 | Average Ticket value. This score combines the three possible responses (no, discount, full price) into a single percentage between 0 and 100%. Top left: value as a function of location and medium. Top right: value as a function of age (log scale) and medium. Bottom left: Interaction between level of education and whether the question was about that individual or about most people. Bottom right: interaction between location and sex. Error bars are standard errors for the mean.

with what was observed in the previous analysis: participants expected other people to be more willing than themselves to consider the experience as acceptable or equivalent to seeing the original. The frequencies of the two extreme responses (worthless, the same) were different for mirror: [$\chi^2(1) = 9.24$, $p < 0.002$] and for reproduction [$\chi^2(1) = 21.0$, $p < 0.001$] and not for monitor [$\chi^2(1) = 0$]. However, the association between type of response and whether the question was about the self (the respondent) or about most people was not confirmed [mirror: $\chi^2(1) = 2.04$, $p = 0.15$; monitor: $\chi^2(1) = 1.78$, $p = 0.18$; reproduction: $\chi^2(1) = 1.26$, $p = 0.26$].

SECOND STUDY

Some results from the first study were clear. The least valued way to see a painting was by a digital device (video camera and monitor). We were surprised by the fact that mirrors were not chosen as a good way to see the image by more people. We reasoned that a mirror should provide a potential link with the actual painting as the light bouncing from the painting itself eventually reaches the eye of the person looking at the mirror. We worried that the wording of the scenario may have not conveyed the special process of how light if reflected and travels from painting to eye. Indeed, the wording made the mirror appear similar to the monitor. Therefore, we conducted a second survey focused on the comparison between mirror and a video camera combined with a monitor. Since location had no major effect in main study we only described the scenario in the same room.

This second study had also an additional motivation. Although the first study collected data online and we know that there was a range of people taking part from many countries, and a range of ages, the majority were students and academics in Britain as this is the target group to whom the study was advertised. Moreover, the language of the survey was English. In the second survey, we had an English version, targeted to undergraduate students in England, and a version in Mandarin, targeted to undergraduate students in China. We are interested in the generality of our findings across languages and cultures.

Using an online questionnaire, we asked participants to consider the impact of not been able to see a painting directly. They were presented with two options (see **Figure 6**), and told that the museum is seeking their advice on what ticket price it might charge for these two "indirect" viewing options.

Think of a precious and well-known painting that you greatly admire – something as famous as the Mona Lisa by Leonardo da Vinci. Let's call it Painting A. You are familiar with this picture and you consider it the most wonderful work of art, but you have never seen the original.

Painting A is in a museum in a foreign city. You have an opportunity to visit that city for one day and you have time free to go to the museum and see your favorite painting. It is displayed on its own in a special gallery in the museum and visitors have to buy a ticket to enter that room and view the painting.

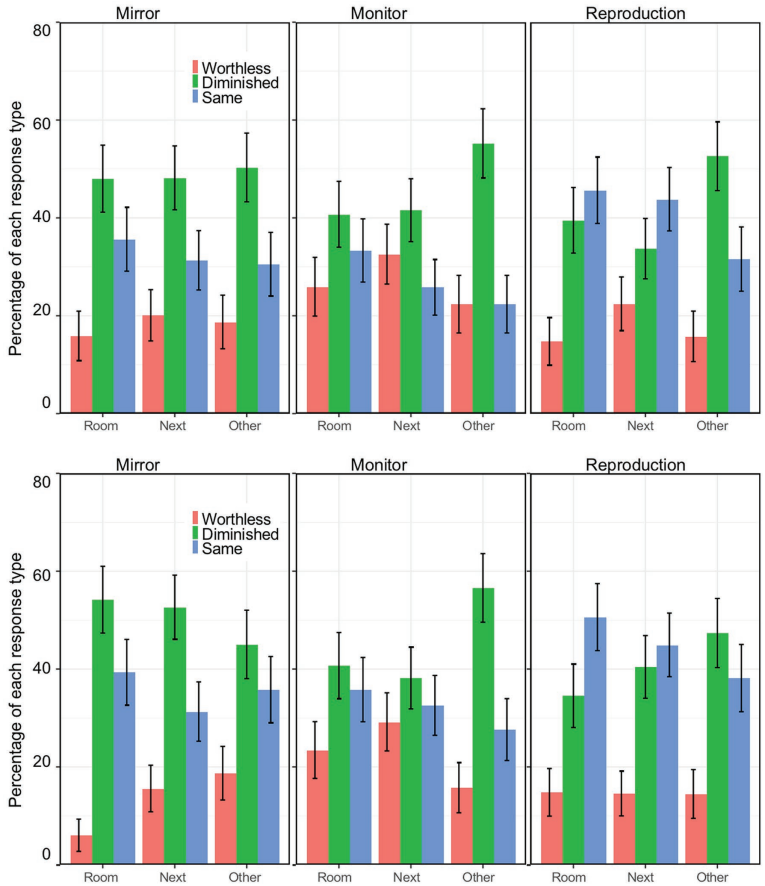

FIGURE 5 | Percentages for the three types of responses (it would be worthless, the experience would be diminished, and the same as the original) as a function of location. These data are for the question about what one would expect if they do not know that the painting is not the original. The columns show the three media (mirror, monitor, and reproduction) and the two rows show the response when the question is about the self, and when the question is about what most people would do. Error bars are standard errors for the mean.

Think of a precious and well-known painting that you greatly admire – something as famous as the Mona Lisa by Leonardo da Vinci. Let's call it Painting A. You are familiar with this picture and you consider it the most wonderful work of art, but you have never seen the original.

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Unfortunately, when you check online, you discover that tickets to see the painting have sold out. However, imagine that the museum is considering offering tickets for two different forms of 'indirect' viewing of the painting.

Please continue to see what options are available ..

<< >>

Option 1

The first possibility is that you could **see the painting via a mirror**. You would be allowed into the first part of the (very long) gallery, where you could look at a reflection of the painting in a large, high-quality mirror. You would see the painting as if it is hanging on the wall in front of you. The optical system would show you the painting with the same colours as the original, at the same size and not mirror-reversed. Note that light from the surface of the original painting would simply pass through the optical system and be reflected off the mirror into your eye.

Option 2

The second possibility would be for you to **see the painting via a video camera**. You would be allowed into the first part of the (very long) room where you could look at a large digital screen, on which you would see an image of the painting relayed from a high-resolution video camera viewing the painting directly. You would see the painting as if it is hanging on the wall in front of you. The digital system would show you the painting with the same colours as the original, at the same size and in fine detail.
The museum is seeking your advice on what ticket price it might charge for these two 'indirect' viewing options.

FIGURE 6 | The scenario described in the second study, and the two options presented in the next page. The order of the two options was randomly chosen per participant.

Unfortunately, when you check online, you discover that tickets to see the painting have sold out. However, imagine that the museum is considering offering tickets for two different forms of 'indirect' viewing of the painting.

Option 1

The first possibility is that you could see the painting via a mirror. You would be allowed into the first part of the (very long) gallery, where you could look at a reflection of the painting in a large, high-quality mirror. You would see the painting as if it is hanging on the wall in front of you. The optical system would show you the painting with the same colors as the original, at the same size and not mirror-reversed. Note that light from the surface of the original painting would simply pass through the optical system and be reflected off the mirror into your eye.

Option 2

The second possibility would be for you to see the painting via a video camera. You would be allowed into the first part of the (very long) room where you could look at a large digital screen, on which you would see an image of the painting relayed from a high-resolution video camera viewing the painting directly. You would see the painting as if it is hanging on the wall in front of you. The digital system would show you the painting with the same colors as the original, at the same size and in fine detail.

The two options were presented in different order for different respondents (randomly). The participant was asked to answer a question identical to that used in the first study about what they would consider a reasonable ticket to pay.

RESULTS (SECOND STUDY)

A total of 360 people completed the Mandarin version of the survey, and 200 people completed the English version. Participants were assigned randomly to one order (mirror first = 280, monitor first = 280). The sample was larger than that of the first study, which is useful to compare the two languages (English and Mandarin). However, participants were mainly undergraduate students, with a mean age of 21.2 (SD = 7.5) and 23.2 (SD = 4.08) for English and Mandarin versions respectively. Thus, we do not have the opportunity of testing the role of education.

For the mirror, more than a third of the respondents said they would not consider the option described: 35.4%. A minority said they were happy and did not need any discount: 10.6%. For the monitor, 22.19% would not consider this option and only 3.82% would pay the same (**Figure 7**). Overall, the pattern is not completely different from the first study except for a much larger proportion of people who opted for the discount. To fully analyze the responses, we computed the Ticket value in which all three responses are combined. These values are shown in **Figure 8**.

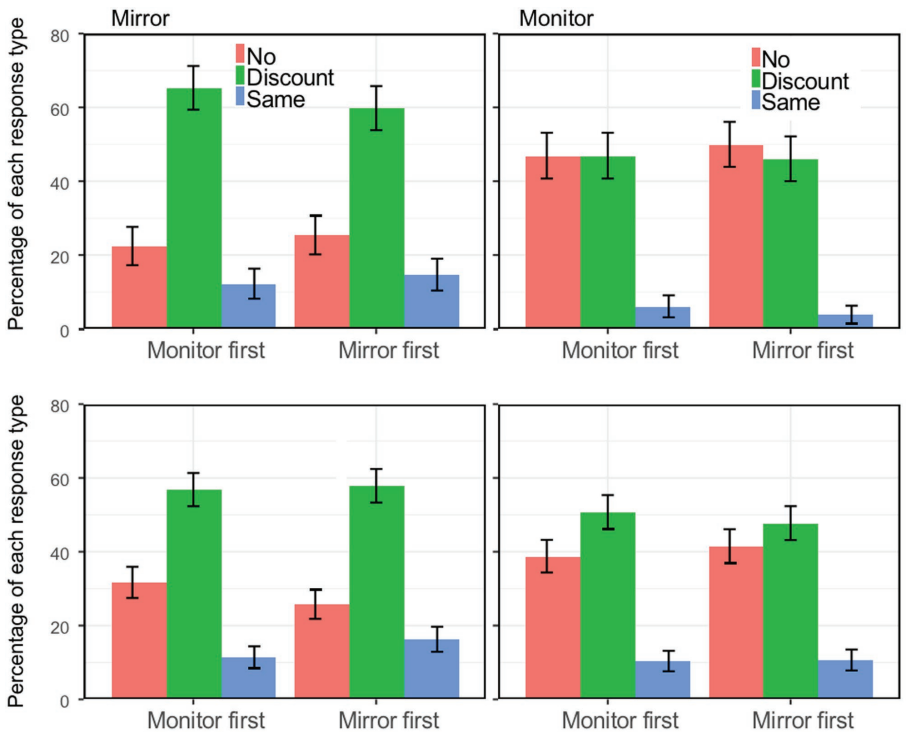

FIGURE 7 | Percentages for the three types of responses (no discount because it would be worthless, a discount, and the same as the original) as a function of Order of question (Monitor first, Mirror first) and separately for Medium (Mirror and Monitor) and for Country (Britain, China). Error bars are standard errors for the mean.

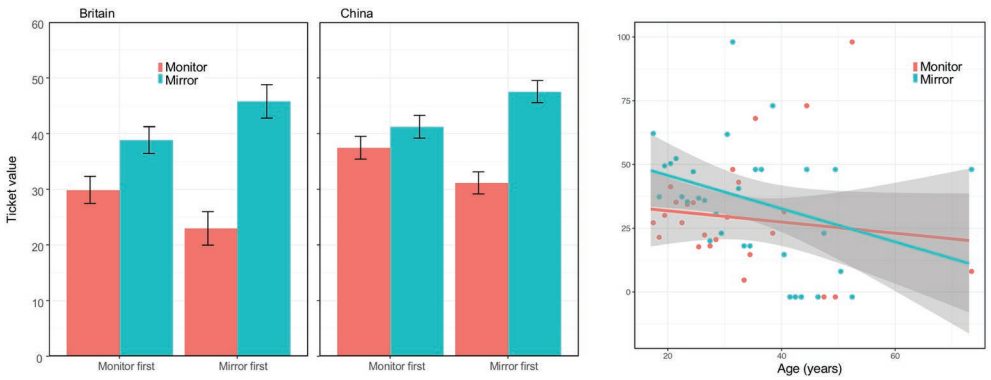

FIGURE 8 | Percentages for the three types of responses (no discount because it would be worthless, a discount, and the same as the original) as a function of Order of question (Monitor first, Mirror first) and separately for Medium (Mirror and Monitor) and for Country (Britain, China). (top right) Value as a function of age (log scale) and medium. Error bars are standard errors for the mean.

We used Ticket value as dependent variable in a mixed ANOVA. The within-subjects factor was the Medium (Mirror or Monitor). The between-subjects factors were the Order of the questions, sex, and language (English or Mandarin). To keep things as similar as possible to the analysis of the first study, we also included Age as a covariate.

There was an effect of Medium [$F(1,551) = 8.72$, $p = 0.003$, $\eta_p^2 = 0.016$]: the Ticket value was higher for the Mirror than for the Monitor. There was also an interaction between Medium and Order [$F(1,551) = 6.71$, $p = 0.010$, $\eta_p^2 = 0.012$]. As one can see in **Figure 8**, the interaction is due to higher values for whichever option is presented first. There was also an effect of Age [$F(1,551) = 6.16$, $p = 0.013$, $\eta_p^2 = 0.011$]. Ticket value decreases with age, as it was observed in the first study. We followed up the interaction effect with two *post hoc* tests to test if the Ticket value was higher for the Mirror condition in each of the two Order conditions. This was confirmed [$t(279) = 2.50$, $p = 0.013$ and $t(279) = 7.92$, $p < 0.001$, for Monitor first and Mirror first, respectively].

The results of the second study are consistent with those of the first study. Seeing the painting in the mirror was judged as a preferred option compared to a digital image of the painting. This was a within rather than a between design and presentation order also affected preference, with a primacy effect. In both studies what people were willing to pay decreased with age. One clear novelty of the second study was the comparison of results from a study in English, taken mainly by British undergraduates, and a version in Mandarin, taken mainly by Chinese undergraduates.

DISCUSSION

Using a survey, we collected views about how the experience of seeing a painting is affected by the way in which the image is made visible. In particular, we compared an indirect view by means of a mirror, and indirect view by means of a video camera and screen, and a direct view of a reproduction. In all cases, we made it very clear that the image had the same size, color, brightness and resolution. We asked to consider a hypothetical scenario where it is not possible to see the original work of art, and as a way to rate the alternative options, we asked to say how much cheaper the price of the visit should be.

Within these hypothetical scenarios, people expressed a range of opinions. It is interesting that there were large numbers of responses at both extremes. For many, it was not worth seeing the painting in any way other than seeing the original, and they did not consider any discount as adequate. However, for others, it was acceptable to pay the same ticket as the people who could see the original painting directly even if they could only see it indirectly or could only see a reproduction. Very different views therefore coexist in the population. Anecdotally, this is also true for the Lascaux Cave discussed in the introduction. Although large numbers of visitors enjoy Lascaux II and IV, some people would not consider traveling to the location of the cave to then only see a reproduction.

Our participants were stricter in the evaluation of what they themselves would find acceptable, compared to what they expected instead for "most people" (see also Leder et al., 2016). The answers to this second question were more tolerant of the options offered. The percentage of the ticket price that they would pay, overall, was only 30.6%, while what they expected for most people was 35.0%. Note these average values are low because they include the 0% from the cases in which they would not consider the option.

Next, we consider the issue of the medium. We compared a mirror reflection, a closed-circuit video camera (monitor), and a reproduction. Here, there was a pattern across the population with preference for the reproduction as compared to the digital (video) medium. The response to the optical (mirror) option was intermediate. We expected a superiority of the mirror compared to a monitor, but we did not expect a preference for the reproduction, which is a different object altogether with respect to the original. Indeed, based on an essentialist heuristic, we expected the copy to be liked the least.

The mirror in particular is an experience similar to a direct view, given the compelling visual experience that people have when seeing mirror reflections, including the image of their own body (Maravita et al., 2002; Bertamini et al., 2011; O'Sullivan et al., 2017).

In study one, we were surprised that the mirror condition was not considered the most valuable. One possibility is that being so close to the actual artwork and yet only being able to see its reflection made people aware of and unhappy with the constraint. This aspect (seeing the original but only indirectly) may not have played so much of a role in the case of a reproduction. We still have to keep in mind that responses varied considerably between individuals and also with sex. When opinions vary so much, the wording of the question is also critical, we can see that in the comparison between study one and study two. In the second study, we highlighted the fact that the light reflected comes from the artwork and that may have given the mirror an advantage over the monitor.

The fact that the preferred option was the reproduction may reflect the value that people assign to the presence of the material canvas, even though in this case it is a copy, as opposed to an indirect view. It is possible that an indirect view, through a mirror or a digital system, may feel less similar to a visit to see the painting. If the view is indirect, perhaps it is not different enough from seeing the painting on television or in a photo, which people can do without traveling to the location where the painting is kept.

In a second study, we compared the mirror and the monitor, and compared an English version with mainly participants from Britain, and a Mandarin version with participants from China. Results confirmed that the mirror was preferred to the monitor, but there was no difference between English and Mandarin groups.

Our methodology focused on choices and behavior, that is, what participants would do about the options. Only the additional question about the importance of knowing that the painting was not the original asked to evaluate the experience. Despite its limitations, hypothetical scenarios can be useful also to study metacognition about aesthetic value and aesthetic emotions. These terms are, however, still debated in the literature (Leder et al., 2004; Marković, 2012; Menninghaus et al., 2019).

In summary, questions about how the experience of seeing a painting is affected by seeing the original, or a reflection, a video, or a copy are not answered unanimously. For some people, not seeing the original is worthless, for others it is perfectly acceptable. Surprisingly, a copy is not always worse than an indirect view, on the contrary it may be the best option (first study) and a mirror reflection is better than an image shown using a video camera and a monitor (second study). Despite the large individual differences, the type of responses were similar in two different cultures (Western sample and Chinese sample).

DATA AVAILABILITY

The datasets generated for this study are available on request to the corresponding author.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Health and Life Sciences Committee on Research Ethics (Psychology, Health and Society). The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

MB collected the data and wrote the report. MB and CB conceived the original idea and completed the manuscript.

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Does Gallery Lighting Really Have an Impact on Appreciation of Art? An Ecologically Valid Study of Lighting Changes and the Assessment and Emotional Experience With Representational and Abstract Paintings

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We report two studies considering the potential for gallery lighting conditions to modulate appraisals and emotional experience with works of visual art. As recently documented in a number of papers, art appreciation represents a complex blend of formal artwork factors, personalities and backgrounds of viewers, and multiple aspects of context regarding where and how art is experienced. Among the latter, lighting would be expected to play a fundamental role. However, surprisingly, this has received little empirical assessment, with almost no ecologically valid gallery analyses and no between-participant designs which would minimize awareness of lighting changes themselves. Here, we employed a controlled paradigm using a spontaneous art viewing context, a gallery-like setting, and a proprietary lighting system which allowed the minute adjustment of lighting intensity/temperature (CCT). Participants viewed a selection of original representational and abstract art under three different CCT conditions (Study 1), modulated between participants, and then reported on their artwork appraisal and emotional experience. The selected lighting temperatures were chosen based on an initial investigation of existing art museums within the Vienna area, addressing how these institutions themselves light their art—a question which, also somewhat surprisingly, has not often been considered. We also allowed the same participants to set the light temperature themselves in order to test hypotheses regarding what might be an 'ideal' lighting condition for art. In Study 2, we explored the question of whether artworks made by an artist to match specific lighting conditions show a resulting connection to the ratings of viewers when shown in the same or different light. Results showed almost no effects from lighting changes in both studies. Viewers' self-set light temperature

(mean = 3777 K) did roughly coincide with the suggested most enjoyable conditions for everyday living and some past research on art viewing, but again showed wide interpersonal variance. Results, and a general review of lighting factors are considered in order to provide art researchers and curators with a tool for conducting future study.

Keywords: lighting, art perception, context, ecologically valid, gallery, aesthetic emotion

INTRODUCTION

Art experience is a complex activity. Engaging art can involve numerous processes, from meaning-making to emotions and appraisals, to personal associations and body response (e.g., Leder et al., 2004; Pelowski et al., 2016), all of which might blend together to produce an aesthetic experience. Even more, emerging research has also highlighted the fundamental role of context in modulating how art is reacted to and appreciated. When we do approach an artwork—in our homes, in a laboratory, and perhaps most saliently in a gallery or in a museum—our interaction is made under the influence of a wide range of factors—setting, hanging conditions, expectations, other people (Newhouse, 2005; Pelowski et al., 2017a for review)—that can color or even change our experience.

One factor that—intuitively—would be expected to play a fundamental role in art perception, is the lighting of art itself. As a visual species, and certainly since the inception of civilization, lighting has been a key aspect of human life (Werth et al., 2013). Lighting may spotlight and guide our attention. It may provide a tone or mood to our environments. Lighting may also be a key aesthetic aspect for artists. Both in art production and in final artwork reception, lighting may interact with certain colors or materials, and be a key part of the ambient art making-(such as North facing studios or plein air painting) environment. The use of lights to highlight and often to enhance artworks is also a universal practice in museums. Each individual museum may spend a great deal of money and attention on lighting, to very different effect. This goes hand-in-hand with an increasing variety of lighting technologies (e.g., LEDs, which can reduce issues of damaging ultraviolet or infrared radiation that had limited previous lighting options), providing curators a wide pallet of light intensities or color temperatures (e.g., Pridmore, 2017) and leading to arguments (e.g., Druzik and Eshøj, 2007) that lighting is *the* most complex and, thus, one of the most important factors in museum design, combining technology with perception, cognition, appreciation, and psychological experience.

However, perhaps due to the very same issues of multiple lighting varieties, potential modulating factors, and difficulties in access to museum spaces and in the ability to change lights, there is little systematic artwork lighting research. It is not established, for example, if there is an 'ideal' lighting condition for art objects. Nor are there standardized procedures for systematic study designs or controlled investigations focused on artwork enjoyment (Scuello et al., 2004b; Michalski, 2007; Nascimento and Masuda, 2014). Equally important, there is a need for empirical research that focuses on the actual impact of different lighting conditions on the spontaneous, ecologically valid experience with art. Present studies, which most often come from technically- or lighting-focused rather than art-focused perspectives, have almost exclusively used lab reproductions (e.g., light boxes with miniature art dioramas or screen-based images with computer generated lighting) and within-participant designs that ask individuals to make multiple appraisals of the same art object—typically assessing simple preference for lighting combinations—with light adjustments themselves very salient. We do not yet know if these results lead to important differences from actual gallery interactions, nor how lighting might impact a wider range of appraisals or emotional and even economic reactions. Nor do we know whether lighting changes, if obscured from the viewer as merely part of the overall museum engagement, have *any* measurable impact, leading to a glaring omission in present museum art research.

This paper offers a first between-participant analysis of the impact of lighting on the appreciation of art as this manifests in ratings, economic decisions, and emotional experience. This was done using an ecologically valid spontaneous art viewing gallery context and the use of a lighting system which allowed the minute adjustment of lighting intensity and temperature within the space, in conjunction with original representational (Study 1) and abstract (Study 2) paintings and a with lighting conditions modulated to minimize awareness of the actual lighting itself. The selected lighting temperatures were chosen based on an initial investigation of existing art museums within the Vienna area, addressing how they themselves light their art—a question which, somewhat surprisingly, has itself not often been considered (Kesner, 1997). In Study 2, via a unique opportunity to work with the artist of our study materials, we also explored the question of whether artworks made by an artist to match specific lighting show a resulting connection to the actual ratings of individuals when shown in the same or different lighting conditions. Because this paper is aimed at the researcher interested in the perception of art, whereas most previous literature is currently in the domain of commercial or technical lighting research, we also begin with a review of main theoretical and practical aspects of lighting choices and existing empirical studies for use in framing this and future research.

REVIEW: LIGHTING OF ART, KEY FACTORS, AND PAST RESEARCH

In order to contextualize the following studies, it is first useful to consider: (1) what are the main parameters of lighting, how do these vary or correspond to technologies (i.e., bulbs or lighting systems), and how do these connect with curator decisions? (2)

What are the existing parameters currently applied to art within galleries? (3) What is the existing art-related research from which this study can build and outstanding questions?

Main Lighting Factors and Types

When curators and museums approach lighting, there are of course several, potentially dueling, factors that might be considered (Scuello et al., 2004b for review). These include conservation and protection of art. Light—especially with paintings or other delicate materials, and with traditional incandescent or gas discharge fluorescent lamps which may emit infrared or ultraviolet light, as well as natural daylight—can cause photochemical damage leading to fading, yellowing, etc. (Fördergemeinschaft Gutes Licht, 2000). Thus, much of the earliest lighting research in museums focused on the conservation aspect, examining the effect of light on material (for review see Nascimento and Masuda, 2014; Pridmore, 2017) or providing suggestions for best practice so as to protect art (e.g.,Commission Internationale de l'Eclairage [CIE], 2004, see also below).

At the same time, emphasis is also given to "aesthetic" (Scuello et al., 2004b, p. 306) aspects of lighting choices. Museums and curators of course want to showcase their art and their spaces in the 'best light' and/or to provide an optimal viewing experience. Here as well, several factors may be important: for example, the brightness or clarity of objects or of details and light's general color (Linhares et al., 2009; Nascimento and Masuda, 2014), reflections of lights from object surfaces (Cuttle, 2007; Druzik and Eshøj, 2007), contrast, ability of lighting to reveal brushstrokes or textures, diversity of illuminated colors (Pinto et al., 2008; Nascimento and Masuda, 2014; Pridmore, 2017), as well as to provide a certain mood to a gallery or to generally increase comfort of viewers (Feltrin et al., 2017). Among these, and when describing art lighting choices, two technical parameters are however most commonly considered: (1) general brightness or illuminance and (2) color temperature.

Brightness, or more precisely, lighting intensity, is defined as the proportion of light that falls on a unit of area. This is typically denoted by the measure of Lux ('lx,' luminous energy by unit time, indicated in lumens per the surface area in square meters)[1]. Color temperature provides a means of quantifying the color impression of a light source (Paul, 1999). This is usually expressed as the "correlated color temperature" (CCT), measured in Kelvin ('K'), and denoting the temperature at which a blackbody radiator has the same color appearance as a source of light. This is a function of the specific spectrum of wavelengths making up a light, with relatively longer wavelengths seen as more yellow/orange and reddish, and shorter wavelengths more blue/purple. The specific balance of wavelengths and their respective power is then perceived by the viewer as a shade of color (Kienle, 1941), often subjectively described as relatively more "cold" (blueish light, having higher power among shorter wavelengths, but, somewhat counterintuitively, of relatively 'higher' Kelvins) or "warm" (higher power among reds and oranges of longer wavelengths, but of a lower Kelvin measure).

As shown in **Figure 1**, which displays several common light bulb types on a spectrum as well as the specific lighting conditions used in our forthcoming studies, artificial lighting styles tend to range from candlelight (∼2000 K) at the subjectively warmest extreme, to incandescent (2700 K) and halogen (3000) bulbs, providing a yellowish impression, to fluorescent or CFL bulbs that can have a wide range from yellow to quite blueish (3000 to 6500). Noon sunlight, about 5500 K, tends to be cooler than most indoor lighting.

Light's color temperature also interacts with an object's colors. Light of similar wavelength to an artwork's colors tends to accentuate these or make them stand out, while light that has an imbalance of power at certain wavelengths tends to diminish the appearance of colors at the opposite end of the spectrum—for example, leading to blackened blues from yellow lighting. The overall color accuracy or naturalness provided by a light, as a function of its balance of spectral power, is given by the Color Rendering Index (CRI). This is derived from a comparison of the color appearance of objects under a test light source against a standard light of the same color temperature, denoted on a scale from 0 to 100 (perfect duplication; see Veitch and McColl, 2001).

As will be seen in the review below, CCT, and to a lesser extent brightness, is the main focus of most past lighting research, and argued to play a key aspect of lightings' subjective experience or viewer preferences (Pridmore, 2017), and thus will also be the main focus of the present study.

Typical Lighting Conditions in Art Presentations/Museums

When looking to existing lighting choices in museums, the above factors appear to arise in a general range of combinations (Scuello et al., 2004b). Until quite recently, lighting decisions and research were primarily driven by needs of conservation. The total radiant energy from a light source that makes its way to an artwork is a function of lux times wavelength—with shorter (cooler color) wavelengths thus subjecting artworks to more total energy and, over a day or a lifetime of exhibition, more potential damage (Veitch and McColl, 2001). This aspect led to suggestions for best practice, with guidelines (e.g., Commission Internationale de l'Eclairage [CIE], 2004; see also Scuello et al., 2004b; Wilson, 2006; Druzik and Eshøj, 2007) recommending keeping art exposures in the range of 50 to 200/300 lx (with the higher number often used with medium sensitivity artworks such as oil paintings) and around 3000 K CCT.

The above guidelines, here too also contained an implicit aesthetic component. The selection of color temperature in relation to brightness followed work in the mid twentieth century by Kruithof (1941; see also Scuello et al., 2004b; and Fotios, 2017). This described a curve suggesting that a preferred range of color

[1]In measuring brightness, a distinction should also be made between "illuminance"—the amount of light that is emitted from a source—and "luminance" or the amount of light that reflects off of a target surface such as a painting (Veitch and McColl, 2001). Many previous studies have involved recordings of the first "illuminance" measure. However, luminance may actually pertain more to lighting's interaction with art as it is perceived by a viewer, and is thus both important to consider and may give a metric for comparing conditions.

temperatures varies with illuminance. The midpoint of the range at 200 lx was 3000 K. Although the exact suggestions from this work have been questioned in more recent empirical research (e.g., Fotios, 2017), many museums followed these guidelines, especially when they employed incandescent gas, fluorescent, and tungsten halogen lighting (Berns, 2011; Pridmore, 2017), which, as recently as a review by Pinto et al. (2008), were suggested to still be the most common modes of lighting in museums.

Note, the above ratio entirely omits color temperatures approaching open daylight—although many museums do employ baffled skylights where possible. Wilson (2006; see also Chartered Institution of Building Services Engineers [CIBSE], 1994) also suggest that a full appreciation of color itself is not possible until about 250 lx. Warm lighting also tends to desaturate blues in paintings, due to blue being complimentary to yellow, and may not accentuate more contemporary pigments of Modern and contemporary painting (Pridmore, 2017). More recent lighting technology such as LED do not emit UV and IR radiation and have a reduced visible radiation, thus potentially providing a fuller spectrum and cooler lighting temperatures (Pinto et al., 2008; Berns, 2011; Pridmore, 2017). This has led to an increasing range of options. For example, Pridmore (2017) suggests that replicated-daylight lamps in use in galleries in Europe and the United States are available in 3500, 4100, 4700, and 5000 K, and that tunable LED fixtures can range from 2000 to 5000 K.

Previous Art/Museum Lighting Studies

Despite the above range of technological advancements and outstanding questions, actual decisions for lighting are still typically based on subjective opinions of curators or museum directors or the above rules of thumb (Druzik and Eshøj, 2007; Nascimento and Masuda, 2014; Pridmore, 2017). Empirical research on the interaction of lighting and art is only now emerging. We briefly review these approaches considering art or museums below (We have also collected the past studies, with more in-depth details on their specific methodology and design aspects in **Supplementary Appendix Table A1**).

As can be seen in the subheadings below and in the Table, previous research has generally followed four main varieties and essentially highlighted a lack of empirical consensus regarding approaches or lighting's actual impact:

Survey/Comparison of Different Museum Conditions

The first type, and one of the earliest contemporary investigations (Kesner, 1997), used a qualitative/interview approach to compare general expectations regarding differing lighting factors among museum decision-makers (conservators, curators, exhibition designers) at multiple United States museums and asked how much effort and money should be invested toward each factor. The answers were joined by a similar survey given to visitors within museums of art. The study found, perhaps unsurprisingly, that both groups had different expectations. For museum staff, preservation was again the most important factor, and reducing glare or viewer visual comfort least important. Visitors gave particular emphasis to art appearance (color range, attractiveness; as might relate to especially CCT), but, interestingly, also claimed that brightness/contrast and reducing glare were least important. Also interesting, following the initial Kesner study, this type of comprehensive documentation of museum conditions is quite rare. Wilson (2006) briefly reported a similar project to measure the relation between background, lighting, and artifacts (mostly stone sculptures) in archeological museums, matched to visitor appraisals of the lighting. Lighting quality was primarily judged—in this case—by degree of contrast between object and background, but again not brightness. They noted that in some

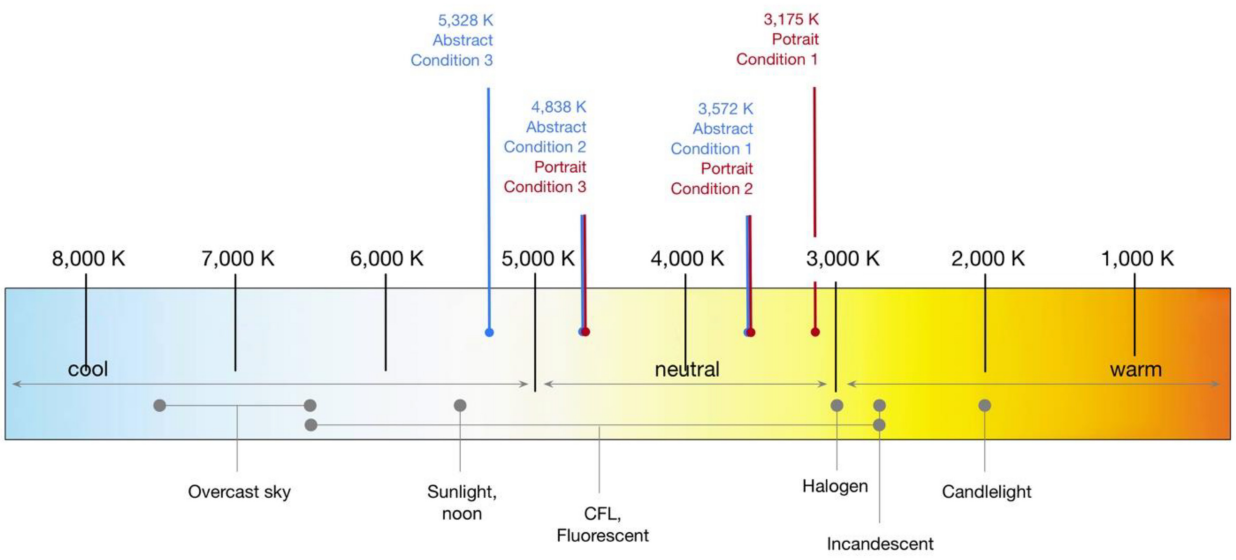

FIGURE 1 | General range of visible light temperatures and specific lighting conditions from Art Museums used in Studies 1–2 (relative temperatures of light technologies are suggestive; see e.g., Paschotta, 2008) (All figures created by the authors).

visitor-preferred configurations detail or clarity of the object would be lost, but, "visitors are unaware of this loss."

Self-Selection of Preferred Lighting

Second, empirical investigations have more directly tested lighting by asking individuals to either self-select certain lighting parameters (typically CCT and in some cases brightness or CRI) according to their taste or by using a series of forced-choice art/lighting comparisons.

Scuello et al. (2004b) displayed postcard-sized reproductions of impressionist/representational paintings (four total, divided among differing main colors, i.e., blues or reds) in light boxes. Viewers (N = 9) could look into the box through a porthole as if it was a diorama of a gallery. Using a forced-choice design, for each trial viewers looked at the same individual painting in two different dioramas with two (of eleven total) light conditions varied in CCT (2500–7000 K; illumination intensity kept constant at 200–250 lx) and selected "whether the painting looked better" and by how much using a 6-point scale. This was repeated for all paintings/illumination combinations, leading to each painting being seen 20 times under each given illuminant. The results suggested that 3600 K—generally supporting the previous rules of thumb above—had the highest percent of cases where it was selected against the alternative. However, the authors note, the results were "not overwhelming." A second spike of CCT preference also occurred at about 5400 K, whereas 3200 and 5000 K showed generally lowest preference. There were also pronounced individual differences, which were not further investigated. They also found very minor evidence for a potential interaction between paintings and lighting. Assessing the art after first acclimating oneself to differing CCT/illumination combinations, in an attempt to replicate what might occur when an individual enters a gallery from a different room, had no effect (see also Scuello et al., 2004a and **Supplementary Appendix Table A1**, for a follow-up study with similar, highly variant, findings).

Another set of related studies, first by Pinto et al. (2006), collected hyperspectral images of five Renaissance era oil paintings (all Madonna and child with dark background). These were used to create computer-generated images reproducing the art's appearance under five CCTs (illumination 200–400). Participants (N = 5) viewed the paintings on a monitor in the lab, with a trial involving the same painting shown twice in sequence with two different lightings and participants asked to choose which they preferred. Each lighting-art pair was observed 20 times (total 500 trials; 100 evaluations made for each individual painting). Across all but one painting-lighting combination, participants preferred higher color temperature (4450–6500), although it was unclear if this was simply a contrast effect tied to light rather than the interaction with art.

Pinto et al. (2008) conducted an extension with 11 oil paintings from the same museum, computer-generated to appear under CCTs from 3600 to 25,000 K (21 equally spaced steps), and a much larger sample of participants (N = 80), divided between art-novice undergraduate students (participating in a laboratory) and art museum visitors (using a computer to participate within the course of their visit to the museum). The lab participants assessed each painting three times on different days; the museum visitors once. Generally, the most preferred CCT was a cooler 5100 K, although again different peaks were found for each painting and participant.

Nascimento and Masuda (2014) conducted a similar study but with the real examples of the above artworks. Participants first viewed each painting on a monitor as above, selecting the ideal CCT (3600–20,000 K; 200 lx), with the entire painting set shown twice in random order. This was followed by a short break and the viewing of an actual paintings, hung on a wall, each shown individually with adjustable lighting. The entire task was repeated with a total number of ratings for each artwork in monitor condition of 8; real condition was 12. In order to ensure an even coverage of light in the real condition, the paintings were partially covered with a black frame. The study used seven participants. No mention was made of whether participants stood in the real art condition, nor if this approximated in any way an actual gallery. Both conditions returned similar results, with an average CCT of 5500 for real, 5700 K for monitor, but once again with a CCT varying between paintings—with roughly half having a mean CCT lower than the previous study's finding and half higher—and also varied markedly between participants.

Scale-Based Rating of Different Lighting-Art Combinations

Third, a few studies have begun to move beyond basic preference to a broader set of scale-based ratings, however still focusing on general artwork appearance. Luo et al. (2013) used six hand-painted copies (made by other artists) of original pieces from the Taipei Fine Arts Museum. The artworks were illuminated by 15 CCT/illumination combinations and placed in a light cabinet (no information given on hanging aspects). Participants (30; half science/engineering students, half art students) sat in front of the cabinet and viewed the art in each lighting combination and rated the paintings for physical attributes (colorful/dull, bright/dark, clear/blurry) and for "psychological perception" factors (warm/cold, relaxed/tense, soft/hard, natural/unnatural, active/passive, comfortable/uncomfortable, modern/classical, pleasant/unpleasant). The preferred lighting was 5000 K for art students and 4000 K for science students, both at 300 lx. Principal Component Analysis of the appraisal scales also suggested two components— "warmth" (warm/cool, classical/modern, soft/hard; presumably connected to CCT) and "visibility" (all other scales, including pleasantness).

Feltrin et al. (2017) affixed a painting on a metal stand at a typical hanging height with a viewer seated in a chair looking into the space (similar to Scuello et al., 2004b), and viewing one of five reproductions of impressionist paintings printed on canvas and with either a prominent color of red, blue, green, yellow, or their combination. The pictures were illuminated with five CCTs (all ∼160 lx) and backed with three different curtains (white, gray, black) to test interaction of lighting, art, and background color. Participants (25, with nine fellow researchers in the same laboratory) viewed each painting under all lighting conditions shown successively in random order (totaling 15 viewings per painting) and reported assessments using six

bipolar scales (painting color's warmth, vividness, brightness, attractiveness; as well as overall appreciation of the arrangement and of the background). Importantly, with each new painting, all five light configurations were first cycled through in order to give participants an idea of the differences, but of course also making the changes very salient. Results, as is of course a theme throughout this review, showed a range of preferences, with CCTs of 3500, 4000, and 5000 K nearly equally preferred. Background color again showed no difference. A similar preference trend was also found for all paintings regardless of the predominant artwork hue (again generally similar to Scuello et al., 2004b).

Lighting Studies in Original or Approximated Gallery Settings

Finally, to our knowledge, only three studies have actually considered art as it might be encountered by a viewer moving somewhat naturally inside a gallery setting. Balocco et al. (2018) used a room with a wall-sized fresco depicting a tree-lined path with a building in the background, and gardens and architectural elements in the foreground. The artwork was lit with three accent lighting conditions modulating CCT. Participants (N = 15) were asked to enter the room and perceive the artwork as it was lit in succession by all three configurations for 15 s each, "expressing [their] own preference." Participant then selected which light they preferred, with the entire paradigm repeated three times (no mention of balancing/randomization). They also employed mobile eye-tracking to consider impact of the light on looking patterns. Roughly half (54%) of participants preferred the coolest (4049 K) light. Participants also showed generally similar areas of visual interest and visual pathways across conditions. However, the preferred, bluish light had relatively more fixations on areas of interest before moving to another, and lower transition entropy, which they suggest might tie to higher clarity of colors and brightness.

Yoshizawa et al. (2013; see Zhai et al., 2015 for results and discussion) provided a brief report in a conference proceeding of one of the most ambitious approaches. They first employed a mockup gallery space with reproductions of three oil paintings (16th century portrait, 19th century impressionist landscape, 20th century abstract) under 52 combinations of CCTs, illuminances, and CRIs. They also conducted a second study in the Morohashi Museum of Modern Art in Japan with real oil paintings seen under nine CCT conditions (illuminance constant). Participants (number not known) viewed each painting-lighting combination and made evaluations using bipolar scales. The ratings were assessed with Structural Equation Models. These suggested the two factors of "visibility" and "texture" were most important for driving preference in both conditions. Notably, while illuminance did show some importance for determining subjective assessment of both factors, CCT showed the strongest relation, with a negative correlation regarding texture and a positive correlation with visibility. Color rendering showed only very low relation to preference variance.

Zhai et al. (2015) conducted a similar study on the combined impact of CCT and illuminance on art appearance and on the general mood or felt "atmosphere" of a gallery. They employed a room mocked up to resemble a museum gallery (white walls, wood flooring), with six paintings (all representational with a slightly impressionistic style; using similar muted pinks, oranges, and blues). These were hung, individually, on one wall. A LED was used to illuminate the paintings, notably acting as a directed spotlight rather than lighting the entire room evenly, and with 12 combinations of CCT/illuminance, corresponding to the lower and upward limits of recommended lighting in museums (Commission Internationale de l'Eclairage [CIE], 2004). Participants (N = 24, divided equally into students majoring in non-art and art fields) viewed each of the paintings under all of the lighting conditions, shown in succession, with the viewer making a rating for each combination using six scales expected to relate to "appearance" (Warm/Cool, Bright/Dark, Clear/Unclear, Colorful/Dull, Natural/Artificial) and eight scales relating to "atmosphere" (High/Low Quality, Active/Negative, Relaxed/Tense, Soft/Hard, Artistic/Business, Lively/Boring, Comfortable/Uncomfortable, Pleasant/Unpleasant). No mention was made of whether the relation of the scales to the paintings or to the room atmosphere was actually communicated to participants. A principle component analysis and Structural Equation Model returned components involving clarity, warmth, brightness, contrast, comfort/pleasantness, and finally "artistic aspects" (relaxed, warm, soft, artistic). Especially, ratings for this latter group decreased as CCT increased (becoming cooler). On the other hand, ratings for contrast, brightness, clarity, and quality showed an opposite pattern. They also suggested that the results "implie[d] that different paintings could be enhanced by applying different lighting conditions," although they do not discuss these differences.

Summary, Issues, and Outstanding Questions With Previous Art Gallery Lighting Research

Overall, the present lighting and art studies, although providing important tools and bases for study designs, do not provide clear or consistent effects. They also include methodological decisions or study foci leaving open many important questions especially for the ecologically valid art engagement. Notably, many of the studies have very small samples (e.g., less than ten) with a range of methodologies and can only be treated as purely exploratory.

Across the above studies there is a quite high variability and inconsistency with even basic aspects such as color temperature (CCT) and illumination. Beginning with CCT, a summary of the reviewed studies shows not only do they not often coincide with the beginning rule of thumb of the typical Kruithof/museum 3000 K range, these have been all over the map, often depending on the individual study: e.g., from 2850 or 2900 (Liu et al., 2013; Zhai et al., 2015) to 5500–5950 (Liu et al., 2013; Nascimento and Masuda, 2014), and notably with several studies reporting both lower and higher CCT preferences in the same analyses depending on different viewers or set-ups. At the same time, more advanced statistical models (Yoshizawa et al., 2013) suggest that CCT especially may have an important impact on subjective assessment of art. Similar variance is found for brightness,

although in art ratings, rather than assessments of clarity, this does not appear to have such importance (see Yoshizawa et al., 2013 for empirical study-based argument; Kesner, 1997 for similar qualitative findings).

Importantly, in trying to unite and understand these differing findings, Nascimento and Masuda (2014) suggested that the CCT differences could be due to study design, with studies using miniaturized paintings or light boxes suggesting preferred illuminants with relatively lower CCTs (around 3600 K), whereas studies with art photographs taken from a gallery but shown on a computer monitor suggest higher preferred CCT (around 5100 K) and experiments with tunable LED on actual paintings leading to a range of CCTs from 3000 to 6000 K, depending on the painting. This argument notably also omits consideration of art in an actual gallery setting. Similar issues can also be raised for the more artwork-focused ratings, which show equally varied findings.

The above issues also raise the importance of ecological validity in regards to art viewing conditions in general. Even beyond the many existing studies conducted on a monitor, which could obviously show differences from real art engagement—i.e., relating to texture, brushstrokes, technique, highlighted differently by different lighting conditions (Pelowski et al., 2017a)—the studies that attempted to mimic a gallery space did so, in most cases, by mocking up a single wall or by only letting individuals look into the space, often with a seated viewer (e.g., Feltrin et al., 2017). By excluding the viewer in this way, this means that the individual is not actually within the lighting and not sharing the same environment as the art pieces. Use of carefully controlled light boxes, although perhaps ideal for focus on uniform lighting, could also omit important aspects. For example, Wilson (2006) suggests that diffuse illumination may increase clarity but also may omit texture on the surface of a painting.

Would a Between-Participant Design and Focus on the Artwork Show a Lighting Impact?

Perhaps most pressing, there is a major question regarding the within-participants designs of past studies and the nature of rating questions. Asking participants to re-rate the same paintings multiple times, in some cases more than ten or twenty ratings for the same artwork, raises serious issues for art appreciation. Although this method obviously has advantages for comparison, the study designs put very obvious stress on the subtle differences between lighting conditions, raising the question of whether it is this design that is driving most results. Most current art studies, which focus on the perception and ratings of the art itself, also stress spontaneity and use of images previously unseen and reducing repeat viewings due to conflation that can occur from previous exposures (fluency, familiarity, mere exposure, contrast effects, etc.; see e.g., Forster et al., 2013). This is also coupled with almost a complete lack of ratings meant to assess the actual enjoyment by participants of the works of art themselves. Rather, questions are almost always addressed to whether an individual prefers a certain light-artwork combination. Thus, it is interesting to assess whether participants might show differences if assessing only the art without obvious awareness of lighting, or how they might answer more hedonic or pragmatic questions of interest to curators or art researchers.

The above issues, essentially, raise the need for a between-participant design. Interestingly, the above arguments, coupled with the present lack of clear effects in studies that do tend to force awareness of, and perhaps subtle differences in, lighting, raise the rather cynical question of whether light has any impact if it were to be tested in such a way, within an ecologically valid art interaction. Veitch and McColl (2001) make this point in their review of one of the more intriguing series of studies for lighting's impact on evaluations or performance—the experiments conducted in the 1920s at the Western Electric plant in Hawthorne, Illinois (Snow, 1927). These involved researchers changing lighting within a designated room of the plant—changing bulb types, increasing and decreasing illuminance; pretending to make changes. In every case, whatever the modulation, performance increased, suggesting only a placebo effect. Veitch and McColl (p. 8) conclude "one lesson to be learned from this series of investigations is that lighting research [may include] the confounding effect of participant expectancies, which can seriously bias empirical outcomes." This is particularly so with within-participant designs "because the nature of the stimulus is impossible to hide [from] subjects."

The argument for only a minor impact from lighting may also be supported in current research that has used between-participants paradigms to investigate the impact of lighting on mood or the 'feel' of a space. Lighting choices, much as with art, are argued to impact mood, most often following the suggestions that we may tend to feel more pleasant in warm/low-lux light and perhaps be more alert in cool/high-lux environments. However, the handful of studies that have tested lighting impact on mood changes using a between-participant paradigm have not found strong or consistent effects in both laboratory and field experiments (see e.g., Baron et al., 1992; Knez, 1995; McCloughan et al., 1999; Knez and Kers, 2000). See also Boray et al. (1989), who reported no differences in attractiveness ratings of human actors between three CCT conditions.

More generally, studies on visual perception also support the suggestion that individuals may be quite good at minimizing lighting impact. The so-called 'color constancy phenomenon' (Foster, 2011; see Nascimento and Masuda, 2014; Berns, 2016; Pridmore, 2017 for discussion in context of art) suggests that human vision tends to maintain the impression of colors between illuminants. That is, although if one is asked to judge a color or a stimulus in a controlled setting minimizing context and putting emphasis on light, there may be differences, if they view an object or a depicted image for which individuals 'know' the color and are not made aware of the changing light, the images do not tend to look different. Such a phenomenon might obviously tend to minimize impact from light on appreciation of art.

Matching Display Lighting to the Intentions/Making Conditions of Artists

Finally, the above issues also touch one other, rarely empirically explored, aspect that will be considered in this paper: artists themselves might have specific recommendations for lighting or display context, or, certain artwork making conditions may assume certain lighting types. Certainly, such arguments are well-documented in art history (e.g., Newhouse, 2005). Authors note the phenomenon of al fresco painting or of artists working in studios with Northern lighting, and suggest that natural lighting (i.e., 5500 K) would be the ideal conditions to view paintings as well (Kemp, 1990; Pinto et al., 2006, 2008; Pridmore, 2017). Other artists may seek out special interactions with lighting via glazes or color palette (Olszewski, 1985; Newhouse, 2005).

To our knowledge, only one study has actually investigated lighting with more specific artist intentions, also highlighting the importance of spontaneous interactions via a between-participants design. Leonards et al. (2007; see also **Supplementary Appendix Table A1**) assessed perceptions of the Renaissance painter Duccio's 'Annunciation,' which depicts a virgin and angel and made strategic use of gold leaf to highlight symbolically important regions (such as the hand of the virgin). The researchers measured the reflective properties of gold leaf and then created digital versions of the painting under lighting conditions mimicking beeswax candlelight (expected light for the artwork) and contemporary display conditions. Individuals viewed the painting in one or the other condition on a monitor while tracking eye movements. The candlelight group had more fixations on the gold leaf areas, rather than areas of typical saliency such as bright colors or faces. They concluded that gold leaf creates a dramatic glow effect when lit by candles, which would be anticipated by the artist.

This raises an intriguing further possibility for lighting interactions, and especially appraisals, as they occur in a gallery. Note, the above study did not include participant ratings of the artwork.

Present Study

The present study used a multi-part procedure to begin testing, in an ecologically valid manner, how lighting influences our spontaneous aesthetic experiences of real artworks: The first part of this project involved the background analysis of how existing art museums themselves light their art. This involved sending a researcher into a representative sample of museums within the Vienna area to measure ambient light conditions of gallery spaces. As one of Europe's preeminent cultural capitals and destinations for art tourists, this provided a large number of museums (containing both classical and contemporary art, although of course confined to only one city). These are briefly reported below in order to provide one more line of information to interested readers regarding the existing range or potential commonalities of lighting approaches. This preliminary research also provided a range of concrete lighting examples for use in the subsequent studies.

In Study 1–2, we then considered if differences in lighting type, selecting from the specific museum examples, modulate both the hedonic ratings (liking, assessed beauty, interest) of art as well as the felt emotional experience and willingness to pay to revisit the works. The studies also made use of both representational (portraits) and abstract paintings, borrowed from area museums and artists. The selected lighting temperatures were chosen to provide a general progression from bluer to yellower (warmer) shades. Thus, although largely exploratory, as a working hypothesis it was expected that we might find either general main effects for certain CCTs (e.g., improvements in both subjective mood and art appraisals as the light temperature moved to the warmer end), or transversely, we might detect an interaction whereby specific temperatures resonated best with specific works or broader abstract/representational styles. We also allowed the same participants to specifically set the light temperature themselves to add one more data point to the above-reviewed range of findings. In Study 2, we further explored the question of whether artworks made by an artist within, or to match, specific lighting conditions, do in fact show a resulting connection to the actual ratings of individuals when shown in the same or different conditions. This was done by using three abstract works painted by an artist with the foreknowledge and actual use of the light apparatus used in our studies, and with each specific work designed to be particularly suited to one lighting level (in regards to its contrasts and colors).

BACKGROUND COLLECTION OF AMBIENT LIGHTING CONDITIONS IN MUSEUMS

Method: Stimuli/Materials and Procedure

To create a beginning understanding of lighting conditions as actually used in museums, measurements were made in 15 institutions, selected in order to provide a representative range of more classical and contemporary spaces and art, as well as to account for all of the major and some lesser-known museums in the area. The measurement procedure was developed together with researchers at Graz University of Technology. All selected exhibition spaces, representing the main or most-representative gallery of the museums, had similar rectangular floorplans, thus the same procedure was used in all cases. The researcher used as a measuring tool a digital spectrometer (UPRtek MK350), capable of recording CCT, CRI, and lux, as well as the RGB color space (i.e., CIE1931). To measure the general ambient lighting conditions (illuminance) of the rooms, the digital spectrometer was positioned at a standard height of 155 cm above the floor at the center of each gallery space and facing one of the four corners. The spectrometer measured the light conditions in the form of a sphere, however, only the average of the first quarter, facing the corner, was recorded. The procedure was repeated for each of the four corners, with the four results then averaged. To measure the CRI, a series of measurements of luminance, or reflected light off of the room surface, were taken with the tool 155 cm above floor and 1 meter from both exhibition walls as well as 10 cm in front of the canvas of all paintings in

the direction of the light source, with the results averaged into general measures. The spectrometer was re-calibrated before each individual measurement.

Results and Discussion

Table 1 displays the lighting conditions (specific museum names have been withheld, however a general description of artwork type is provided). As can be seen, the results do suggest quite a range of lighting CCTs—5328 K at the coolest temperature to 2919 at the warmest—covering the spectrum of the arguments in the above literature review. The mean temperature (3759.3 *SD* = 727.9) was generally higher than the earlier Kruithoff-based/museum best practice arguments for around 3000 K, and much closer to the empirical findings of preferred illuminants around 3600 K from light box studies. A comparison based on the broad types of art in the museum collections showed that galleries with classic artworks tended to have the lowest, quite consistent CCTs (M = 3274 K, SD = 92.0); museums with Pre-Modern (e.g., impressionism, etc.) to early Modern artworks had higher (M = 3686.3, SD = 802.8), and museums with late Modern to contemporary art had the highest (M = 3977.8, SD = 789.0).

The measured illuminance, overall, also showed a wide range—50 to 697 Lux. Interestingly, while the classic art museums had illuminations directly in line with typical best practice guidelines (M = 200 lx), Contemporary galleries actually had a lower mean of 190.5 lx, while Pre- to early-Modern museums showed a higher 249.5 lx. A rather large positive correlation (r = 0.617) was found between CCT and Lux. This of course would tend to go against the general Kruithof-based practice, and with these findings suggesting, as intuited in the introduction, that there does appear to be, even within this small sample, a large number of lighting solutions with little in the way of clear shared patterns.

TABLE 1 | Ambient lighting conditions in galleries of museums in the Vienna area.

Museum	Art type	Date of measurement	CCT (K)	CRI (0–100)	Lux
04	Classic	5/28/17	3175	88	66
11	Classic	3/7/18	3357	92	399
14	Classic	3/30/19	3290	85	135
02	Pre-Modern	4/7/17	4838	87	505
08	Pre-Modern – Modern	11/9/17	3397	91	64
13	Pre-Modern – Modern	3/9/19	3530	93	281
15	Pre-Modern – Modern	5/14/19	2980	90	148
06	Modern – Contemporary	8/12/17	4824	89	126
07	Modern – Contemporary	8/12/17	3618	79	62
12	Modern – Contemporary	3/7/18	4192	89	70
01	Contemporary	3/29/17	3572	90	50
03	Contemporary	4/30/17	2919	95	108
05	Contemporary	10/17/17	5328	86	697
09	Contemporary	11/14/17	3989	96	195
10	Contemporary	11/24/17	3380	81	216

Values represent an average value from multiple systematic measurements of single exhibition spaces inside the selected institutions. The chosen exhibition space represented the most representative room in the institutions.

STUDY 1 AND 2—EMPIRICAL COMPARISON OF LIGHTING CONDITIONS WITH THE SAME ART

We then moved to the experimental portion of this project, wherein we considered if lighting, using specific examples chosen from above, modulates the appreciation of art.

Participants

The studies involved 63 participants (32 female; M_{age} = 22.63, SD = 2.32), recruited as part of a bachelor's seminar at the University of Vienna, however on a voluntary-basis without class credit or other remuneration. All participants had normal or corrected-to-normal vision and were not color blind. All were art novices (as confirmed by post-study interview and survey), without any previous training in art history, philosophy, or art production. The gender distribution was intentionally balanced (as much as possible), due to previous suggestion of gender differences in regard to hedonic responses to lighting conditions (e.g., females tend to prefer softer, warmer, less intense light, Knez and Kers, 2000). However, this did not prove to be a key factor in the findings (see also below).

All participants completed both Study 1 and Study 2. However, as described more fully below, the lighting conditions were changed between-participants, with the participant sample therefore further divided into groups based on the specific lighting condition (see also **Table 2**), leading to 20 participants for Study 1 Condition 1, 20 for Condition 2, and 23 for Condition 3 in the portrait rooms; and 22 participants for Study 2 Condition 1, 21 for Condition 2, and 20 for Condition. Importantly, groups did not show any significant differences in age, gender distribution, or art knowledge.

Materials and Room/Art Set-Up

For the studies, two gallery spaces were provided to the authors by the University of Applied Arts Vienna (see **Figure 2**). Both rooms were 4 × 4 m, with a doorway on one wall to an outside anteroom and without any other views or windows to the outside

TABLE 2 | Lighting conditions for Studies.

Condition	CCT (Kelvin)	Lux	CRI	Museum/type (from prelim. Study) ['ideal' artwork match for Study 2]
Study 1 (Portraits)				
Condition 1	3175	580	93	04/Classic
Condition 2	3572	590	92	01/Contemporary
Condition 3	4838	505	87	02/Modern-Contemporary
Study 2 (Abstract)				
Condition 1	3572	590	92	01/Contemporary [Artwork 4]
Condition 2	4838	505	87	02/Modern-Contemporary [Artwork 6]
Condition 3	5328	520	86	05/Contemporary [Artwork 5]

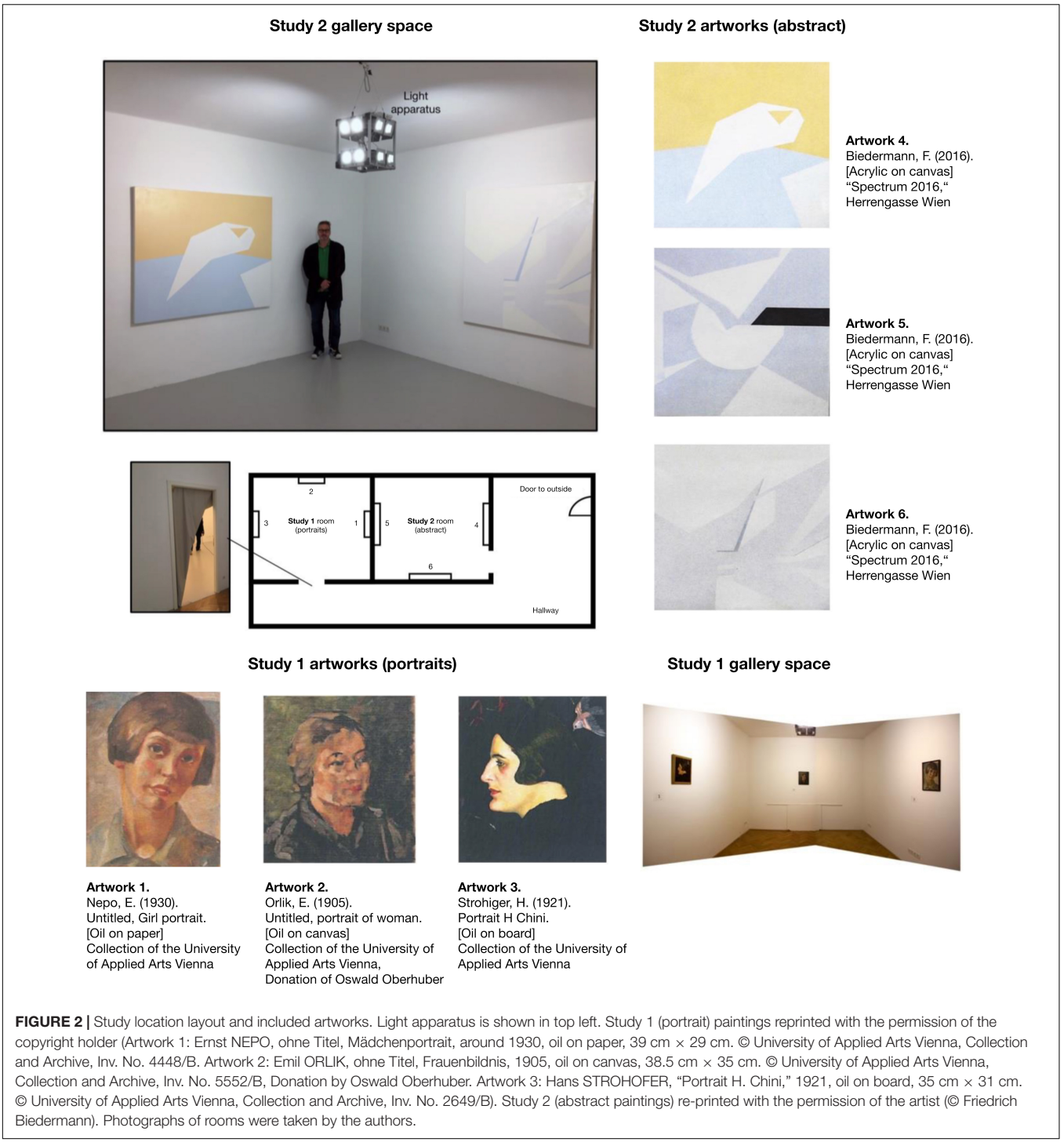

FIGURE 2 | Study location layout and included artworks. Light apparatus is shown in top left. Study 1 (portrait) paintings reprinted with the permission of the copyright holder (Artwork 1: Ernst NEPO, ohne Titel, Mädchenportrait, around 1930, oil on paper, 39 cm × 29 cm. © University of Applied Arts Vienna, Collection and Archive, Inv. No. 4448/B. Artwork 2: Emil ORLIK, ohne Titel, Frauenbildnis, 1905, oil on canvas, 38.5 cm × 35 cm. © University of Applied Arts Vienna, Collection and Archive, Inv. No. 5552/B, Donation by Oswald Oberhuber. Artwork 3: Hans STROHOFER, "Portrait H. Chini," 1921, oil on board, 35 cm × 31 cm. © University of Applied Arts Vienna, Collection and Archive, Inv. No. 2649/B). Study 2 (abstract paintings) re-printed with the permission of the artist (© Friedrich Biedermann). Photographs of rooms were taken by the authors.

or to each other. The doorways to both rooms were also covered with a curtain to block any ambient outside lighting. The rooms were painted white (walls and ceiling), mimicking a typical 'white cube' gallery. The specific paint for the walls (clear white matte, "StoColor Rapid Ultramatt") was chosen based on pilot testing (seven samples of different manufacturers, all recommended for exhibition spaces) to maximize the range of wavelengths reflected so as to ensure the fidelity of the artwork colors and lighting. Each room was fit with a light apparatus, hung in the center (see below), and had three different artworks (each hung individually on one wall). The common anteroom was used as a welcome area during the study phase. All windows of the anteroom were also covered and it used a light source with a similar spectrum and CRI to those used inside the exhibition

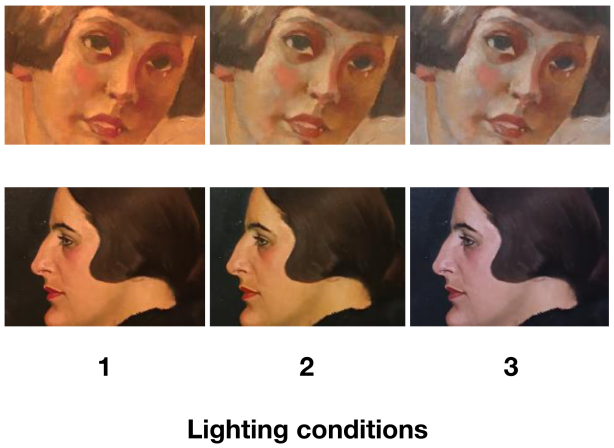

FIGURE 3 | Paintings (Study 1, portraits) seen under different lighting conditions. Paintings reprinted with the permission of the copyright holder (Top: Ernst NEPO, ohne Titel, Mädchenportrait, around 1930, oil on paper, 39 cm × 29 cm. © University of Applied Arts Vienna, Collection and Archive, Inv. No. 4448/B. Bottom: Hans STROHOFER, "Portrait H. Chini," 1921, oil on board, 35 cm × 31 cm. © University of Applied Arts Vienna, Collection and Archive, Inv. No. 2649/B). Photographs of paintings under different lighting conditions were taken by the authors.

spaces, so that the eyes of the visitors could adjust to the artificial light.

The paintings for Study 1 consisted of three figurative portraits of young women (all similarly sized oil on canvas with a realistic/slightly impressionistic style consistent with the early 20th century; see **Figure 2** for images and artist information; **Figure 3** shows the paintings under the different lighting conditions) from the collection of the Oskar Kokoschka Zentrum of the University of Applied Arts Vienna. The paintings were selected in agreement with a curator and art historians, included a generally wide-range of colors and darkness/lightness, and represented artworks that we expected most novice viewers might consider to be 'typical' non-abstract paintings as seen in many museums.

Study 2's paintings consisted of three abstract artworks (acrylic on canvas; all 1.4 × 1.6 m; see **Figure 2**). All were by the artist Friedrich Biedermann (from the 2016 series, "Spectrum 2016"). The paintings consisted of geometric shapes on a colored background. All were painted in such a way as to specifically anticipate a certain lighting condition. This was done by converting the measured light conditions (CIE1931 color space, which provides a measure of the mixture of RGB elements) taken from museums in Study 1 and mixing the actual paint for the artworks so that these matched. Thus, as noted in the introduction, when displayed under the corresponding lighting, the chosen colors would be accentuated or, transversely, if shown under light with opposing characteristics, would become generally black or fade into the background.

Lighting Apparatus and Conditions

The light source for both rooms was a custom unit created in part for this study (by studio Okular, Mag. AG, Architect). These used a cube-like design with four LED spots (Human Centric Lighting system PiLED, 500 mA with mixing chamber, SMD high power LED Module, Lumitech Produktion und Entwicklung GmbH, Jennersdorf, Austria) on each side of the apparatus. This allowed the control of CCT (1800 to 16,000 K) as well as visible colors (CIE-xy points and RGB colors) and illuminance. For both rooms, the lighting conditions were controlled via a laptop computer (PiLed and Loxone software) situated in a storage space not visible to the participants.

For the purpose of the studies, we used lighting conditions corresponding to actual conditions within three Viennese museums as measured in the preliminary study, manipulating CCT while keeping Lux relatively constant (505–590). Note also that the CRIs were relatively constant as well (86–93). For Study 1 (portrait room), which tested the basic potential for different lighting to modulate appraisal or art experience, we selected three light conditions covering a general range from 3175 K, corresponding to typical Kruithof-based museum conditions; 3572 K, corresponding to suggested CCT findings from lightbox studies; 4838 K, corresponding to monitor and potentially museum-based results (Nascimento and Masuda, 2014). Study 2's (abstract art) room also used three lighting conditions with a similar range. These also corresponded to actual lighting conditions of specific museums (see **Table 1**). However again, in this case, these were selected by the artist to specifically match ideal conditions (accentuating blues, yellows, grays, respectively) for enhancing the experience when viewing the paintings.

Procedure

Participants were invited to the testing location and met in the hallway outside the testing rooms. Participants were informed that they would be asked to view a selection of art and to make some ratings and signed an informed consent. Importantly, no mention was made of the varying light conditions, and participants were only exposed to one lighting condition per room. The participants were led individually to each room, given a paper survey and pencil, and asked to enter, view, and then to rate the individual paintings using the corresponding scales. The participants had no time limit and were asked to treat the encounter as if they were visiting a museum or gallery. After they finished viewing and rating the art in one room, the first survey was collected and the entire procedure was repeated for the second room.

Artwork Rating Surveys

The post-viewing surveys for both rooms consisted of a series of Likert-type scales assessing: (1) general artwork appraisal (beautiful-ugly, like-dislike, interesting-boring, would/would not pay to see again; 7-point, bipolar)[2]. These terms were selected to coincide with many previous empirical studies of art and

[2]Note, the original study design had included four additional scales (active-passive, high quality-low quality, meaningful-meaningless, strongly affecting-weak-affect). However, following data-collection and participant exit interviews, it was determined that these scales were highly redundant with the above selected terms or (in the case of quality) showed wide variance in participants'

generally assessed aspects of hedonic appraisal as well economic factors of interest to museums. (2) We also assessed general emotional experience when viewing the paintings using three unipolar 7-point scales (1 = 'not at all'; 7 = 'extremely') for positive emotions, negative emotions, and arousal. The scales were repeated three times in each room for the different artworks with a label identifying the artwork they should be addressed to (and corresponding to a wall label).

Self-Adjustment of 'Optimal' Art-Viewing Light Temperature

Finally, after completing both artwork viewing/rating tasks, participants were asked to again enter the portrait (Study 1) room and to adjust the color temperature (Kelvin) of the lighting using a sliding scale on a provided laptop connected to the LED light. The task used the following directions: "Imagine you are a curator tasked with adjusting the lighting so that the artworks look best." Before entering, a researcher first entered the room and set the ambient light temperature (bottom, top, or middle of the range, counterbalanced between participants) in order to control for potential anchor effects. After the participant had made their adjustment, the levels were recorded using both the laptop software and matched to a spectrometer reading (UPRtek M350).

Ethics Statement

This study was carried out in accordance with the recommendations of the Ethics Committee of the University of Vienna. All subjects gave informed consent in accordance with the Declaration of Helsinki. The protocol was approved by the Ethics Committee of the University of Vienna.

RESULTS

All participants completed all sections of the study, and all data were used in the following analyses. As noted above, due to previous research suggesting a potential gender difference in response to certain lighting conditions, we first compared responses between male and female respondents. However, independent *t*-tests conducted within each lighting condition showed no significant differences for all scales. The data were therefore combined in the following analyses.

Study 1 (Portraits): Lighting's General Impact on Representational Art Experience

Results with artwork appraisals are summarized in **Figure 4**. As can be seen, appraisals of the artworks tended to fall in a range at about the midpoint of all scales. Answers for the four different rating scales also showed moderately high significant correlations with each other within each artwork (e.g., ratings for Artwork 1 all *r*s = 0.55 to 0.85; Artwork 2 *r* = 0.59 to 0.74; Artwork 3, *r* = 0.27 to 0.82)[3]. Looking to ratings on the same scales between the artworks, made again by the same individuals, both beauty and liking did not show significant correlations, whereas, ratings for interestingness (all participants' *r*s = 0.22 to 0.43) and willingness to pay (*r*s = 0.50 to 0.47) did show a significant positive correlation.

TABLE 3 | Results of ANOVAs for Lighting Conditions × artwork differences in regards to four hedonic appraisals of art (Portraits).

	F (df)	η_p^2	*p*
Beauty			
Lighting	2.608 (2, 59)	0.081	0.082
Painting	0.066 (2, 118)	0.001	0.936
Lighting × Painting	4.092 (4, 118)	0.122	0.004*
Liking			
Lighting	0.476 (2, 58)	0.016	0.624
Painting	1.215 (2, 116)	0.021	0.300
Lighting × Painting	2.044 (4, 116)	0.066	0.093
Interest			
Lighting	0.528 (2, 59)	0.018	0.593
Painting	3.755 (2, 118)	0.060	0.026*
Lighting × Painting	1.819 (4, 118)	0.058	0.130
Willingness to pay to see			
Lighting	0.295 (2, 59)	0.010	0.745
Painting	3.882 (2, 118)	0.062	0.023*
Lighting × Painting	1.641 (4, 118)	0.053	0.168

*Results based on mixed ANOVAs with painting (3) as a within-participants factor, lighting condition (3) varied between participants, and with each of the four appraisals (beauty, liking, interest, willingness to pay) as the dependent variable, conducted separately. *Denotes significance at $p < 0.05$. All statistics are reported without Bonferroni correction for multiple comparisons. Probability values in bold designate items that would retain significance following familywise correction (all individual comparisons = 21, including positive emotion, negative emotion, and emotion arousal from **Table 4**; adjusted $\alpha = 0.0024$).*

To analyze our first research question, regarding the impact of lighting on the experience of paintings, we ran a series of repeated measures ANOVAs with the three *Paintings* as a within-participant factor and *Lighting* condition as a between-participant factor. These were conducted for each of our dependent variables (appraisals and general emotion) separately. The results are shown in **Tables 3**, **4**. Note, due to the exploratory nature of this study, we discuss the results below and throughout the paper without correction for multiple comparisons. However, the reader should be mindful of this point when making any inferences. For the reader who is interested in such a correction, we include information on adjusted alphas following Bonferroni correction in the table notes.

As can be seen, we found no significant main effect for *Paintings* in terms of beauty and liking, however, mirroring the correlations above, we did find a significant main effect for interest and willingness to pay. Moving to our main

interpretation of their meaning. Thus, these were not analyzed or included in the study.

[3]Despite the generally moderate to high correlations between the four rating scales, the decision was made not to employ data reduction measures (i.e., Factor Analysis or Principle Component Analysis) due to the smallish size of the sample and our interest in considering what, if any, effects lighting might have on this range of scales of typical interest in previous empirical art research and not on the nature of artwork assessment (i.e., specific axes or clustering of appraisals) itself.

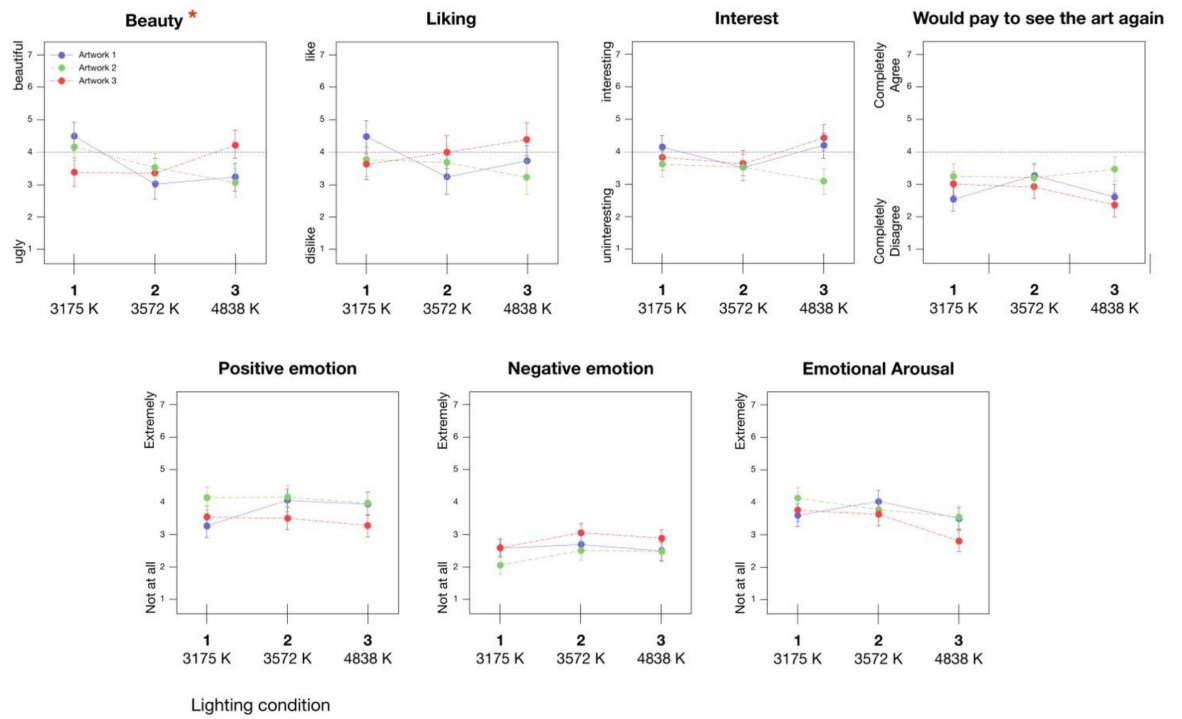

FIGURE 4 | Effect of changing lighting temperatures (Kelvin) on appraisals and felt emotion with representational art (* corresponds to significant interaction between lighting and paintings, $p = 0.004$, mixed ANOVA lighting × artwork. No significant main effects for lighting were detected for any scale).

research question, we found no main effect for *Lighting* on any of our rating variables. However, we did detect a significant interaction of *Lighting* × *Paintings* for ratings of beauty. This suggests that different lighting conditions either relatively lowered or raised beauty ratings for specific works of art in different ways depending on the specific painting. Looking at **Figure 4**, lighting Condition 1 tended to lead to relatively higher beauty ratings for Painting 2 and 1, when compared to the other lighting conditions. On the other hand, this same lighting condition tended to lead to relatively lower beauty ratings for artwork 3, especially when compared to lighting Condition 3. Condition 2, which, incidentally also corresponded to a museum showing contemporary art, tended to coincide with generally low beauty ratings for all three artworks.

Although not significant, it is worth noting that lighting did also show a trend in regards to a main effect on ratings of beauty ($p = 0.08$), while a similar trend regarding the *Lighting* × *Paintings* interaction was also found for liking, and, in conjunction with the beauty finding, suggesting that there might at least be some lighting conditions that are suitable for both particular artworks and for the overall art style (portaits). However, looking to the effect sizes, with the exception of ratings for beauty, very little impact was detected for lighting conditions in the rooms. For comparison, the effect sizes (**Table 3**) regarding a main effect of the different paintings were from two to six times larger.

The results of analyses regarding emotional experience are shown in **Table 4**, see also **Figure 4**. In this case, we again found a main effect of *Paintings* on both positive and negative emotions. Artwork 3 appeared to evoke more negative emotions (and less

TABLE 4 | Results of ANOVAs for Lighting Condition × artwork differences in regards to reported emotional arousal and valence while viewing art.

	F (df)	η_p^2	*p*
Emotional arousal			
Lighting	1.206 (2, 59)	0.039	0.307
Painting	2.347 (2, 118)	0.038	0.100
Lighting × Painting	1.171 (4, 118)	0.038	0.327
Positive emotion			
Lighting	0.232 (2, 59)	0.008	0.794
Painting	4.887 (2, 118)	0.076	0.009*
Lighting × Painting	1.161 (4, 118)	0.038	0.332
Negative emotion			
Lighting	0.433 (2, 59)	0.014	0.651
Painting	4.391 (2, 118)	0.069	0.014*
Lighting × Painting	0.503 (4, 118)	0.017	0.734

*Results based on mixed ANOVAs with painting (3) as a within-participants factor, lighting condition (3) varied between participants, and with each of the three emotion factors as the dependent variable, conducted separately. *Denotes significance at $p < 0.05$. All statistics are reported without Bonferroni correction for multiple comparisons. Probability values in bold designate items that would retain significance following familywise correction (all individual comparisons = 12; adjusted $\alpha = 0.0042$).*

TABLE 5 | Results of ANOVAs for Lighting Conditions × artwork differences in regards to appraisals and reported emotion with Abstract art.

	F (df)	η_p^2	*p*
Beauty			
Lighting	1.878 (2, 60)	0.059	0.162
Painting	0.038 (2, 120)	0.001	0.963
Lighting × Painting	0.963 (4, 120)	0.031	0.431
Liking			
Lighting	0.068 (2, 60)	0.002	0.934
Painting	0.239 (2, 120)	0.004	0.788
Lighting × Painting	1.413 (4, 120)	0.045	0.234
Interest			
Lighting	0.528 (2, 60)	0.009	0.755
Painting	1.469 (2, 120)	0.024	0.234
Lighting × Painting	0.456 (4, 120)	0.015	0.768
willingness to pay to see			
Lighting	0.636 (2, 60)	0.020	0.538
Painting	0.289 (2, 120)	0.005	0.749
Lighting × Painting	1.303 (4, 120)	0.042	0.273
Emotional arousal			
Lighting	1.486 (2, 59)	0.048	0.235
Painting	1.923 (2, 118)	0.032	0.151
Lighting × Painting	0.907 (4, 118)	0.030	0.462
Positive emotion			
Lighting	0.106 (2, 59)	0.004	0.900
Painting	0.988 (2, 118)	0.016	0.375
Lighting × Painting	1.296 (4, 118)	0.042	0.276
Negative emotion			
Lighting	4.929 (2, 59)	0.143	0.010*
Painting	2.878 (2, 118)	0.047	0.060
Lighting × Painting	0.783 (4, 118)	0.026	0.538

*Results based on mixed ANOVAs with painting (3) as a within-participants factor and lighting condition (3) varied between participants, conducted separately for each appraisal/emotion factor. *Denotes significance at $p < 0.05$. All statistics are reported without Bonferroni correction for multiple comparisons. Probability values in bold designate items that would retain significance following familywise correction (all individual comparisons = 12; adjusted $\alpha = 0.0042$).*

positive) than Artworks 2 and, to a lesser extent, 1. Both the main effect of *Lighting* and the *Lighting* × *Painting* interaction were not significant.

Study 2: Lighting and Ratings/Emotional Experience With Abstract Art

We then considered the impact of lighting on the abstract art (**Figure 5**; note, the color coding for the lighting conditions and paintings identifies the artist-intended combinations). In the case of the ratings, once again, the general level of scores was similar to those with the representational portraits in Study 2, falling in a range around the midpoint of all scales. We also again found a correlation of all appraisal scales within each artwork. In addition, individual ratings (e.g., beauty, liking) were significantly correlated between all pairs of artworks ($r = 0.26$ to 0.60), presumably because these were even more similar in terms of style compared to the art from Study 1.

The results of another series of repeated measures ANOVAs with *Paintings* as a within-participants factor and *Lighting* condition as a between participants factor are shown in **Table 4** and **5** (see also the table note for information on Bonferroni correction). In this case, no significant effects were found for *Paintings* on any of the appraisals. Similarly, no significant effects were found for *Lighting* or for the *Lighting* × *Painting* interaction, suggesting that not only did specific lighting styles not generally modulate the appraisals of the art, but the artist-intended matches between certain paintings and lighting conditions did not show the expected differences when compared to other, non-intended lighting conditions. The only significant result was a main effect of *Lighting* on negative emotions. As can be seen in **Figure 5**, this appeared to be driven especially by lighting Condition 3, denoted by a particularly blueish light, which led to higher negative emotion ratings for all three paintings.

Does Lighting Used/Intended by the Artist Show Higher Ratings When Employed in Display?

Because the artworks had again been designed with the expectation for a specific match to one of the three lighting conditions, we also conducted a simplified analysis in which we compared the responses on the above appraisal and emotion scales regarding the one artwork which was expected to match a specific light condition versus the averaged responses made to the other two artworks which were not expected to match the lighting (see **Figure 6**). However, again, both a similar series of repeated measures ANOVAs (match/no match × Lighting condition/painting group) as well as *t*-tests across all participants in the differing lighting conditions returned no significant differences or notable trends.

What 'Ideal' Light Temperature Would Participants Choose for Study 1 Art?

Finally, we assessed the results from the last study task in which individuals were asked to set what they would deem the ideal light temperature (in Kelvin, adjusted on a sliding scale from 2715 to 5322) for the Study 1 portraits. An analysis of the results showed that the spectrometer reading and the computer controls consistently provided similar readings. Therefore, as the spectrometer reading taken inside the rooms presumably most closely approximated the actual light temperature as it was perceived by the participant, we used these data for the analyses.

Figure 7 displays a histogram and group mean of the participant settings for the 'ideal' viewing temperatures. Overall, participants showed a mean of 3776.87 K (SD = 711.21; Mdn = 3740.50). However, the results also showed a rather wide range of answers between 2631 K at the warm end and 5672 K at the cool end (25th to 75th quartiles = 3323.0 to 4097.25, respectively; highest concentration of answers in 3250 to 3750 bin). Note, the range of participant answers also covered all of the selected museum-based temperature settings, with a mean closest to the portrait Condition 2. Interestingly, in the Study 1 results above, which used the same portrait paintings as used in the present assessment, this

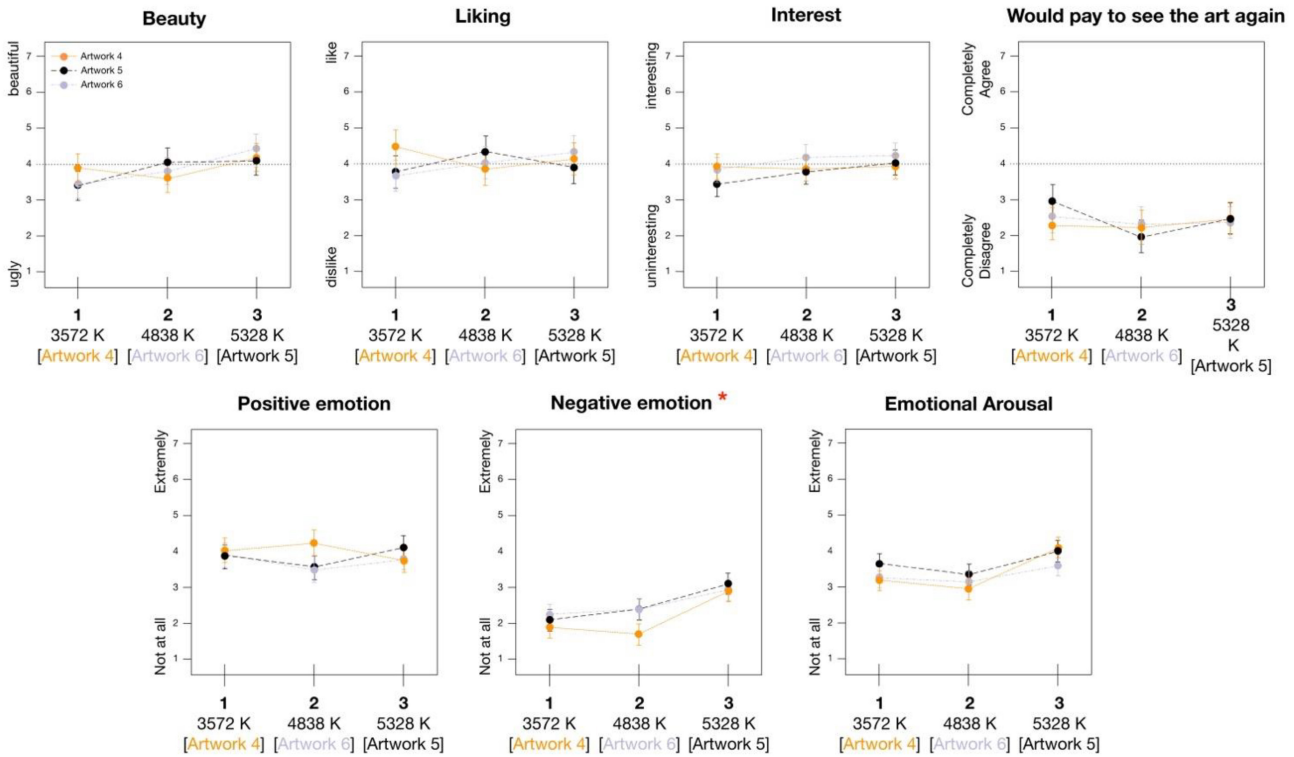

FIGURE 5 | Effect of changing lighting temperatures (Kelvin) on appraisals and felt emotion with abstract art. Color coding of artwork labels corresponds to lighting condition suggested as ideal for viewing by artist (* corresponds to significant main effect for lighting on rating, $p = 0.010$, mixed ANOVA lighting × artwork).

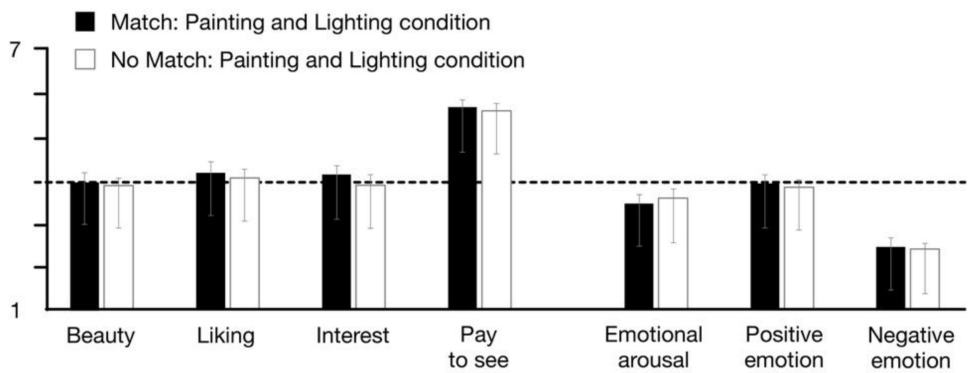

FIGURE 6 | Comparisons of mean ratings and reported emotion when lighting conditions did or did not match the artist-suggested 'ideal conditions' for viewing (No sig. differences detected, parallel repeated measures ANOVA, match/no match × Lighting condition/painting group).

lighting condition actually corresponded to one of the only significant effects, regarding lowered beauty ratings. A linear regression with either beauty ($t = -0.139$, $p = 0.890$) or liking ($t = 0.510$, $p = 0.612$) ratings from Study 2 above as dependent variables and the participant settings for lighting temperature as a predictor showed no significant relation. A similar lack of significant results was also found for the other ratings and participant demographic factors, suggesting the absence of a clear relationship between temperature of lighting and appraisal of the art.

DISCUSSION AND CONCLUSION

We assessed the impact of lighting conditions on the spontaneous appraisal and the felt emotional experience with visual art. This was designed to move beyond previous studies, which often used both non-ecologically valid (non-gallery and real artwork) designs and employed within-participant paradigms with overt emphasis on lighting changes, matched with multiple comparative ratings of the same art or room, most probably inflating emphasis on any lighting influence. In response, we

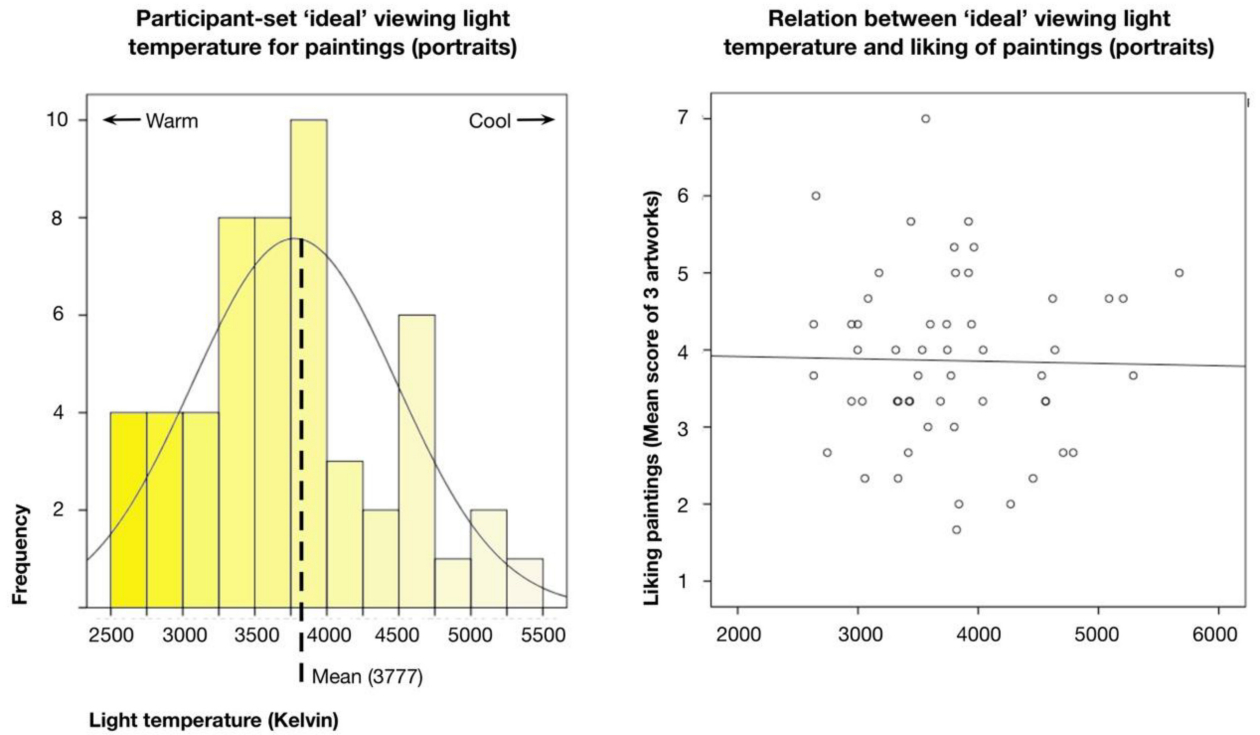

FIGURE 7 | (Left) Histogram of participant answers to 'ideal' viewing conditions (light temperature in Kelvin) for representational artworks (portraits room, Study 1). Dotted line indicates group Mean. **(Right)** Scatterplot of relation between participants' settings for 'ideal' viewing light temperature of portrait room and liking ratings from previous study of same art.

employed, for the first time, a between-participant design allowing us to consider the more spontaneous influence of ambient lighting on works of art as encountered in an ecologically valid gallery setting.

Looking to our results, and considering the titular question for this paper, the most salient takeaway across all of our study components would be an answer of '*no, generally lighting did not appear to make much difference to the art experience*.' In the case of both the representational and abstract paintings, changing the lighting in both gallery spaces did not have any significant main effect on appraisals or, for the most part, emotional experience. Rather, the ratings for the paintings tended to stay within a rather neutral range of scores, moving slightly up and down depending on certain painting-lighting combinations, but well within the error for the studies. Similar results were also found for lighting impact on felt emotional arousal and valence with representational art, and for positive emotions and arousal with abstract. Similarly—and perhaps more surprising—the results from Study 2 suggested that art viewed in conditions different from those in which it was created and certainly not matching those suggested by the artist for best appreciation, also resulted in no detectable difference in the viewer experience.

In fact, the only significant general finding in regards to the experimental questions involved a main effect of lighting on negative felt emotions with the abstract art. As can be seen in the second panel of **Figure 4**, this appeared to be driven especially by lighting Condition 3, denoted by a particularly blueish light and which was in fact the coolest light setting used in the studies (5328 K). Perhaps more interesting, we also detected an interaction between lighting and paintings for the representational art (Study 1) in terms of ratings of beauty, where lighting Condition 1 tended to lead to relatively higher beauty ratings for Painting 2 and 1, and on the other hand, tended to lead to relatively lower beauty ratings for artwork 3, and lighting Condition 2, which also corresponded to a museum showing contemporary art, coincided with generally low beauty ratings for all three artworks. This indicates of course that there may be combinations of one particular painting with one particular lighting condition that can enhance the aesthetic experience. However, these detected effects should also be considered in light of other contrasting factors. Notably, the differences between paintings themselves, for both abstract and representational art, typically showed two- to six-times the effect size regarding appraisals as did the lighting.

Finally, we also found a rather wide-range when participants were given the chance to set their own 'ideal' light temperature for viewing. The Mean temperature (3777 K) roughly coincided with the suggested most enjoyable conditions for everyday living and some past art research (especially the 3600 K as found by Scuello et al. (2004b) in their analysis with postcard art reproductions). This result may lend some credence to Nascimento and Masuda's (2014) argument that art viewing in actual gallery conditions as

opposed to viewing images on a screen, lead to lower (warmer) preferred temperatures. However, it was also lower than the only other previous study conducted with non-reproduction or screen-based works of art (5500 K reported in the Nascimento and Masuda, 2014 study). The differences could of course be due to a number of factors including type of art (in this case representational) which may have better matched a redder or yellower light. At the same time, in our opinion, the more important result was the wide variance—the range of answers went from quite cool to quite warm, covering all of the museum lighting conditions used in our studies, and suggesting that even if individuals prefer a warmer light in general there is again no clear consensus or even pattern to the answers.

These findings, therefore, support a rather—at least to ourselves—surprising conclusion. The actual impact of the lighting as detected in the present study appears to play only a small role in the actual felt emotions and ratings of art. This finding may be key for the curator or art-focused scientist, suggesting that lighting may not really be so important in designing art display. Certainly, there does not appear to be one ideal lighting temperature for viewing art. A similar finding is also found in most of the past lighting research whereby individuals are given the opportunity to select their own CCT. Although there are of course unique one-to-one relationships whereby one lighting temperature may help or harm the reactions to specific works, the effects detected here do not even show the same relationships or directions within an artwork class such as similarly-styled portraits or abstracts pieces by the same artist.

This study also highlights the important methodological difference of within- versus between-participant designs, and suggests that the former, which has been the main form for past lighting and art research, may be driving most effects. This finding would essentially fit the previously suggested results in study designs wherein the lighting changes are obscured from a viewer (e.g., Snow, 1927, of course not considering visual art) and suggesting that if these are not salient, they really do not appear to have much effect. This should be considered or perhaps contrasted within- and between-participant in future lighting and art research.

At the same time, this result also raises the obvious next question: given the persistent emphasis on lighting as a key component of the contemporary gallery, and with lighting's ability to adjust how an artwork literally looks, why does light not seem to significantly impact art perception or emotional experience? This is important both for the pragmatic question of artwork display and appreciation, as well as for the more general discussion of context in empirical psychological studies of art, which have documented the importance of various modulating factors in appraisal or response.

One explanation might again follow arguments such as a color constancy hypothesis (Foster, 2011; Liu et al., 2013; Nascimento and Masuda, 2014; Berns, 2016; Pridmore, 2017). It may be that viewers, especially with the representational paintings in Study 1, know how a person 'should' look or what colors they 'should be,' and thus are not that impacted by actual lighting-related changes. In the same vein, the lack of effect found in this study may also relate to, for example, previous studies showing a "facsimile accommodation hypothesis" (Locher et al., 2001, 1999), whereby lab viewers do not always show differences in many types of ratings comparing between original and reproduced or screen-based art (Brieber et al., 2015). People may 'look past' the presentation or visual conditions and evaluate the 'underlying art.' Such a suggestion is also supported in the original surveys of Kesner (1997) where brightness/contrast were not found to be important factors by art museum visitors. This may be similar to how we approach especially modern or post-modern art which does play with 'natural' colors. This result may also be inflated by the lay viewer sample, who may rely more on mimetic content for making ratings (e.g., see Pelowski et al., 2017b; Grüner et al., 2019; for such findings with artwork assessments).

On the other hand, this finding, especially as it regards classic color constancy discussions, is also made more interesting by the inclusion of abstract art. In the case of our selected abstract paintings, these put great emphasis on color, with only minimal geometric design. As these paintings were being seen for the first time, it would be difficult to presume that viewers knew what colors they should be and thus should have focused more on their actual vibrancy or appearance. In the same Kesner (1997) study, visibility and color range were of course also suggested to be key. However, again, when actually tested in our gallery conditions, changing the lighting made no detectable difference. Even more, the artworks and making conditions were in fact chosen by the artist to anticipate certain types of light, which, again, did not show the interaction that was expected. The fact that individuals can look past something so prevalent as lighting, raises interesting questions for future studies of context.

The present study also of course comes with important caveats and demands for future research. The study was confined to only two types of art, with only three examples of each and three lighting conditions. It may well be that a larger study with more viewers and art examples could find lighting-related differences. I should be noted that even relatively tiny effect sizes—such as certain paintings becoming slightly more beautiful—can be meaningful when one considers the sheer amount of people that visit museums. Why would a museum not want to put its art in the best light, if it knows what that would be? Future study might also consider those with more or less interest or knowledge in art, or frequent museum/gallery connoisseurs, for whom we might again detect important differences. The question of how lighting might guide other processes, such as attention (e.g., measured by eye-fixations), may also provide compelling findings. It is our hope that this paper will thus provide an important roadmap to individuals interested in display of art and a useful tool for future research.

DATA AVAILABILITY STATEMENT

The datasets for this manuscript are not publicly available due to data protection and storage regulations. Requests to access the datasets should be directed to the corresponding author.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Ethics Committee of the University of Vienna. The participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

AUTHOR CONTRIBUTIONS

MP, ES, AG, MF, and HL contributed to the conception and design of the study. ES, MF, and AG contributed to the data collection. MP and ES contributed to the data analysis. MP, ES, JH, MF, and AG contributed to the initial manuscript writing. All authors contributed to manuscript revision, read, and approved the submitted manuscript.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2019.02148/full#supplementary-material

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Conflict of Interest: The lighting apparatus used in this study was designed by the commercial architecture firm Studio Okular, Vienna, Austria, of which AG is a principle member. However, this entity did not have any relation to the study design, analyses, or interpretations.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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ORIGINAL RESEARCH
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Viewing Landscapes Is More Stimulating Than Scrambled Images After a Stressor: A Cross-disciplinary Approach

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Research has demonstrated that nature is beneficial for many aspects of one's health. This pilot study aimed to investigate whether viewing landscape artworks, as a form of representational nature, could improve psychological and physiological recovery from a laboratory stressor. A sample of 30 participants was randomized to one of two conditions: landscape and scrambled. After a laboratory stress task, participants in the landscape condition viewed a series of landscape paintings for 30 min; participants in the scrambled condition viewed digitally scrambled versions of these artworks as a control condition. Pupil size was measured while viewing the images using an eye tracker. Affect, drowsiness and fatigue, and the salivary stress biomarkers, cortisol, and alpha-amylase were measured at baseline, after the stressor, and after the artwork viewing period. After the viewing period, the scrambled condition had increased reports of low negative affect (which contains the variables of sleepy, dull, and sluggish) ($p = 0.045$, $\eta_p^2 = 0.12$) and increased reports of drowsiness ($p = 0.038$, $\eta_p^2 = 0.12$). Salivary cortisol levels decreased more rapidly while viewing the scrambled images compared to the landscape artworks ($p = 0.027$, $\eta_p^2 = 0.62$). Lastly, pupil size while viewing the landscape artworks was larger than when viewing a blank screen ($p = 0.025$, $\eta_p^2 = 0.33$), an effect not seen in the scrambled condition. This pilot study suggests that viewing landscape artworks was more stimulating and reduced drowsiness after stress when compared to viewing scrambled images.

Keywords: nature, artwork, stress, fatigue, cortisol, pupil size

INTRODUCTION

Throughout history, exposure to nature has been touted as restorative for health and research supports this proposition. Although nature is experienced in multi-sensory ways, research has focused on the effects of viewing nature on health, due to the dominance of vision in experiencing nature (Ulrich, 1981).

Viewing nature has been found to have effects on health in both healthy and patient populations. One review found that the effects of nature fall into three categories: short-term recovery from stress, recovery from illness, and long-term improvements in mood (Velarde et al., 2007). Viewing nature, either live or through photographs and videos, has been linked with a wide range effects, including increased relaxation as shown through EEG (Chang, 2002), decreased anxiety about surgery (Ulrich et al., 1993), increased heart rate variability (Gladwell et al., 2012), decreased job stress, increased life satisfaction (Kaplan et al., 1988), and decreased pain (Vincent et al., 2010; White et al., 2019). A recent study by White et al. (2019) found that the optimal dose for improved health and well-being was 120 h of nature contact per week; however, the beneficial effects of nature have been found to occur within less than 5 minutes (Ulrich, 1992).

Research has also shown that nature has a restorative effect on the stress response. Stressed individuals report improved mood after viewing nature scenes compared to viewing nothing or urban scenes (Ulrich, 1979). Nature can also improve physiological recovery from a stressor when viewed after (Ulrich et al., 1991) or before (Brown et al., 2013) experimental stressors. Lastly, nature has also been found to lower cortisol levels in both stressed and unstressed individuals (Olafsdottir et al., 2018; Hunter et al., 2019).

Three main theories have been proposed for the beneficial effects of viewing nature on health; evolutionary theory, attention restoration theory (ART), and nature as positive distraction (Nanda et al., 2010). Evolutionary theory proposes that responses to nature are influenced by genetics (Kweon et al., 2008). As humans evolved in natural environments, we have an innate predisposition to experience restoration as a response to nature (Ulrich et al., 2003). As a consequence of our evolutionary heritage, natural environments are processed more efficiently, as our sensory, cognitive, and emotional systems evolved in this landscape (Ulrich et al., 1991). Conversely, these systems are likely to function more poorly in artificially constructed, urban environments that are more recent phenomena. This theory explains why natural scenes are more beneficial to health than urban scenes.

ART postulates that stress causes mental fatigue which impacts cognitive processes. However, the restorative characteristics of nature can counteract this, resulting in better recovery from this mental fatigue (Kaplan, 1995). In this theory, nature is restorative because it is attention-grabbing and engaging, in a non-threatening way, and therefore, reduces cognitive strain (Berman et al., 2008). ART therefore provides a possible explanation as to why people exposed to nature have reduced stress responses.

The last theory is that nature is a form of positive distraction. Positive distraction refers to an element of the environment that produces positive feeling and holds attention effortlessly. This attracts attention away from negative stimuli and experiences such as stress. Nature is effective as a positive distraction because it is stimulating and evokes interest and positive affect, allowing the displacement of negative affect (Hartig et al., 2011).

These three theories are not mutually exclusive. The attention system of the human brain (Posner and Petersen, 1990; Petersen and Posner, 2012) has a long evolutionary history (Graziano, 2014) and includes a range of processes, which include focusing attention, managing cognitive resources, and responding to distractions. Research to date shows strong evidence that viewing nature is beneficial to health and aids in stress recovery. There is also growing evidence indicating that representations of nature through artwork can have similar effects through the same mechanisms (Ulrich et al., 2006).

Artworks that depict nature scenes have increasingly been used in research and healthcare settings to reduce stress and improve health. Research demonstrates that, like real views of nature, artwork can reduce anxiety (Binnie, 2010), reduce depression (Staricoff et al., 2003), improve mood (Karnik et al., 2014), increase relaxation (Wang et al., 2015), and decrease anxiety medication usage (Nanda et al., 2011) when compared to no artwork. This collection of studies demonstrates that nature artworks can significantly improve psychological well-being. However, some research shows null results. A recent study found that nature artworks did not improve mood, pain, anxiety, depression, and satisfaction for chemotherapy patients (George et al., 2017). But in subsequent interviews, the patients reported the artwork provided a positive distraction from chemotherapy.

Although this evidence indicates that nature artworks have a positive effect on psychological health, there is a scarcity of evidence for the effects of these artworks on physiological outcomes. An early study by Heerwagen (1990) found that heart rate was lower for dental patients on the days where a landscape mural was hung in the waiting room compared to no mural. Mastandrea et al. (2019) found that visiting art museums lowered systolic blood pressure compared to visiting an office with no artworks; however, this study did not look specifically at artworks depicting nature. Therefore, more research is needed to determine whether experiencing nature artworks can improve physiological outcomes.

Most nature research has used urban scenes as a control. However, this approach has many confounding variables such as the degree of color in the nature vs. urban scenes, as color is an important mediator in the relationship between art and mood (Lankston et al., 2010). A more appropriate control is scrambled images, as used in previous research on the effects of artwork on attention and memory (Wang et al., 2015). Scrambled images are edited versions of artworks that have been digitally disarranged. We propose that these images act as better controls as they retain the colors and brightness of the original artwork, but the representation of nature is removed (Wang et al., 2015). This allows a better understanding of whether the depiction of nature in the art is the key factor in improving outcomes, rather than structural features.

The current pilot study used an interdisciplinary approach to investigate whether nature artworks can improve psychological and physiological recovery from a laboratory stressor, when compared to viewing scrambled images of the artworks. Stress responses were assessed using measures of: self-reported affect, fatigue and drowsiness, and salivary cortisol and alpha-amylase. Participants' pupil size was also measured while viewing the artworks to provide an indication of the degree of stimulation and arousal that the artworks provided.

In this pilot study, we investigated the feasibility of study procedures, as well as estimates of effect size. Based on prior research, it was hypothesized that viewing nature artworks after a laboratory stressor would lead to improved stress recovery, as indexed by decreased salivary cortisol, alpha-amylase, fatigue and drowsiness, improved affect levels, and increased pupil size compared to the control condition who viewed scrambled images.

MATERIALS AND METHODS

Sample

A sample of 30 adults (20 female, 10 male; average age 27.20 years, age range 18–52 years) was recruited from the community through flyers and email advertisements. Participants were included if they were over the age of 16 and spoke English. Ethics approval was granted by the University of Auckland Human Participants Ethics Committee.

Procedure

In accordance with salivary sampling procedures, participants were instructed not to chew gum or drink caffeine, juice, or alcohol 18 h prior to the study and not to eat or brush their teeth in the hour before their session. Prior to their laboratory session, participants were randomized to one of two conditions: control (scrambled images) or nature (landscape images). Randomization was performed by a researcher uninvolved in the experiment using a random number generator. Randomization was concealed until the start of the session, when the sealed envelope containing the group allocation was opened.

Participants attended a 90-min experimental session and gave written informed consent. The procedure is shown in **Figure 1**. Baseline questionnaires about the participant's demographics and affect levels were completed, and the participant provided a saliva sample. Once baseline measures were taken, participants were exposed to a shortened version of the Trier Social Stress Test (TSST; Kirschbaum et al., 1993). Participants were given 3 min to prepare and 3 min to present a speech to convince the experimenter to give them their dream job. Participants were told their speech would be recorded and a panel of judges would review it and award the best speech with a $100 voucher. A shortened version of the TSST was used as a recent meta-analysis has shown that the shortened version produces similar physiological stress responses to the full TSST paradigm (Goodman et al., 2017).

The participants then completed the affect measures and provided a saliva sample for a second time. They then viewed a 30-min slide-show comprising of 26 images based on their random group allocation. Participants in the landscape condition were shown a set of landscape artworks by New Zealand artists. The landscapes were included if they contained a nature scene that was relatively void of detailed focal points and non-natural stimuli. The scrambled condition viewed digitally scrambled versions of the landscape artworks, similar to work by Wang et al. (2015). A two-dimensional Fast Fourier transform was performed on each image, in order to generate the scrambled version. These images no longer have any sense of "objectness," but they preserve the color and luminance profiles of the original images. Examples of the original artworks and their scrambled versions are shown in **Figure 2**. Participants' pupil size was tracked during the viewing period.

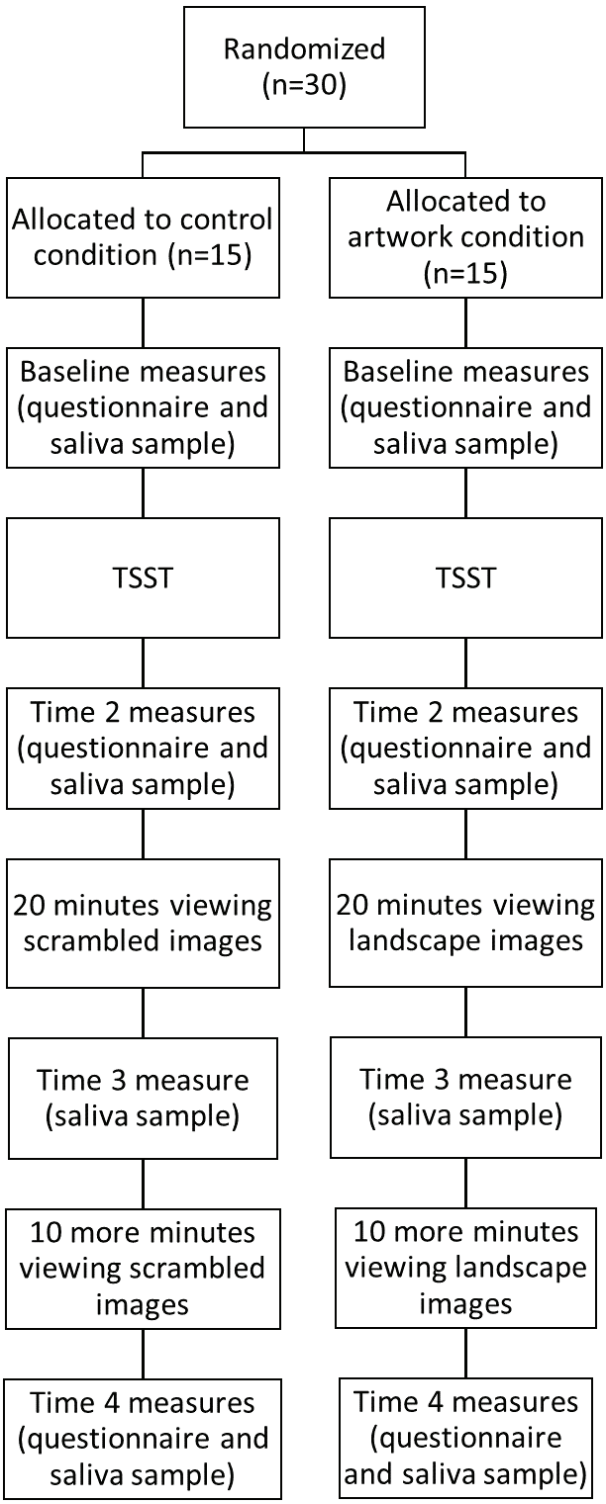

FIGURE 1 | Flow chart showing the procedure of the study.

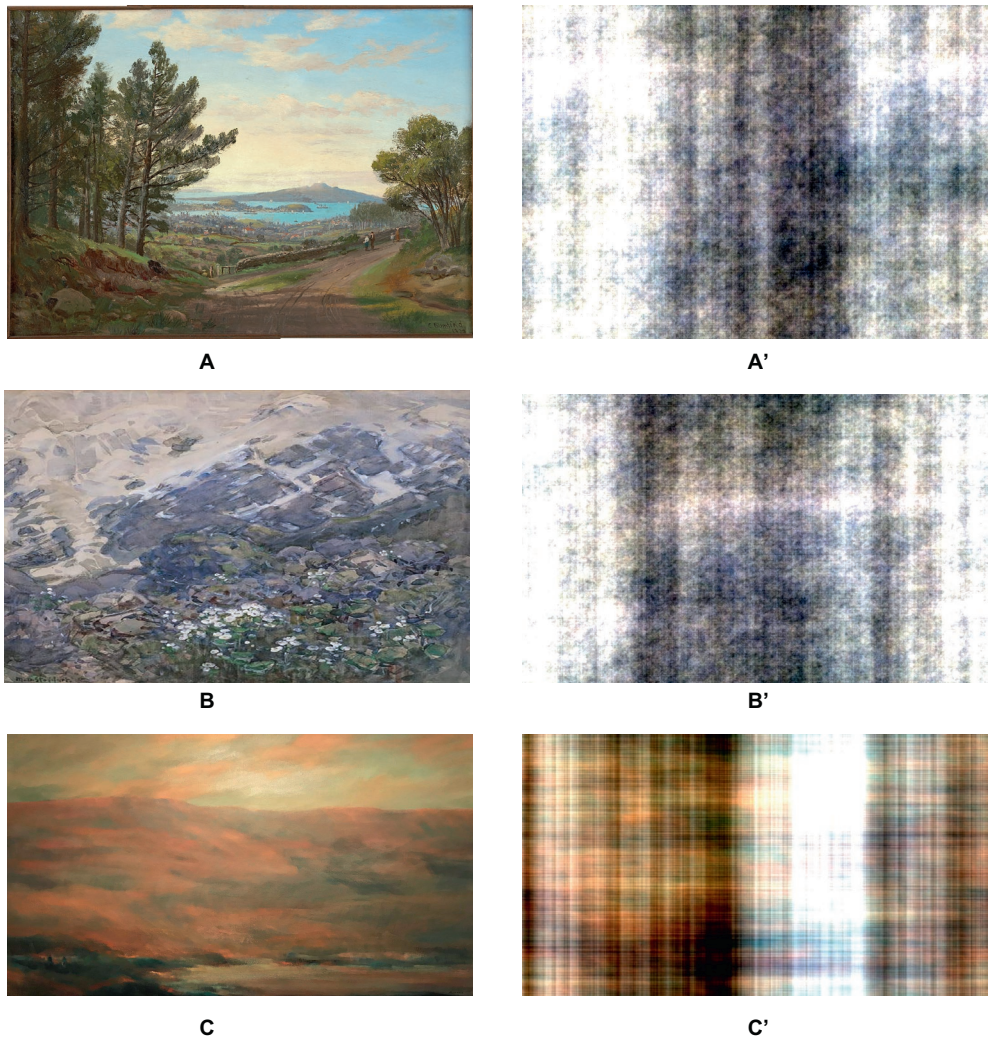

FIGURE 2 | Examples of the landscape artworks **(A–C)** and their scrambled versions **(A′–C′)**. **(A)** is a painting by Charles Blomfield, Auckland Harbour from Mt Eden, which is in the public domain. **(B)** is by Margaret Stoddart, Mountain Lilies, reprinted with permission by the Christchurch Art Gallery Trust Collection. **(C)** is by Elizabeth Rees, Cove, reprinted with permission provided by Elizabeth Rees.

Twenty minutes into this viewing period, the researcher entered and asked the participant to provide another saliva sample. Participants viewed the images for a further 10 min before completing the final set of measurements. At the end of the session, participants were debriefed and received a $40 voucher for participation.

Measures

Demographics

At baseline, participants were asked about their demographics including: gender, age, height, weight, and ethnicity.

Affect

Affect levels were assessed at baseline, after the stressor, and after the viewing period using a modified version of the Actual Affect Subscale of the Affect Valuation index (AVI; Tsai et al., 2006). This scale consisted of a list of 25 emotions, and participants were asked to rate how much they felt that emotion at that present moment on a scale of 1 (not at all) to 5(extremely). These instructions were modified from the original scale, which asked the participants to rate how they felt over a typical week. These modified instructions have been used successfully in previous studies (Nair et al., 2015; Robinson et al., 2017).

Eight aggregate component scores were calculated: high arousal positive affect (HAP; strong, excited, and enthusiastic), low arousal positive affect (LAP; calm, relaxed, rested, and peaceful), positive affect (PA; happy, content, and satisfied), negative affect (NA; sad, lonely, and unhappy), high arousal negative affect (HAN; hostile, fearful, and nervous), low arousal negative affect (LAN; dull, sleepy, and sluggish), low arousal affect (LA: quiet, still, and passive), and high arousal affect (HA; aroused, surprised, and astonished). This scale is valid

and reliable across different populations, and each component score has high internal consistency (Tsai et al., 2006).

Fatigue and Drowsiness

Participants were asked to rate how much they were feeling fatigue and drowsiness on a scale from 0 (not present) to 3 (severe) at baseline, after the stressor, and after the viewing period (Petrie et al., 2014).

Salivary Stress Biomarkers

Saliva samples were collected at baseline, after the stressor, 20 min into the viewing period, and after the viewing period as per protocol using SaliCaps collection device (IBL, Hamburg, Germany). These samples were taken to examine any changes in stress biomarkers (salivary cortisol and alpha-amylase) associated with the viewing and stress tasks (Strahler et al., 2017). Participants were asked to rinse their mouths with water, before collecting saliva using the passive drooling technique. Participants collected their naturally secreted saliva in their mouths for 2 min by not swallowing, before transferring the accumulated saliva to the SaliCap. The samples were stored at −20° C at the University of Auckland before they were shipped on dry ice to the University of Vienna, where they were biochemically analyzed. Concentrations of salivary cortisol were measured using commercially available enzyme-linked immunosorbent assay (ELISA, IBL, Hamburg, Germany). Salivary alpha-amylase activity was determined using a kinetic colorimetric test (Strahler et al., 2016) using reagents obtained by Roche (Roche Diagnostics, Mannheim, Germany). Intra- and inter-assay coefficients of variance of both tests were below 10%.

Pupil Size

Participants viewed digital versions of the artworks and scrambled images on a 23″ monitor, controlled by a Dell Optiplex PC. Viewing distance from the screen was approximately 60 cm, and changes in pupil size were monitored by an eye tracker (the EyeTribe, Denmark). Participants rested their chin on a chin rest, to keep their heads still during the viewing period. During the first (20 min) block of images, participants viewed 17 images in succession; in the second (10 min) block of images, participants viewed nine images. Each trial began with presentation of a dark screen with white cross in the centre for 3 s, followed by a uniform gray screen for 4 s, followed by an image (landscape or scrambled image) for 60 s. Participants were instructed to look at the white cross at the beginning of every trial. Following the disappearance of the cross, participants were free to move their eyes to explore the succeeding images. Each participant viewed a different random sequence of images, and allocation of images to trial blocks was counterbalanced.

Statistical Analysis

Data were analyzed using IBM SPSS Statistics 22. Mixed factorial ANOVAs were completed to analyze the interaction and main effects of time-point (baseline, post-stressor, during artwork, and post-artwork viewing) and condition (scrambled vs. landscape) on affect, cortisol, and alpha-amylase. ANCOVAs for changes in cortisol and alpha-amylase controlling for baseline levels were conducted for the recovery period (from post-stressor to post-viewing period). The cortisol and alpha-amylase data violated the assumption of normality and was transformed using a natural log transformation and logged values were used in the analyses. Mean pupil size data (in mm^2) were entered into a mixed factorial ANOVA with image (gray screen vs. image) and trial block (one vs. two) as within subjects factors; group (landscape vs. scrambled) was the between-subjects factor.

All tests were reported using the Greenhouse-Geisser adjustment due to violations in sphericity (Vasey and Thayer, 1987). All significant interaction effects were followed up using simple pairwise comparisons with Bonferroni corrections.

RESULTS

Baseline characteristics are given in **Table 1**. No significant differences between the two conditions were found.

Affect

No significant main effects were observed for the effect of condition on any of the eight AVI component scores (all p's > 0.05). Significant main effects of time-point were found for the following components: HAP [$F_{(2,53)} = 21.33$, $p < 0.001$, $\eta_p^2 = 0.44$], LAP [$F_{(2,46)} = 6.38$, $p = 0.006$, $\eta_p^2 = 0.19$], PA [$F_{(2,55)} = 3.96$, $p = 0.025$, $\eta_p^2 = 0.12$], HAN [$F_{(2,51)} = 6.46$, $p = 0.004$, $\eta_p^2 = 0.19$], LAN [$F_{(1,35)} = 19.49$, $p < 0.001$, $\eta_p^2 = 0.41$], LA [$F_{(2,53)} = 7.04$, $p = 0.002$, $\eta_p^2 = 0.20$], HA [$F_{(1,71)} = 4.62$, $p = 0.029$, $\eta_p^2 = 0.14$]. *Post hoc* tests indicated that irrespective of condition, the stressor caused PA and LAN to decrease, and the artwork viewing caused the low arousal affect components to increase and high arousal affect components to decrease. Therefore, irrespective of condition, the stress and viewing tasks change participants' affect.

TABLE 1 | Summary of demographic and baseline characteristics of participants across condition.

Baseline variable	Scrambled	Landscape	*p*
Age (years) *M* (SD)	27.53 (8.83)	26.87 (5.41)	0.805[a]
Gender (%)			0.439[b]
Female	11 (73%)	9 (60%)	
Male	4 (27%)	6 (40%)	
Ethnicity (%)			1.000[b]
NZ European	6 (60%)	6 (60%)	
Non-European	9 (40%)	9 (40%)	
BMI *M* (SD)	24.50 (4.31)	25.28 (4.70)	0.640[a]
Exercise days/ week, *M* (SD)	4.07 (1.75)	4.00 (2.20)	0.928[a]
Baseline salivary cortisol (nmol/L), *M* (SD)	3.61 (2.44)	4.01 (5.15)	0.778[a]
Baseline salivary alpha amylase (U/ml), *M* (SD)	81.92 (99.00)	44.49 (51.18)	0.204[a]

M, mean; SD, standard deviation; %, percentage of participants in that category. p was calculated by independent samples t tests[a] and Chi-square tests[b].

A significant interaction effect was observed on the LAN component [$F_{(1,35)}$ = 3.97, p = 0.045, η_p^2 = 0.12]. Follow-up tests for each time-point revealed that there were no significant differences in LAN across the conditions at any time-point (all p's > 0.05). However, the differences between conditions were approaching significance after the viewing period [$t_{(28)}$ = 1.85, p = 0.075] with the scrambled condition having higher LAN affect (M = 8.33, SD = 3.42) than the landscape condition (M = 6.07, SD = 3.31).

A significant interaction effect was also observed on the HA component [$F_{(1,37)}$ = 3.81, p = 0.048, η_p^2 = 0.12]. Follow-up tests revealed that there were no significant differences in HA across the conditions at any time-point (all p's > 0.05). No significant interaction effects were observed for any other components.

ANCOVAs on change scores of the AVI components from post-stressor to post-viewing period, controlling for post-stressor scores, are shown in **Table 2**. LAN change scores across this period were significantly different between the two conditions with the control condition having a larger increase in LAN than the artwork condition.

Fatigue and Drowsiness

Kruskal-Wallis tests were conducted to examine the effect of condition on fatigue and drowsiness after the viewing period. There was a significant difference in drowsiness between the conditions [$H_{(1)}$ = 4.30, p = 0.038, η_p^2 = 0.12], with the scrambled condition indicating more drowsiness (mean rank = 18.40) than the landscape condition (mean rank = 12.60). The difference in fatigue between conditions after the viewing period approached significance [$H_{(1)}$ = 3.64, p = 0.057, η_p^2 = 0.09] with the scrambled condition reporting more fatigue (mean rank = 18.23) than the landscape condition (mean rank = 12.77).

Salivary Stress Biomarkers

No significant main effects were observed for the effect of condition on cortisol [$F_{(1,26)}$ = 1.11, p = 0.302, η_p^2 = 0.17] or alpha-amylase [$F_{(1,26)}$ = 1.53, p = 0.227, η_p^2 = 0.22]. A significant main effect of time was found for cortisol [$F_{(3,68)}$ = 7.87, p < 0.001, η_p^2 = 0.98]. Follow-up polynomial contrasts indicate a significant linear trend [$F_{(1,26)}$ = 18.03, p < 0.001, η_p^2 = 0.98], with cortisol decreasing over the course of the experiment in both conditions: baseline (M = 1.03, SD = 0.84), post-speech (M = 0.76, SD = 0.94), during viewing (M = 0.76, SD = 1.04), and post-viewing (M = 0.59, SD = 0.82). There was no significant main effect of time for alpha-amylase [$F_{(2,58)}$ = 0.89, p = 0.427, η_p^2 = 0.21].

There were no significant interaction effects of time-point and condition on salivary cortisol [$F_{(3,\ 68)}$ = 1.72, p = 0.176, η_p^2 = 0.40] or alpha-amylase [$F_{(2,\ 58)}$ = 1.65, p = 0.197, η_p^2 = 0.36]. However, there was a significant difference between conditions in the quadratic trends in cortisol over the session [$F_{(1,26)}$ = 4.49, p = 0.044, η_p^2 = 0.53]. Follow-up contrast analysis showed the quadratic trend was significantly greater for the landscape condition (M = 0.37, SD = 0.78) than the scrambled condition (M = −0.19, SD = 0.61), indicating that the landscape condition had a significant inverted U-shape relationship where cortisol levels decreased from baseline, but increased again after the viewing period. The scrambled condition did not have this U-shaped relationship.

ANCOVAs for change scores across the viewing period (after the stressor until after the viewing period) controlling for baseline levels were conducted for cortisol and alpha-amylase. Change scores for cortisol over the viewing period showed a significant difference between conditions when controlling for baseline cortisol [$F_{(1,26)}$ = 5.49, p = 0.027, η_p^2 = 0.62]. The scrambled condition had a significantly greater mean decrease in cortisol over the viewing period (M = −0.36, SD = 0.43) than the landscape condition, which stayed fairly stable (M = 0.02, SD = 0.37). This demonstrates that during the viewing period, the scrambled condition had a larger decrease in cortisol levels. Change scores over the viewing period showed no significant differences in alpha-amylase between conditions when controlling for baseline values [$F_{(1,26)}$ = 0.22, p = 0.216, η_p^2 = 0.23].

Changes in Pupil Size

Pupil size data were not available for one participant, in the landscape condition, due to technical difficulties. Results for the remaining participants are shown in **Figure 3**, which illustrates moment-to-moment changes in pupil size during the 60 s viewing period. Each plot shows the difference between pupil size at each viewing time-point, averaged across

TABLE 2 | Differences between control and artwork conditions in mean change scores of the AVI component scores from post-stressor to post-viewing period, controlling for post-stressor scores (positive change scores indicate an increase in the parameter, while negative change scores indicate a decrease).

AVI component	Control, adj *M* (SD)	Artwork, adj *M* (SD)	*F*	df	*p*	η_p^2
High arousal positive	−2.19 (2.36)	−1.68 (1.39)	0.62	1, 27	0.440	0.02
Low arousal positive	2.13 (4.18)	2.41 (4.22)	0.04	1, 27	0.840	0.00
Positive	0.05 (2.41)	1.02 (1.44)	2.09	1, 27	0.160	0.07
High arousal negative	−1.16 (1.62)	−0.71 (1.18)	0.80	1, 27	0.380	0.03
Negative	−0.12 (0.83)	−0.08 (0.70)	0.02	1, 27	0.879	0.02
Low arousal negative	3.67 (3.11)	1.46 (2.42)	4.55	1, 27	0.042*	0.14
Low arousal	2.23 (2.26)	1.23 (2.23)	1.61	1, 27	0.215	0.06
High arousal	−1.19 (2.31)	−0.48 (1.30)	2.92	1, 27	0.099	0.10

*adj M, adjusted mean change score (post-viewing period – post-stressor), controlling for post-stressor scores; SD, standard deviation. *p < 0.05.*

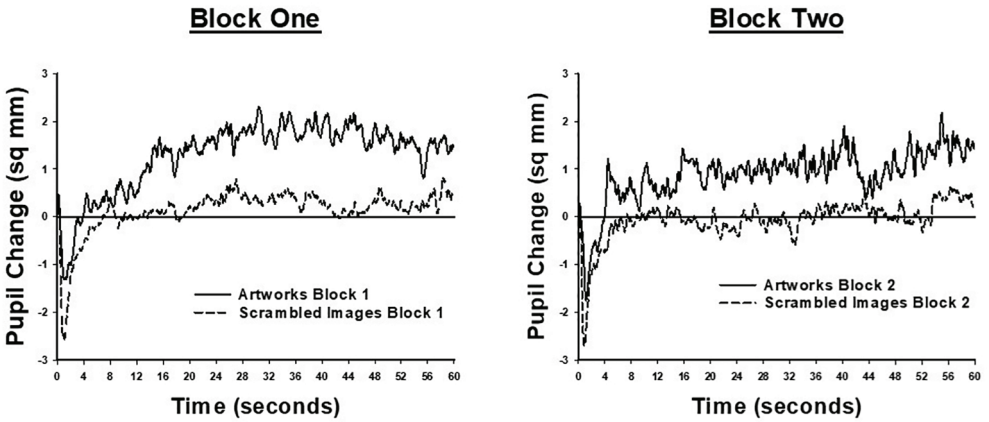

FIGURE 3 | Moment to moment changes in pupil size, when participants viewed landscape artworks (solid lines) and scrambled images (dashed lines). Each plot shows the difference between pupil size at each time-point during the 60-s image viewing period and average pupil size when viewing the uniform gray screen presented before each image. The left-hand panel shows data from the first trial block, comprising 17 images; the right-hand panel shows data from the second trial block, comprising nine images.

image trials, and mean pupil size, averaged across trials, during the 4 s of viewing a uniform gray screen, prior to each image. Data are shown separately for each block of viewing trials. As **Figure 3** shows, in both blocks of trials, and for both conditions, image presentation was associated with a phasic pupil constriction within the first 1–2 s, followed by an extended period in which pupil size remained relatively constant. From very early in the trial (including during the phasic response to image onset) until the end of the viewing period, mean pupil area was larger for the landscape condition, relative to the scrambled condition. Following the initial phasic response to image onset, the pupils of the landscape condition remained larger than when viewing the uniform gray screen. In contrast, the pupil area of the scrambled condition remained similar to the mean pupil size recorded during the pre-image gray screen.

Statistical analyses confirmed this description of the pupil size findings. The main effect of trial block was significant [$F_{(1,27)} = 35.43$, $p < 0.001$, $\eta_p^2 = 0.57$] showing that mean pupil size was significantly larger in block two ($M = 24.69$, SE = 0.51) than block one ($M = 23.10$, SE = 0.48). The main effect of image was significant [$F_{(1,27)} = 5.40$, $p = 0.028$, $\eta_p^2 = 0.17$]; however, this effect was qualified by an interaction with condition [$F_{(1,27)} = 4.74$, $p = 0.038$, $\eta_p^2 = 0.15$]. This interaction was analyzed further by assessing effects of image separately for each condition. For participants in the landscape condition, pupil size was significantly larger when viewing a landscape artwork ($M = 24.99$, SE = 0.93) than when viewing a gray screen [$M = 23.90$, SE = 0.75, $F_{(1,13)} = 6.41$, $p = 0.025$, $\eta_p^2 = 0.33$]. For participants in the scrambled condition, pupil size when viewing a scrambled image ($M = 23.36$, SE = 0.56) and a gray screen ($M = 23.32$, SE = 0.51) did not significantly differ ($F < 1$, $\eta_p^2 = 0.002$). These results demonstrate that viewing landscapes led to an increase in pupil size which was not seen in the scrambled condition.

DISCUSSION

The aim of this research was to investigate whether viewing nature artwork in the form of landscape paintings could improve psychological and physiological responses after a stressor, compared to viewing scrambled versions of the artwork that blurred perceptual details. This pilot study was conducted to assess feasibility and estimated effect sizes and was not powered to detect significant effects. Nonetheless, there were some significant effects, and these results will inform a larger study.

Viewing the scrambled images compared to the landscape images led to an increase in low arousal negative affect (feeling dull, sleepy, and sluggish) and drowsiness. These subjective ratings are consistent with observations of pupil size. While viewing scrambled images, average pupil size was similar to when participants viewed a uniform gray screen, and smaller than when viewing landscapes. Physiological work has shown a remarkably close relationship between moment-to-moment changes in pupil size and activity in the locus coeruleus of the brain stem (Aston-Jones and Cohen, 2005; Joshi et al., 2016). The locus coeruleus plays a key role in the regulation of arousal. Accordingly, our observation of reduced pupil size is consistent with subjective reports that while participants viewed the scrambled images, they experienced feelings of drowsiness and low arousal.

This is the first study to examine the effects of scrambled images or artworks on cortisol. Contrary to our hypothesis, salivary cortisol levels decreased faster after viewing the scrambled images compared to the landscape artworks. Cortisol has been linked with higher alertness and lower fatigue (Tops et al., 2006), so these results suggest that people in the scrambled condition felt less stimulated. Again, these results are consistent with the pupil size findings, as increased pupil size has been associated with increased cognitive engagement, effort and increased arousal (Laeng et al., 2012; Sirois and Brisson, 2014). Taken together, these results suggest that the landscapes were

more stimulating and engaged the viewers more than the scrambled images. This may be because artwork can be a form of visual environmental enrichment.

These preliminary results support theories and research on nature and demonstrate that these effects may translate to nature represented through art. The finding that landscape paintings led to less drowsiness, larger pupil size, and higher cortisol supports Kaplan's (1995) ART theory which proposes that nature engages attention and therefore reduces the fatigue effects caused by stress. These results also agree with the research that has found that viewing nature leads to "wakeful relaxation" compared to viewing urban scenes (Ulrich, 1981).

These results also support Wang et al. (2015) who suggest that traditional Chinese paintings, where perceptual details are blurred, increased an "inward oriented" frame of mind inducing high levels of relaxation and mind wandering. This was in contrast to viewing realistic paintings that had the opposite effect and was occupied with a high level of attention and stimulation. Blurred images, which are plentiful in abstract art, traditional Chinese painting, and impressionism, could be examined in a larger study, with the aim of informing an effective and integrated multi-sensory approach to recovery. Therefore, the scrambled images may have acted similarly to abstract art and traditional Chinese paintings.

However, the findings that the landscape artworks increased stimulation also contradict previous research which demonstrated that viewing nature murals compared to no mural led to lower arousal as indicated by decreased heart rate (Heerwagen, 1990). However, this previous study was conducted with dental patients awaiting procedures, and therefore, the nature mural may have worked more as a distraction, rather than being restorative.

This study had a number of limitations. Most importantly, as a pilot study, this study had a small sample size which limited the power of the analyses to find significant effects. Future research should expand on this study with a larger and more diverse sample, including a larger diversity of ages and cultures. Secondly, the study was conducted in a laboratory setting which may have affected the ecological validity, making it difficult to generalize the results to everyday settings where artwork may be placed to improve health, such as in hospitals.

A further limitation was that the landscapes contained more realistic and recognizable features than the scrambled images. Therefore, the results may have been due to the realism of the artwork rather than the natural content. Future research should include urban landscapes and their corresponding scrambled images, as well as natural landscapes and their scrambled versions, to see whether realism or nature is the effective component.

Lastly, there was little indication that the TSST lead to a physiological stress response in participants with no increase in stress biomarkers observed. It may be that participants were not given enough time to acclimatize before taking the baseline saliva sample and were therefore feeling anxious at baseline. Also, the samples were taken around 15 min after the beginning of the stressful task. Research demonstrates that a peak in cortisol is expected at least 20 min after the onset of acute stress exposure, and therefore, this study may not have allowed enough time to sample the entirety of the physiological stress response (Dickerson and Kemeny, 2004; Kirschbaum and Hellhammer, 2007). Future research should allow for a longer sampling time after the stressor and the artwork viewing of at least 20–30 min to potentially ensure more reliable stress biomarker findings.

Research on the effects of viewing artworks on stress responses could consider multiple factors. These include content, perspective, color, composition, and level of abstraction. Research also needs to consider whether the art is viewed before or after a stressor. It would be difficult for one study to include all of these factors. This study compared landscape artworks with mostly natural content with a moderate level of realism to scrambled images after a stressor and found that the landscapes were more stimulating than the scrambled images. More research is needed to consider the role of other factors, such as those listed above.

CONCLUSION

This pilot study gives an early indication that landscape artworks may reduce drowsiness and increase stimulation after stress compared to their scrambled images. We have yet to research whether the same results would be found for other types of artworks. This study sets up a framework to further explore these effects in a larger and more diverse sample. It is recommended that future research allow for a longer sampling time after the experimental tasks to be able to detect possible differences in salivary stress hormones, conduct the research in a more naturalistic setting, and use multiple control images. If certain kinds of artworks are found to be beneficial, this could inform their use in stressed populations.

DATA AVAILABILITY STATEMENT

The datasets generated for this study are available on request to the corresponding author.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the University of Auckland Human Participants Ethics Committee. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

ML, GM, AL, and EB contributed to the conception and design of the study. ML, LT-E, and MB ran the study procedures. ML statistically analyzed the psychological data. AL and NR statistically analyzed the pupil size data. UN and NS analyzed

the saliva samples and statistical analysis of this data was done by ML. ML wrote the first draft of the manuscript. AL wrote sections of the manuscript. GM, AL, UN, NS, LT-E, and EB provided revisions to the manuscript. All authors provided approval for publication of this content.

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How the Visitors' Cognitive Engagement Is Driven (but Not Dictated) by the Visibility and Co-visibility of Art Exhibits

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The spatial arrangement of artworks is recognized as one of the key elements of exhibition design. The underlying assumption is that the layout can strengthen the impact of individual exhibits, because the way visitors visually engage with artworks affects how they are cognitively processed. This paper explores the influence of the exhibits' visual properties on the visitors' attention and their memory of artworks. Attention was recorded with the use of mobile eye-tracking and memory was measured by an unanticipated recognition test immediately after the visit. The paper analyses both the total amount of attention spent on interacting with each artwork, as well as the strategy through which attention was allocated: through primarily longer ("diligent") looks, versus primarily shorter ("distracted") glimpses. Results of two experiments demonstrate that the visibility and co-visibility of artworks affected the amount of attention allocated to them, and the strategy of attention allocation. While the amount of attention contributed to improving the recognition memory of pictures, the strategy of attention allocation did not. These findings demonstrate the power of the exhibition's visual properties to influence the experience of museum visitors but also highlight the visitors' ability to employ alternative viewing strategies without diminishing the cognitive processing of artworks.

Keywords: eye-tracking, memory, art gallery, museum, visibility, co-visibility

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INTRODUCTION

The unique role of physical art galleries prevails despite the ease of online access to the arts from the comfort of one's own living room. Therefore, exhibiting art in a physical and curated setting must carry a unique value that is impossible to realize with aspatial and self-curated means of viewing art. Key functions of the gallery's curated spatial layout lie in affecting the visitors' cognitive engagement (Robinson, 1928; Bitgood et al., 1988; Peponis et al., 2004) and in supporting the interpretation of exhibits (Wineman and Peponis, 2010).

However, it is difficult to quantify the impact of the spatial layout on visitors' cognitive processes. In controlled psychological experiments that study art viewing on a computer monitor, the challenge is to maintain ecological validity. In real (non-virtual) art exhibitions that are already designed to give more prominent locations to better artworks, the challenge is to isolate

the influence of the physical setting on individual cognitive processes. The work here presented studies two processes (visual attention and memory), indicative of the visitor's *engagement*. The key underlying argument is that it is the engagement (hereby defined as perceiving and cognitively processing artworks) that forms the necessary initial step for more complex understanding to arise. The paper addresses the challenge of disentangling the influence of visual properties of exhibitions from other factors affecting the visitor's engagement with art exhibits.

To date, measuring the visitors' engagement with artworks has been tackled by two research streams aiming to understand: (1) how visitors explore exhibits, and (2) how visitors understand and appreciate exhibits.

One line of research, known as "timing and tracking" studies (Diamond, 1999; Yalowitz and Bronnenkant, 2009; Westat, 2010, Dalton et al., 2012; for a historical review see Kirchberg and Tröndle, 2012), investigated whether the number of visible pictures affects the time visitors spend looking at them. Robinson (1928) conducted laboratory-based experiments where he varied the number of pictures simultaneously presented to participants. He found that the time spent on observing a single picture did not decrease proportionally to the number of presented artworks and that the most effective way to prolong the viewing time was to present the artwork in a complete isolation (Robinson, 1928). This was followed by museum-based observations of Melton (1935) who noticed that people stopped in front of a smaller number of paintings as the number of artworks in the gallery increased, but that their viewing time per painting remained close to 10 s. He suggested that artworks "compete" for the visitors' attention (Melton, 1935). Bitgood et al. (2013) revisited these results arguing that the competition is driven not only by the content of pictures, but also by the subjectively perceived potential value of engaging them; and that this value fluctuates with the visitor's distraction, fatigue, satiation, and selectivity. These factors can be influenced by the size and design of the exhibition space. For instance, larger exhibitions are walked through faster (Serrell, 1997). However, the viewer's exploration strategy also plays an important role: visitors who traveled through fewer sections of the Louvre museum were shown to spend more time inside, than those who "rush through" a larger number of spaces (Yoshimura et al., 2012). It thus seems, that museum visitors have some limited amount of cumulative engagement time they are ready to "spend" on exploring the exhibits and that they adjust their exploration strategy *in situ* in order to accommodate this.

Trying to explain how such *in situ* adjustments take place, Smith and Smith (2001); see also: Smith et al., 2017) manually recorded the visitors' stopping behavior in front of artworks. They observed a repeatable pattern consisting of two phases: the initial period of viewing shorter than 10 s (when possibly the decision is being made about stopping for longer or progressing forward) and the period of diligent viewing, averaging to about 30 s per picture, but greatly varying across them. However, such manual recordings [just like other measures of engagement in timing and tracking studies: reading interpretive text (Bitgood and Patterson, 1993), or having a conversation about the exhibit (Bitgood, 1993)] are likely to be biased toward detecting an already *diligent* engagement. They might ignore (or not explicitly distinguish) the role of shorter, haphazard interactions with the artworks, for instance occurring when visitors only glimpse at a painting without clearly stopping in front of it. In contrast, the aim of the current paper is to record *any* visual engagements with the exhibits (both diligent and not) and measure their impact on the recognition memory of artworks. We hypothesized that the visitors can vary their distribution of "haphazard" and "diligent" interactions independently of their cumulative viewing time and that the two variables are influenced by separate visual properties of the gallery space. Given this aim, we studied the visual attention directly, by recording the viewer's eye movement.

This approach can be traced back to Buswell (1935) who recorded scan paths of his participants' eye movement on an analog film while they were examining artworks inside his laboratory. After observing that the viewers' attention was not uniformly distributed, he suggested: "it is probable that most of the visitors to an art gallery look at the pictures with this (quick survey) type of perception and that they see only the main centers of interest" (Buswell, 1935, p. 142). With the availability of mobile eye-tracking devices, today similar hypotheses can be investigated *in situ* (Hayhoe and Ballard, 2005; Tatler and Land, 2015; Kiefer et al., 2017).

Wessel et al. (2007) recorded the eye movement of three students during a small exhibition, showing that they employed a two-staged viewing strategy: first, they visually skimmed through a larger area (e.g., an entire wall), and only then analyzed individual exhibits in detail. Heidenreich and Turano (2011) asked four participants to view 14 paintings in the Baltimore Museum of Art, but found no significant correlations between eye fixations and the painting's "saliency map" (i.e., a calculated prediction of the most visually salient areas of the image; Itti and Koch, 2000), nor between viewing times and the subsequent esthetic judgments of the artworks (see also Isham and Geng, 2013 for a similar result). It therefore seems that the two-stage viewing process suggested by Smith and Smith (2001) is reflected in the eye movement of gallery visitors, but that it cannot be explained by the visual saliency of artworks.

While "timing and tracking" studies investigated visitor behavior *in situ*, the field of experimental esthetics investigated how people form a deep impression of artworks, in controlled laboratory-based settings. It has broadly adopted the assumption about the two-stage nature of this process. For instance, the cognitive model of esthetic appreciation proposed by Leder et al. (2004) distinguishes between "automatic" and "deliberate" cognitive processes. According to this framework, when people see an artwork, its perceptual features and implicit memory relations are first analyzed by automatic cognitive processes. Only in the second phase, deliberate processes (such as domain specific expertise and contextual interpretation) become involved in the appreciation. Another model (Locher et al., 2007) also emphasized the two-stage nature of the esthetic experience, differentiating between a quick, automated decision (a "gist"), and longer, diligent viewing. In the supporting experiment, the participants' eye movement was recorded alongside think aloud protocols while they were rating artworks for pleasingness. Viewers spent 32.5 s on average before doing so - a duration in

line with Smith and Smith's results (2001) and interpreted as the indication of the external validity of the model (Locher et al., 2007). Similarly, Bitgood (2010) presented a model adapted to the context of an entire art gallery visit. According to his "capture-focus-engage" framework, art appreciation is also sequential and the initial "capture" and "focus" stages do not involve deeper cognitive processing of the artwork. However, it is unclear where would lie the threshold between the initial "gist" phase and the deeper engagement. In Locher et al. (2007) studies, 2 s have passed before participants began to verbally describe the holistic features of an artwork. They also based their impressions on those image parts that they saw within the first 3 s of viewing. In line with this, Bitgood (2010) proposed that at least "a few seconds" must past before the viewer progresses beyond the "focus" phase to a deeper engagement.

In approaching and engaging art, the museum space surrounding it plays a key role (Newhouse, 2005; Hillier and Tzortzi, 2007; Zamani, 2009). The constellation of factors creating the difference between a museum and "any other" space has been jointly referred to as the "museum context." To show its relevance, Brieber et al. (2014) asked two groups of participants to freely view the same art exhibition either in an art gallery or on a computer screen in a psychological laboratory. Participants inside the museum viewed pictures for longer. In a different study, Brieber et al. (2015) demonstrated that the same artworks were remembered better, liked more, and rated as more arousing, positive, and interesting when viewed in the real museum, compared to a computer-based simulation. Tröndle et al. (2014) recorded psychophysiological responses indicating arousal of visitors in a public art gallery. They observed that reactions were negligible when an artwork was hung just outside the entrance to the designated exhibition area and that they increased immiedietly after participants crossed the entrance. These studies demonstrate the effect of the "museum context." It remains unclear, however, which aspects of the museum's physical environment have the largest impact on the visitors' experience.

One considered variable are the visual properties of the artworks' hanging locations. The visibility and accessibility of exhibits were shown to predict the visitors' stopping behavior and engagement (Bitgood et al., 1988; Hillier et al., 1996; Peponis et al., 2004). As demonstrated in the wayfinding literature, objects that are more visible in space are also more likely to be remembered (von Stülpnagel and Frankenstein, 2015). However, in the context of a museum visit, not all visibility is equally impactful. Stavroulaki and Peponis (2003) proposed that frontal visual catchment areas (quantified as 60° visibility cones extending from the front of the artworks) have particularly strong impact on the visitor experience.

Another spatial aspect attracting the researchers' interest has been the co-visibility of exhibits. Bitgood et al. (1988) demonstrated that "competition" that arises from two exhibits being potentially co-visible by the viewer decreases the visitors' stopping probability (see also: Melton, 1972 and Bitgood et al., 2013). However, co-visibility can also enrich the visitors' experience. Lu and Peponis (2014) systematically modified the co-visibility of artworks in a virtual reality simulation of an art gallery. In their experiment, participants freely explored the virtual exhibition and graded its "clarity." The co-visibility of artworks was correlated with a better understanding of the exhibition. The above studies therefore suggest that co-visibility might have a negative impact on the amount of attention allocated to individual exhibits, but that it can also simultaneously enhance the visitor's deeper cognitive processing of the exhibition's content.

The aim of the current work is to quantify the influence of the visibility and co-visibility of exhibits on the visitors' cognitive engagement. This is achieved by: (a) dissociating the influence of the spatial location from the influence of the individual artwork, (b) systematically varying the visibility and co-visibility of artworks, and (c) jointly measuring the strategy of attention allocation, the cumulative amount of the allocated attention, and the memory resulting from it.

This manuscript expands on two earlier publications, which separately reported that eye-movement is correlated with the visibility of artworks' locations (Krukar and Conroy Dalton, 2013) and that the overall spatial layout of a gallery affects the memorability of artworks (Krukar, 2014). It includes previously unreported data from Krukar (2014) and an entirely new experiment. The paper is therefore the first to ever consider the causal relation between the museum space, the visitor's visual attention, and the resulting memory of artworks, in a single statistical model.

We hypothesized that the visual properties of exhibits (their visibility and co-visibility) affect both (a) the amount of attention (total viewing time per picture) and (b) the strategy with which attention is allocated to exhibits (haphazard vs. diligent viewing). We further expected that pictures that are viewed for longer and in a less haphazard manner, will be memorized better. It is thus proposed that the influence of visual properties of exhibits on the cognitive processing of artworks is mediated by the allocation of visual attention.

MATERIALS AND METHODS

Both experiments reported below employed the same procedure. Participants (recruited from the general population through public advertisement; but not artists, curators, nor architects) individually explored a non-public, mock-up art gallery. They were asked to wear a mobile eye-tracker during their visit and given the instruction to explore the space "as you would explore a regular art exhibition" for maximum 30 min (although they were not interrupted until 35 min – a limit imposed by the battery capacity of the eye-tracker). Participants were specifically asked to enter each space and to look at each picture. After exiting the gallery, they performed an unanticipated recognition memory test on a computer. Both studies received university's ethical clearance. All participants signed an informed consent form and were paid 6 GBP.

Artworks displayed in the gallery were digital collages of equal dimensions (portrait-oriented A3), created by the artist Susi Bellamy (**Figure 1**). No labels or textual information about the artworks were provided and no other distractors were present in the gallery. As all artworks were untitled, any potential labels

FIGURE 1 | Artworks used in the experiments. "Strike a Pose": www.susibellamy.co.uk. Used with permission. Labels **(A–N)** were added by the researcher for the purpose of distinguishing artworks in the data analysis (labels were not shown to participants).

would be identical in content – their role in affecting the visitors' engagement would therefore, most likely, be similar for each exhibit. The artworks were hung on locations which were kept identical within each experimental condition. However, the order in which each artwork appeared in the gallery (i.e., the placement of individual artworks at any given location) was randomized for each participant. Two participants exploring the gallery within the same experimental condition saw the same locations on the walls being occupied by artworks, saw the same set of artworks, but the exact artwork hanging on each location differed. This experimental design made it possible to distinguish the influence of spatial location and the influence of the individual picture. The subsequent data analysis involved three aspects: the analysis of the visual properties of artwork locations, the analysis of the eye movement, and the analysis of the recognition memory of artworks.

Visual Properties

Two variables were used to analyze the visual properties of each artwork location:

Visibility Catchment Area (VCA)

The area size of a 60° visibility cone extending from the center of the artwork. This angle was selected based on previous work of Stavroulaki and Peponis (2003), as it permits distinct and undistorted viewing. The analysis was conducted using the DepthMapX software (Varoudis, 2012) and the area was measured in the arbitrary software units. The resulting numbers were transformed into z-scores so that their mean equaled 0, and the unit was their standard deviation. This makes the variable relative to the size of other VCAs in the studied gallery.

Co-visibility

The number of other artworks visible from the given location. The number is calculated from the central point of the artwork on the wall. Note that this measure only approximates the number of potentially co-visible artworks, since the visitor would need to stand with their back to the wall in order to see all other co-visible artworks. This method is chosen because it is independent of the path taken by participants and of their standing position.

Eye Movement

Eye movement was recorded with the Tobii Glasses 1 mobile eye-tracker, sampling eye movement at 30 Hz. Fixations were detected using the built-in algorithm. Three variables were used to analyze eye movement:

Dwell Time (Amount of Attention)

Total cumulative time (in seconds) that the person spent looking at each artwork. In the reported experiments, it ranged from 1 to 303 s per picture, and the mean values per picture in all reported conditions were close to 30 s. Total dwell time has been previously linked to the meaning of the viewed area, its informativeness and interest (Holmqvist et al., 2011), as well as to the memory of the object's position (Tatler et al., 2005).

Normalized Dwell Time (Relative Amount of Attention)

The percentage of total dwell time allocated by each participant to each individual artwork, in relation to the total time spent by them inside the gallery. The measure ranges from 0 to 100%. A participant spending an equal amount of attention on each artwork (and not dwelling on any non-artwork parts of the building) in Experiment 1, would achieve the value of $(1/14) \times 100 = 7.14\%$ for each artwork. This measure indicates the relative amount of attention allocated to each exhibit while preserving the distinction between viewers who spent a large proportion of their viewing time fixating on exhibits and those who fixated on other elements of the environment (e.g., for the purpose of navigation or due to distraction).

Normalized dwell time was used in the analysis of Experiment 1 where the interest lies in the relative amount of attention in comparison to other exhibits. Raw dwell time was used in Experiment 2 where the differences between individual exhibits were not in the center of interest.

Dwell Ratio (Strategy of Attention Allocation)

The relation between the number of dwells longer than 2 s to dwells shorter than 2 s, per participant, per artwork. A single dwell is the time from the moment the participant's scan path entered the boundaries of the image until it left them. A typical participant therefore employed more than one dwell on each artwork. For example, if there were 8 dwells in total, and five of them lasted longer than 2 s, while three of them lasted less than 2 s, the dwell ratio would equal 5/8 = 0.625. This metric ranged between 0 and 1. A higher number indicated that most visual engagements were longer ("diligent"). A lower number indicated that most interactions with the artwork occurred through short, haphazard glimpses.

This measure is based on the qualitative difference suggested to exist between different modes of art viewing (Smith and Smith, 2001; Leder et al., 2004; Locher et al., 2007; Bitgood, 2010) and describes the strategy with which attention was allocated to each exhibit. However, it is not implied that any particular strategy is undertaken intentionally. Although other ways to classify dwell types are possible, the current method has been selected in order to integrate the insight from observational visitor studies and laboratory-based experimental esthetics. Note that employing a different classification could affect the reported results.

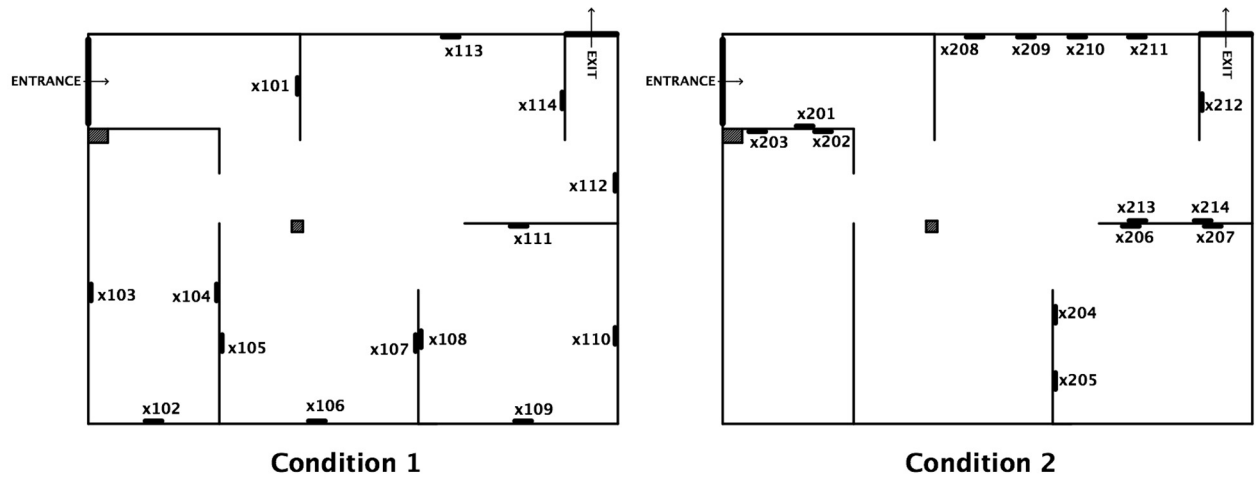

FIGURE 2 | Two conditions arranged within Experiment 1, together with unique identifiers of artwork locations.

Eye-tracking videos were coded manually and the interrater reliability analysis was carried out on 10% of the video material. Cohen's Kappa was 0.99 for the total dwell time variable, and 0.98 for the normalized dwell time.

Recognition Memory

Recognition memory was assessed using a computer-based image-discrimination task administered using the OpenSesame software (Mathôt et al., 2012). Participants were presented with pictures appearing sequentially, in a random order. Their goal was to answer whether they saw the picture inside the gallery by pressing the key marked as "yes" or "no." The image set included all artworks present in the gallery, as well as the matching number of foils (new pictures, not present in the gallery). Foils were created from other artworks of the same artist, and by manipulating the graphic properties of the images present inside the gallery.

In both experiments, the ratio between response times and accuracy was stable across conditions, confirming no uneven speed-accuracy trade-off (Kahana and Loftus, 1999). This makes it possible to analyze the accuracy of responses as a key variable of interest. Using this measure in a linear mixed-effect model does not require aggregating the data by-participants (e.g., unlike the d' metric), making it possible to simultaneously consider the differences in accuracy between participants, between stimuli, and between the original locations of their corresponding artworks in the gallery.

EXPERIMENT 1

Experimental Design, Procedure, and Participants

Two experimental conditions were arranged (**Figures 2**, **3**). The shape of the gallery walls was identical in both conditions but the spatial arrangement of artwork locations differed. **Table 1** summarizes their VCA and co-visibility measures. Condition 1 included only one artwork per wall, while Condition 2 consisted of a denser arrangement of artworks on individual walls, with more walls being empty. Participants were randomly allocated to one of the two conditions and invited to explore it while wearing Tobii Glasses 1. After disregarding recordings with poor eye-tracker calibration (4 participants), the data of 28 participants were included in the analyses (Cond. 1: 13, Cond. 2: 15; of which 3 and 8 females, respectively; participants' age range: 21–47 and 20–63, respectively). **Figure 4** presents an overview of the procedure.

Data Analysis

The current paper focuses on the individual influence of each location on eye-movement and recognition memory. Both conditions are only analyzed here as a means of assessing whether the behavioral patterns hold in two different spaces. In that framework, systematic differences distinguishing the two conditions do not confound the linear effect of VCA and co-visibility on attention and memory.

The artwork's location influences how much visual attention it attracts (and what kind of attention); this attention in turn influences how well the artwork is remembered. Visual attention variables (normalized dwell time and dwell ratio) are dependent

FIGURE 3 | Views from the mock-up art gallery used in Experiment 1.

TABLE 1 | Visual properties of all locations in Experiment 1 (VCA is provided in arbitrary units of the DepthMapX software, which were standardized and mean-centered for the purpose of further analyses).

Condition 1			Condition 2		
Location	**VCA**	**Co-visibility**	**Location**	**VCA**	**Co-visibility**
x101	52121	1	x201	16829	0
x102	110788	2	x202	130217	1
x103	48408	3	x203	95532	1
x104	32137	2	x204	72764	5
x105	112856	6	x205	59763	5
x106	235743	3	x206	71270	3
x107	70784	2	x207	58939	3
x108	71857	4	x208	212837	5
x109	125122	3	x209	224943	5
x110	161844	3	x210	194981	7
x111	73819	4	x211	129182	7
x112	198118	0	x212	5259	1
x113	186388	2	x213	60790	5
x114	164517	5	x214	56346	6

variables influenced by visual properties of artwork locations; however, they can also be treated as independent variables (predictors) of the recognition memory performance. In order to statistically verify this causal relation, Piecewise Structural Equation Modeling (SEM) is used (Lefcheck, 2016). The main difference between Piecewise SEM and traditional SEM is the consideration of random effects within the framework of linear-mixed effect models. Three random effects are considered in the main analysis: the by-participant random effect (individual participants' responses are likely to be related), the by-location random effect (responses to objects hanging on the same location are likely to be related), and the by-picture random effect (responses to the same picture are likely to be related). This approach does not require aggregating the data across the participants or across the locations.

The constructed Piecewise SEM evaluates whether the visual properties of individual locations influence the amount of attention each participant allocated to the artwork currently hanging on that location and, in turn, how likely the person was to recognize this artwork in the subsequent memory test. The tested structure initially consisted of three models, presented in **Table 2** (two linear mixed-effect models, and one mixed-effect model with a binomial link for explaining the categorical variable of reaction time accuracy; random effects structure is denoted in the form accepted by the lme4 R package; Bates et al., 2015).

TABLE 2 | Mixed-effect models included in the SEM analysis of Experiment 1.

Model	Response	Fixed effect predictors	Random effects structure
m1	Norm. dwell time	VCA + co-visibility	(1| location) + (1| participant)
m2	Dwell ratio	VCA + co-visibility	(1| location) + (1| participant)
m3	Memory accuracy	norm. dwell time + dwell ratio	(1| location) + (1| participant)

The influence of individual pictures was initially considered but disregarded: each model was tested against alternative structures of random effects. Considering the random by-picture effect, either instead of, or together with the by-location effect, did not improve the models' fit. The random effect structure that consistently provided the best fit was the one including the random by-participant effect and the random by-location effect. Moreover, including the effect of condition in the random effects structure did not improve the fit of any of the models, suggesting that the relation between the strategies of attention, amount of attention, and memory is similar in both conditions.

Results

Descriptive Statistics

Participants spent between 1 and 29 min inside the gallery. The mean time spent inside was 10:15 min in Condition 1 and 7:54 min in Condition 2 (difference not statistically significant when measured by the Wilcoxon rank sum test: $W = 139$, $p = 0.444$). Individual visitors dedicated between 52 and 94% of their time inside to looking at artworks (as opposed to looking at other elements of the environment, e.g., for the purpose

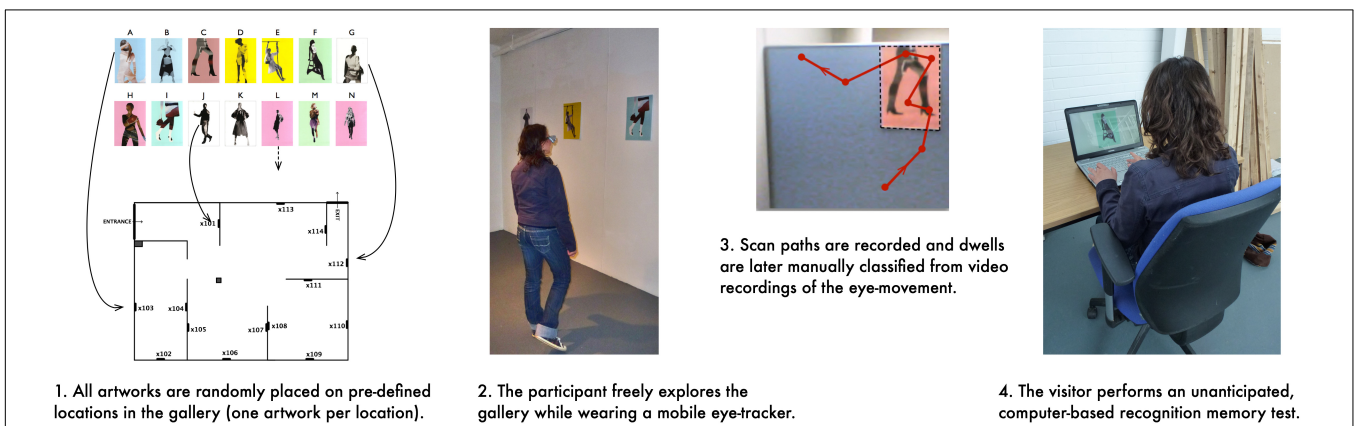

FIGURE 4 | An overview of the experimental procedure.

of navigation or due to distraction). This difference between conditions was not statistically significant (Cond. 1: M = 81%, Cond. 2: M = 72%, W = 146, p = 0.077). Mean normalized dwell time (per picture and per participant) was 5.47%. The dwell ratio ranged from 0.24 to 0.60 per participant, with the mean value of 0.37 in Condition 1 and 0.42 in Condition 2 (W = 72.5, p = 0.14). Recognition memory accuracy ranged from 0.36 to 1.00 when aggregated by-participant, from 0.64 to 1.00 when aggregated by-picture, and from 0.67 to 1.00 when aggregated by-location (further analyses account for these effects simultaneously). Considering all interactions, across all participants and both conditions, the average total viewing time of a single artwork was 32 s, which validates our procedure in-line with visitor observations in "timing and tracking" studies inside working art galleries (Smith and Smith, 2001; Smith et al., 2017). Average recognition memory accuracy was 0.78. Three participants did not look at all artworks, missing a single artwork each (picture D at location x201, G at x212, and F at x212); although it is possible that an existing glimpse was too short to be registered by the eye-tracker. As linear-mixed effect models include by-participant random effects, we decided not to remove outliers based on any subjectively chosen threshold (e.g., of minimum visit time), but instead let the statistical model to adjust for extreme outcomes through the statistical process of shrinkage.

Modeling the Interaction of the Visual Properties, Attention, and Memory

Statistical models that were used in the Piecewise SEM are separately summarized in **Table 3**. They demonstrate that the more visible an artwork was (i.e., the larger its VCA), the more dwell time it attracted, relative to other artworks: increasing VCA from 0 to 1 *SD* resulted in attracting 0.51% more normalized dwell time. Considering that the difference between VCAs of individual locations ranged from −1.57 *SD* to 1.97 *SD*, it can be estimated that the difference between the least and the most visible location in normalized dwell time caused by the effect of visibility alone (while controlling for other by-location effects) is 1.80%. Higher VCA was also associated with lower dwell ratio: an increase in VCA from 0 to 1 *SD* caused lowering the dwell ratio by 0.09, meaning that participants looked at more visible locations in a more "distracted" manner.

Also the co-visibility had a significant effect on decreasing the dwell ratio: each additional 1 co-visible artwork was associated with a decrease in dwell ratio by 0.02. Since co-visibility in the studied locations varied from 0 to 7, this translated to a difference of 0.16 between dwell ratios of the least and the most co-visible artwork in the galleries. This effect can be related to the influence of the co-visibility alone, while controlling for VCA and for other unexplained (random-effect) differences between locations. More co-visible artworks were engaged with in a more distracted manner - through a lower proportion of diligent dwells.

Recognition memory accuracy was significantly predicted by normalized dwell time, but not by the dwell ratio. Each additional 1% in the normalized dwell time was associated with a change in the odds ratio of correctly remembering the picture, equal to 1.28:1. Odds ratios are calculated by taking the exponent of the estimated coefficient and can be interpreted similarly to betting odds; it can be thus said that for a 1 unit increase in the normalized dwell time, we expect a 28% increase in the odds of remembering an artwork.

The final Piecewise SEM is presented in **Figure 5**. A d-separation test for missing paths (Shipley, 2013; Lefcheck, 2016) indicated that the model should also include the correlation of the normalized dwell time with dwell ratio, meaning that the longer each participant looked at a particular picture, the higher proportion of those dwells were "diligent". As this correlation does not have a clear causal direction, it has been modeled in the form of a correlated error (Lefcheck, 2016). The model's goodness-of-fit was verified by the Fisher's C statistic being non-significant (C = 2.00, p = 0.735), meaning that the model represents the data well. It can be summarized that visual properties of the exhibits' locations affected the memory accuracy of artworks indirectly: by influencing the visual attention.

Differences Between Locations

The main effect of VCA and co-visibility can be interpreted despite other possible differences across the locations (e.g., due to other spatial variables not considered in the model) and across the conditions. Nevertheless, it is valuable to investigate the differences between individual locations in detail, as they might reveal systematic biases in how visitors engaged with them. **Figure 6** presents a forest plot of the random effect of locations (Lüdecke, 2017) in Models m1 and m2 visualizing the influence that each location has on the dependent variable after considering the effects of VCA and co-visibility. For example, the value of 0.48 for the location x211 in the Model m1 (dependent variable: normalized dwell time) indicates that objects hanging at this location are predicted to receive the normalized dwell time higher

TABLE 3 | Piecewise SEM relating spatial predictors, visual attention, and recognition memory in Experiment 1 (R^2 estimates the proportion of variance in the data explained by the fixed factors alone; Conditional R^2 estimates the proportion of variance explained by the fixed and random factors).

Model	R^2	Cond. R^2	Response	Predictor	Estimate	Std. error	*p*-value
m1	0.03	0.09	Norm. dwell time	VCA	0.508	0.183	**0.010**
			Norm. dwell time	Co-visibility	−0.017	0.091	0.853
m2	0.18	0.36	Dwell ratio	VCA	−0.090	0.018	**<0.001**
			Dwell ratio	Co-visibility	−0.022	0.009	**0.025**
m3	0.07	0.18	Memory accuracy	Norm. dwell time	0.250	0.077	**0.001**
			Memory accuracy	Dwell ratio	0.763	0.573	0.183
Corr. err.			Norm. dwell time	Dwell ratio	0.143	–	**0.002**

Significant p-values lower than 0.05 are marked in bold.

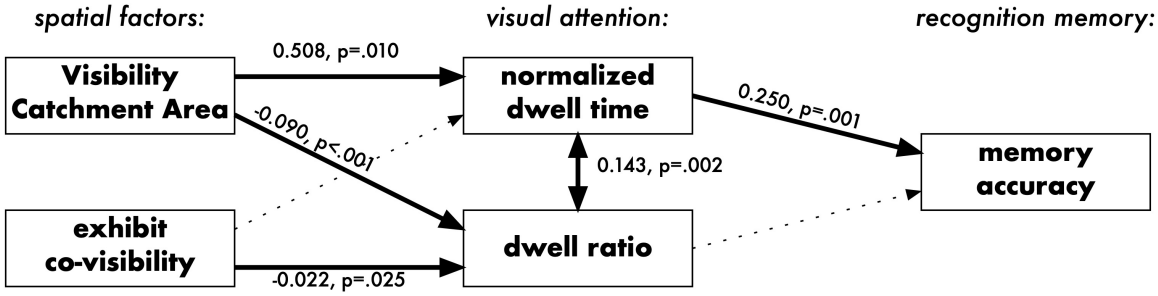

FIGURE 5 | Piecewise SEM relating spatial predictors, visual attention, and recognition memory in Experiment 1. Dotted lines represent non-significant pathways. Numbers are the estimated effects of the linear model: e.g., an increase by 1 SD in Visibility Catchment Area (VCA) is associated with an increase by 0.508 in normalized dwell time.

by 0.48 after considering the fixed effects of VCA and co-visibility. If location had no effect on visual attention, these values would equal 0. Location x113 attracted the highest amount of attention (i.e., on average it was viewed the longest, compared to other locations); location x108 attracted the least attention (i.e., on average it was viewed the shortest, compared to other locations).

DISCUSSION

Results demonstrate that accounting for only two variables (visibility and co-visibility of artworks) can explain a significant portion of the variance in the visitors' behavior. Data show that visual properties of artworks' locations had a significant influence on the relative amount of attention allocated to artworks (normalized dwell time in Model m1) and on the strategy of attention allocation (dwell ratio in Model m2). The amount of attention had a significant influence on the memory accuracy, but the strategy of attention allocation did not (Model m3). This demonstrates that local visual properties of hanging locations in an art gallery directly affect the amount of attention each artwork receives, the strategy of attention allocation and, in turn, indirectly affect the memory of the engaged artworks.

Results confirm that more visible locations attract more attention - a finding made earlier in the context of zoos and science exhibits (Bitgood et al., 1988; Peponis et al., 2004). However, after controlling for other confounding factors, this effect was small: the difference between the least and the most visible locations that can be associated with the isolated effect of VCA was 1.80% in the normalized dwell time. Further, Model m2 had a considerably higher R^2 value, compared to Model m1. This shows that the strategy of attention allocation was affected more, compared to the amount of attention: Modifying visibility and co-visibility of artwork locations in a gallery bears a limited change to how long visitors will engage with them but a more consistent change to their viewing strategy. It is thus likely that the amount of attention is driven primarily by the individual preferences of each viewer (Brieber et al., 2014) - an assumption that is not tested in the current paper as we explicitly focused on cognitive engagement and not subjective preferences in art viewing.

The influence of space on recognition memory is indirect, and it seems to be driven primarily by the mediating role of the amount of allocated attention. Artworks hanging at more visible locations are remembered better *because* they are viewed for longer. This causal path is an important property of the human-environment interaction in the art gallery because it can be very sensitive to interference. Many elements of the visit (e.g., visitors' goals, additional interpretive material), can disrupt the carefully planned spatial influence envisioned by the curator.

While the recognition memory performance was directly influenced by the proportion of attention allocated to individual artworks, it was not significantly predicted by the dominant strategy of attention allocation. This result is counterintuitive and contrary to the dominant assumption in the visitor studies literature, which traditionally tends to link this strategy of attention allocation with the inferior understanding of the exhibition. What could be interpreted as a more "distracted" viewing behavior did not jeopardize the cognitive processing of the artworks' content.

The exact benefit of increasing the relative visibility of artworks is difficult to judge because there seem to be two contrary processes at play at the perceptual stage of the interaction. More visible locations were likely to be looked at in a more distracted way but, simultaneously, participants looked at more visible locations for proportionally longer. Experiment 2 was designed to disentangle the effect of the two studied visual properties (VCA and co-visibility).

EXPERIMENT 2

Experimental Design, Procedure, and Participants

Two layouts were created in a different space than the one used in Experiment 1. In both conditions, VCAs of all locations were identical (**Figures 7**, **8**). The co-visibility of each artwork varied across the conditions (co-visibility = 0 in Condition 1 and co-visibility = 5 in Condition 2). Twelve, instead of 14 pictures from the same set were used in this study (excluding pictures G and H from **Figure 1**). Compared to Experiment 1, the artworks' number was reduced, in order to preserve an empty wall section

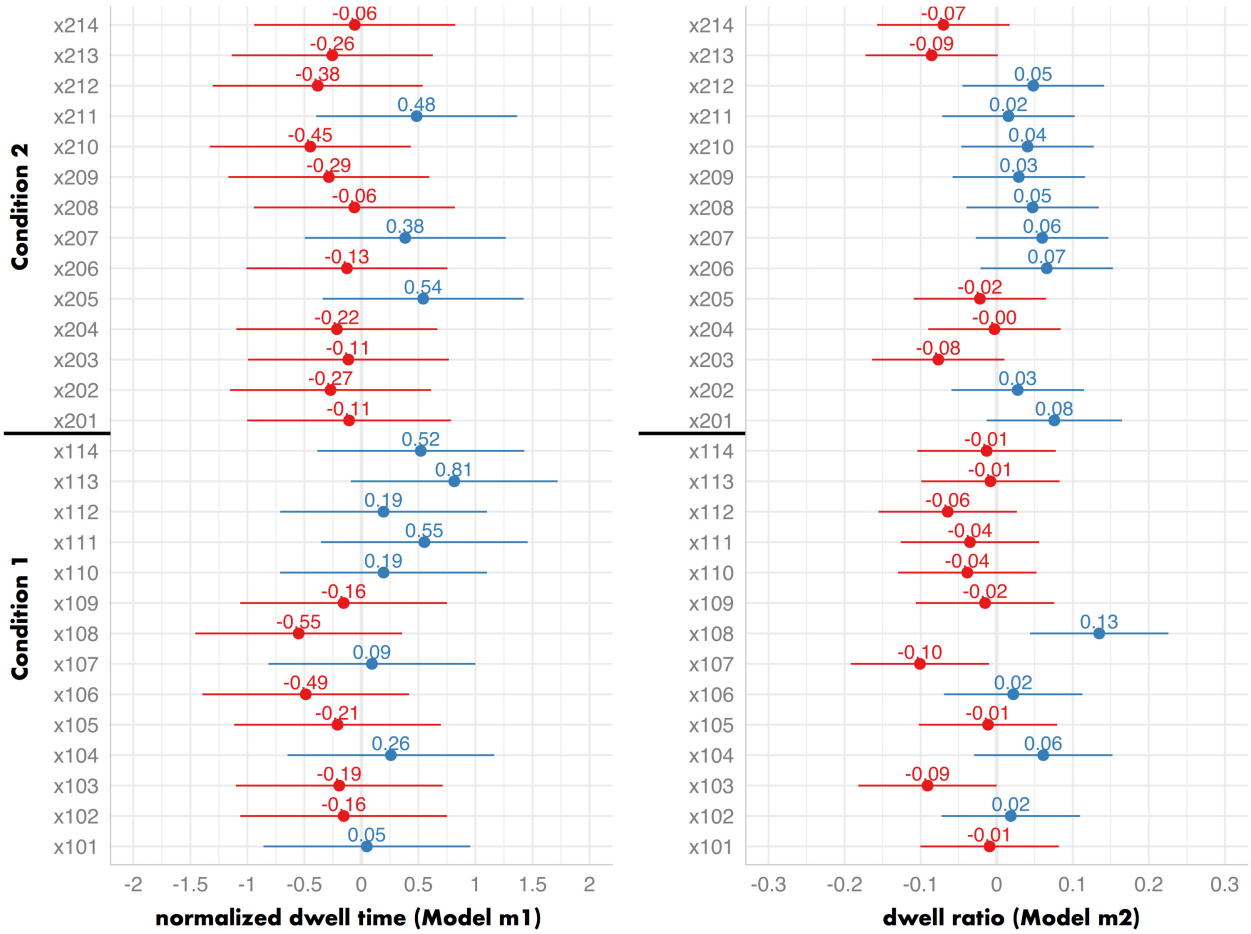

FIGURE 6 | A forest plot of random by-location effects in Experiment 1 (left: Model m1; right: Model m2), with 95% Confidence Intervals. It demonstrates how the models' predictions are affected by each individual location. If location had no effect on visual attention, these values would equal 0.

at the far end of the artwork sequence - this was intended to prevent participants from rapidly turning around the wall and spotting the first image on the opposite side of the wall from an unusually close distance which could confound the uniformity of otherwise similar locations. The procedure followed that of Experiment 1. Participants were randomly allocated to one of the two conditions and the location of artworks was randomized for each visitor. After disregarding uncomplete recordings (of 16 participants in total, due to faulty battery slot of the eye-tracker and poor eye-tracker calibration due to technical issues with lighting), the data of 29 participants were included in the analyses (Cond. 1: 10, Cond. 2: 19; of which 6 and 14 females, respectively; participants' age range: 26–68 and 23–67, respectively). Most statistics are calculated on *participant-artwork interactions*, i.e., on (10+19) participants x 12 artworks = 348 data points.

Data Analysis

Unlike in Experiment 1, the main source of variation in the influence of visual properties lay across the conditions, not across the locations. For this reason, the data analysis based on Piecewise SEM was altered compared to the procedure described for Experiment 1. Firstly, the visual predictors (VCA and co-visibility) were substituted by the categorical variable distinguishing between Conditions 1 and 2. Secondly, normalized dwell time was substituted by the raw dwell time, as it is more informative to compare two conditions on a non-relative scale (i.e., total dwell time in seconds). However, the raw dwell time measure is confounded by the time spent inside the gallery (which differed substantially across the individuals and across the conditions). It can be expected that pictures are viewed for longer by those participants, who spend more time inside the gallery. In order to account for this, time inside the gallery (per participant)

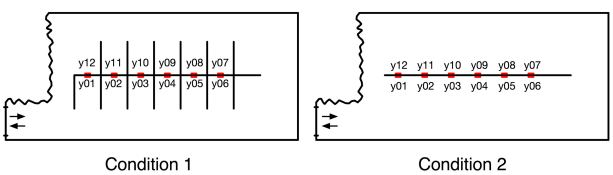

FIGURE 7 | Two conditions arranged within Experiment 2.

FIGURE 8 | A view from Condition 1 **(left)** and Condition 2 **(right)** arranged within Experiment 2.

was included as a control variable in the models presented below. This way, all other effects (for instance, the effect of experimental condition) can be evaluated even under the presence of noticeable differences in the times spent inside the gallery. Thirdly, the random effect of locations was substituted by the random effect of pictures, as little variation was expected to arise across so uniformly arranged locations.

The tested Piecewise SEM consisted of three models, presented in **Table 4**. Each model was tested against alternative structures of random effects. The random effect structure which consistently provided the best fit was the one including the random by-participant effect and the random by-picture effect. Considering the random by-location effect, either instead of, or together with the by-picture effect, did not improve the models' fit.

Results

Descriptive Statistics

Participants spent between 2 and 35 min inside the gallery. Mean time spent inside was 8:25 min in Condition 1 and 7:39 min in Condition 2 ($W = 112$, $p = 0.456$). Visitors dedicated between 56% and 97% of their time inside to looking at artworks (and the difference between conditions was statistically significant; Cond. 1: $M = 78\%$, Cond. 2: $M = 87\%$, $W = 39$, $p = 0.009$). The dwell ratio ranged from 0.13 to 0.95 per participant, with the mean value of 0.71 in Condition 1 and 0.40 in Condition 2 (a significant difference, as demonstrated in statistical models below). Recognition memory accuracy ranged from 0.50 to 1.00 when aggregated by-participant, from 0.76 to 0.98 when aggregated by-picture, and from 0.75 to 0.94 when aggregated by-location. When to consider all interactions, across all participants, and both conditions, the average total viewing time of a single artwork was 34 s, which is in-line with *in situ* observations of museum visitors (Smith and Smith, 2001; Smith et al., 2017).

TABLE 4 | Mixed-effect models included in the SEM analysis of Experiment 2.

Model	Response	Fixed effect predictors	Random effects structure
m4	Dwell time	Condition (1 vs. 2) + time inside	(1| picture) + (1| participant)
m5	Dwell ratio	Condition (1 vs. 2) + time inside	(1| picture) + (1| participant)
m6	Memory accuracy	Dwell time + dwell ratio + time inside	(1| picture) + (1| participant)

Average recognition memory accuracy was 0.86. All participants looked at each artwork at least once.

Modeling the Interaction of the Visual Properties, Attention, and Memory

Models explaining the relation between the experimental conditions, visual attention measures, and memory are summarized in **Table 5**. Results demonstrate that the dwell time was associated with the experimental condition: participants in Condition 2 viewed each artwork for 3.8 s longer on average, after controlling for the effect of the total time spent inside the gallery. Unsurprisingly, time spent inside the gallery was also a significant predictor of dwell time per picture: each additional minute of the gallery time contributed to 4.7 s of viewing, on average, per artwork. Dwell ratio was lower in Condition 2 by 0.30, meaning that participants in Condition 2 employed a viewing strategy based on a lower proportion of long dwells - their viewing behavior was more "distracted". Recognition memory was predicted by dwell time but not by the dwell ratio. Each additional second of dwell time was associated with the increase in odds of remembering an artwork by 6%; 10 s of additional dwell time would increase the odds of correctly remembering the artwork by 76% (i.e., to 1.76:1). Time spent inside the gallery had a negative relation with the recognition memory (but not statistically significant): each minute in the gallery was associated with a decrease in the odds of remembering an artwork by 15% (0.85:1).

The final Piecewise SEM is depicted in **Figure 9**. A d-separation test indicated that the model should include the correlation of dwell time with dwell ratio, which was modeled in the form of a correlated error. The model's goodness-of-fit was verified by the Fisher's C statistic being non-significant ($C = 0.46$, $p = 0.794$), meaning that the model represents the data well. Considering the differences between individual locations (a random by-location effect) did not significantly improve the models' fit and therefore is not reported in detail.

Discussion

The Piecewise SEM demonstrates that the experimental condition significantly affected the strategy of attention allocation and the amount of attention dedicated to individual pictures. Participants in Condition 2 explored the pictures in a manner based on shorter glimpses but cumulatively looked at them for 3.8 s longer, on average. Participants in Condition 1 explored the artworks mainly through longer engagements. In line with the results of Experiment 1, the amount of attention spent on each picture had an impact on its recognition memory, but there was no corresponding evidence for the impact of the strategy of attention allocation (i.e., dwell ratio did not predict recognition memory accuracy).

Experiment 2 confirms and expands findings of Experiment 1 when explaining the relationship between the visual properties of space, visual attention, and memory. Co-visibility affected the visual attention of museum visitors. After considering the role of visual attention, no further effect of experimental condition on recognition memory was detected by the missing-path analysis. This suggests, that the key difference between the two spaces is

TABLE 5 | Piecewise SEM relating two spatial conditions, visual attention, and recognition memory in Experiment 2.

Model	R^2	Cond. R^2	Response	Predictor	Estimate	Std. error	*p*-value
m4	0.78	0.79	Dwell time (sec.)	Condition	3.796	1.348	**0.005**
			Dwell time (sec.)	Time inside (min.)	4.738	0.133	**<0.001**
m5	0.24	0.53	Dwell ratio	Condition	−0.304	0.066	**<0.001**
			Dwell ratio	Time inside (min.)	<0.001	0.007	0.980
m6	0.09	0.15	Memory accuracy	Dwell time (sec.)	0.057	0.020	**0.004**
			Memory accuracy	Dwell ratio	0.869	0.657	0.186
			Memory accuracy	Time inside (min.)	−0.168	0.087	0.054
Corr. err.			Dwell time (sec.)	Dwell ratio	0.123	–	**0.011**

Estimates for conditions represent a predicted change from condition "1" to condition "2." Significant p-values lower than 0.05 are marked in bold.

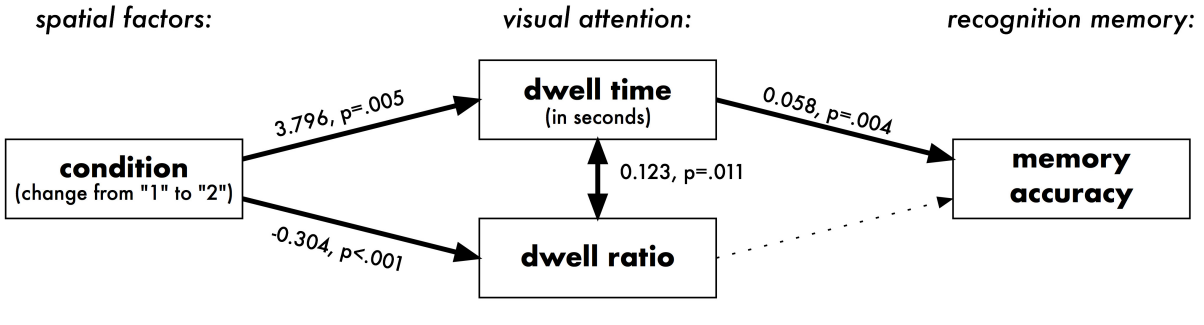

FIGURE 9 | Piecewise SEM relating two spatial conditions, visual attention, and recognition memory in Experiment 2. Dotted lines represent non-significant pathways. All paths control for the total time spent inside the gallery by each participant (not visualized).

in how they mediate attention. Similarly to the Experiment 1, however, the strategy of attention allocation had a negligible effect on memory, and it was primarily the dwell time that affected how well participants remembered individual artworks. This casts doubt on the common assumption of many cognitive models of the esthetic experience that make a qualitative distinction between the gist and the deeper cognitive processing of artworks. It is unlikely that appreciating art is based on a strictly sequential cognitive process (Nadal and Skov, 2017) and the presented experiments confirm that the role of "gist" in the processing of artworks should not be undervalued. Orienting in space (e.g., for navigational purposes) and haphazard glimpses are not a "distraction in", but an intrinsic part of the cognitive experience of art gallery visitors. Researchers interested in studying the visitor experience in an ecologically valid manner should employ methods sensitive to the impact of short and seemingly haphazard interactions with the art.

The experimental condition also had an effect on viewing times per artworks, even after accounting for individual differences in the time spent inside the gallery - participants in Condition 2 (which caused "more distracted" viewing), cumulatively looked at pictures for longer. This is contrary to the classic findings of Robinson (1928) who suggested that a complete isolation of artworks increases their viewing times. In the current study, a complete isolation increased the proportion of long, "diligent" dwells but decreased the cumulative engagement times. One reason for this disparity might be the difference in methods used. Eye-tracking is sensitive to short, haphazard glimpses in the situated context of an art gallery visit. It was unavailable to Robinson and a similar effect is difficult to simulate in laboratory-based paradigms. Classical methods based on third-person observations of gallery visitors are likely to underestimate total dwell times accumulating from shorter interactions.

The findings also demonstrate the situated character of the visitors' cognition inside distinct art gallery layouts. What could be seen as less optimal, or a "distracted" way of interacting with artworks, in fact resulted in enhancing the interactions. It is unclear, whether the visitors purposefully compensated for the "distracted" way of looking at images by engaging them for longer, or whether the prolonged viewing times are a "side-effect" of the more haphazard viewing behavior. The former could occur if short glimpses are not subjectively perceived as satisfactory, desired, or pleasant interactions (even though they implicitly contribute to strengthening the memory trace of artworks). The latter explanation is possible if an initial period of "gist" is a necessary element of any diligent engagement: some interactions in Condition 2 would therefore consist of the "gist" *alone*, while others would consist of the "gist" *followed by* a period of more involved viewing. An increased number of engagements would thus automatically be associated with a higher number of "gist"-periods, additively increasing the cumulative viewing times.

An important contribution of the presented data is expanding the traditional notion of the exhibits' "competition" (Melton, 1972; Bitgood et al., 2013, 1988). In Experiment 1, location had a significant impact on visual attention (c.f., **Figure 6**). In Experiment 2, however, it did not (including the random by-location effect did not improve final models). This demonstrates

that in Experiment 2 differences in the amount of attention allocated to individual pictures lay primarily between participants (e.g., their interests), and between pictures (e.g., their content). Such a contrast to the results of Experiment 1 shows that the competition can arise either between the spatial prominence of artworks' locations (Experiment 1) *or* between the artworks' content (Experiment 2). When the visibility and the co-visibility of individual artworks are diversified, the competition is driven by the spatial prominence (Experiment 1). When the visibility and the co-visibility of each artwork in the gallery are similar, the competition is driven by the content (Experiment 2).

LIMITATIONS

While aiming to isolate the influence of spatial factors, this research studied pre-arranged environments, using a single set of artworks. This implies limitations that should be considered before applying the findings to the context of art galleries typically found outside research laboratories.

First, no interpretive text was included in the exhibitions. Visitor studies have repeatedly reported the crucial role that the presence and design of the interpretive text can have on the visitors' engagement with the exhibits (Bitgood and Patterson, 1993; Bitgood, 1996, 2014). In the reported studies, as all artworks were untitled, all potential labels would be identical: their influence on the visitor experience would therefore likely be smaller, compared to exhibitions with diverse labels.

Second, the studied variables involved visual engagement with and the recognition memory of artworks. These should not be confused with a more diligent form of engagement (involving interpretation, reading, or talking about the exhibits) that have typically been the main focus of research in the visitor literature. While low-level cognitive processes such as those described in the current paper can be seen as the "building blocks" of the more holistic cognitive experience, they are not synonymous with it.

Third, only the works of a single artist were presented in the described studies. More work is necessary to verify whether similar patterns hold for other types of art (e.g., for more diverse types of images, sculptures, or media installations) and for exhibitions containing works of multiple artists.

Fourth, all reported analyses are path-independent. It is not claimed that individual paths, viewing sequences, or angles of approach do not have an impact on the visitor experience. From the curatorial point of view, however, it might be beneficial to understand the effect that the relative visibility and co-visibility of artworks have on the visitors when "all other things are kept equal."

Fifth, the paper focuses on visual properties of artwork locations, and not on the shape of the gallery, its hallway topology, or the floor area size. The underlying reason is that the distribution of hanging locations is a factor most amenable to curatorial interventions.

Lastly, it bears noting that while a higher proportion of short glimpses has been discussed in the context of "distracted" engagement, it is possible that some of this behavior was driven by the explicit willingness to *compare* co-visible artworks. Distinguishing seemingly similar eye-movement data driven by these two distinct reasons lay beyond the scope of the current paper. While the current paper analyzed exhibitions as a set of separate artworks, it is their *synergy*, resulting in exhibitions becoming more than the "sum of their parts," that remains a truly challenging question open to future work.

CONCLUSION

The more visible an artwork was, the more attention it attracted. Artworks that were more co-visible, were viewed in a more haphazard way. However, more haphazard viewing strategy simultaneously resulted in higher cumulative viewing times and did not negatively affect the cognitive processing of artworks. Memory of artworks seems to be affected by the cumulative amount of attention allocated to them (including even short glimpses) but not by the strategy of attention allocation. The role of space in steering the visitors' cognitive engagement is not so much to affect the amount of engagement, but rather to facilitate the strategy with which it occurs.

The strategy with which people view artworks is not necessarily going to affect the depth of their cognitive processing but can have other influence on the experience. Exploring an art exhibition is an embodied experience (Pallasmaa, 2013; Zisch et al., 2013), and what happens to our body–including the type of viewing behavior it was prompted to exert–is likely to be integrated into the retrospective evaluation of the visit. Space bears a profound influence on this aspect, by guiding the strategy with which attention is allocated. This happens both on the local level of individual exhibits (by creating differences between the exhibits' visibility and co-visibility in space: Experiment 1), and on the global level of the entire exhibitions (in cases where the differentiation between individual exhibits is minimalized: Experiment 2).

Future research on the influence of museum space can benefit from mobile eye-tracking, as this method enables detecting subtle patterns of attention. Structural equation modeling and hierarchical modeling are appropriate techniques for studying the mediating character of attention (Hine et al., 2016). These methods demonstrated that what traditionally could be interpreted as a poor, "distracted" visitor experience, had little negative impact on the cognitive processing of artworks. Visitors were able to adjust their viewing strategies inside a potentially less optimal space. This finding supports the planning of more diverse spatial interactions with the art.

DATA AVAILABILITY STATEMENT

The datasets generated for this study are available at: https://osf.io/d6mwe/.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Northumbria University. The participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

JK and RD contributed to the conception and design of the studies, manuscript revision, and read and approved the submitted version of the manuscript. JK collected the data, performed the statistical analysis, and wrote the first draft of the manuscript. RD supervised the work.

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OPINION
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Using Visual Aesthetic Sensitivity Measures in Museum Studies

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For over a century, differential psychologists (e.g., Cattell, 1890; Eysenck, 1940), educational psychologists (e.g., Thorndike, 1916; Seashore, 1929) and art theorists (e.g., Graves, 1948; Götz, 1985) have attempted to capture one's ability to form judgments of aesthetic objects that agree with external standards defined by stimulus construction criteria, layperson consensus, and/or expert consensus. In the visual domain, this ability—generally discussed as visual aesthetic sensitivity (Child, 1964) and measured through (notably) the Visual Aesthetic Sensitivity Test (VAST; Götz, 1985), its revision (VAST-R; Myszkowski and Storme, 2017), the Meier Art Tests (MAT; Meier, 1928) and the Design Judgment Test (DJT; Graves, 1948)—has recently regained interest, but has been mainly studied through its relations with individual differences in art expertise, personality, and intelligence among adults (e.g., Furnham and Chamorro-Premuzic, 2004; Myszkowski et al., 2014), and has remained unstudied in museum settings. In this paper, we review the current state of research on the validity of visual aesthetic sensitivity tests, and propose how to best implement them in museum studies.

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ELEMENTS OF VALIDITY OF VISUAL AESTHETIC SENSITIVITY MEASURES

Most frequently, visual aesthetic sensitivity tests operationalize Child's (1964) definition using "controlled alteration" (Meier, 1928, p. 188), a procedure which consists of deteriorating or creating an altered version of an aesthetic stimulus, and in presenting examinees with the altered and original stimuli, with the task of recognizing which is of better aesthetic quality. The construct validity of tests based on it are however controversial (Gear, 1986; Liu, 1990; Corradi et al., 2019), as it was notably argued that absolute aesthetic standards cannot exist, dismissing any operationalization of Child's definition. Nevertheless, the availability of *absolute* standards is not a necessary condition for the operationalization of Child's definition (Myszkowski et al., 2020): Aesthetic sensitivity tests rely instead on *empirical* standards, obtained through expert and/or laypeople consensus. Consequently, they compare an examinees' response with the typical response of experts—as originally suggested by Thorndike (1916)—or use expert agreement to select items—as used in the VAST. While using expert and/or laypeople consensus in lieu of absolute standards seems crude, it is actually common practice whenever *correctness* is not self-evident: It is for example used in the measurement of emotional intelligence (Mayer et al., 2003) or creativity (Amabile, 1982).

Still, using empirical standards poses the question of measurement (in)variance, especially across cultural backgrounds: Two artworks A and B may be aesthetically ordered as A > B for a group but as B < A for another. Fortunately, on that matter, studies of cultural measurement invariance—especially on the VAST (Iwawaki et al., 1979; Chan et al., 1980; Eysenck et al., 1984)—have provided encouraging results, with positive strong correlations between the item difficulties of the test across different groups differing in gender, age, and nationality (England, Japan, Hong Kong, Germany, and Singapore). More robust analyses (e.g., using differential item functioning), are certainly called for, but there is currently no empirical evidence of problematic

measurement variance across cultures. We could speculate that the reason for this is that the controlled alteration method leads to examinees having to judge stimuli that are in the same (sub)category. Indeed, in visual aesthetic sensitivity tests, examinees do not compare Picasso's *Guernica* with Da Vinci's *Mona Lisa*—rather, they are asked to compare an original work of art with an almost identical (yet altered) version. Therefore, responding is less a matter of personal/cultural inclination regarding movements and styles, but more a matter of detecting an "out-of-tune" execution. It thus engages more the "ability to perform a set of basic perceptual analyses of the stimulus" (Myszkowski et al., 2014, p. 16) than one's ability to apply culturally relative norms.

Another sign of construct validity can be found in the concurrent validity of visual aesthetic sensitivity tests. This point is also quite controversial (Corradi et al., 2019; Myszkowski et al., 2020), but this is mainly because the nomological network of visual aesthetic sensitivity is yet to be clearly defined. Notably, Eysenck introduced confusion by originally discussing the construct as intelligence in the aesthetic domain (1940) to then speculate that the construct should be independent from intelligence (Frois and Eysenck, 1995)—which is contradicted in a recent meta-analysis (Myszkowski et al., 2018), which showed across 23 studies that its correlation with intelligence is significant and around 0.30. Nevertheless, one can reasonably expect that, as is found empirically, visual aesthetic sensitivity would be positively correlated with intelligence—because common cognitive processes are likely engaged in both measures (Myszkowski et al., 2018), and because it is common to observe relations between sensory perception in other domains and intelligence (e.g., Troche and Rammsayer, 2009)—or with personality traits like openness to aesthetics (Myszkowski et al., 2014)—because individuals with stronger interest in aesthetics may engage in more extensive processing, leading to higher accuracy, as it was for example found (Myszkowski, 2019) that, in these tests, response speed is negatively correlated with accuracy. Therefore, even though the nomological network of visual aesthetic sensitivity is not sufficiently (nor consistently) discussed, the pattern of relations between aesthetic sensitivity and other measures does suggest that visual aesthetic sensitivity measures present evidence of concurrent validity (Myszkowski et al., 2020).

These signs of validity could lead to a wide use of visual aesthetic sensitivity tests in the field where they would seem to belong: In contexts that naturally involve aesthetic judgments, such as museum visits. As they are however absent from museum studies, we will now discuss ways to facilitate their implementation in such contexts.

HOW TO MEASURE VISUAL AESTHETIC SENSITIVITY IN MUSEUM CONTEXTS

Because several visual aesthetic sensitivity tests are still in use, a first challenge could be to select one. Although these tests have showed satisfactory internal consistency in recent studies—with satisfactory Cronbach's αs (Furnham and Chamorro-Premuzic, 2004; Myszkowski et al., 2014; Summerfeldt et al., 2015)—their unidimensionality—a condition to even investigate internal consistency—and thus also their structural validity are largely unstudied. An exception is the VAST-R, which has been showed to present unidimensionality and structural validity—with a satisfactory fit of unidimensional Item-Response Theory models (Myszkowski and Storme, 2017). In addition, the VAST (and VAST-R) items present better evidence of content validity with the selection of the correct items by unanimity of a panel of 8 art experts (Götz et al., 1979). Finally, evidence of measurement invariance (though limited) is only provided for the VAST(-R) items (as discussed previously). Therefore, based on the current state of research we would suggest to prefer the VAST-R to other tests.

A second issue relates to scoring. While it seems straightforward to use sum/average scoring here, since the items of such tests are pass-fail items and vary greatly in difficulty (Myszkowski and Storme, 2017), one would advise to instead use Item-Response Theory (IRT) scoring. Using IRT in scoring such tests presents several advantages, such as obtaining conditional standard errors, which allows to identify cases that have been unreliably measured, or accounting for the guessing phenomena present in these tests. Still, using IRT remains challenging: It often requires specific training absent from many curricula (Borsboom, 2006) and demands large sample sizes for accurate estimation, which are not easily found in museum studies. Hopefully, regarding the VAST-R (other tests have not yet been studied with IRT), correlations between person estimates from (well-fitting) IRT models and sum/average scores are near perfect (Myszkowski and Storme, 2017). Therefore, even though IRT scoring is preferable, should IRT modeling not be possible, one could still use sum or average scores as an excellent proxy for IRT factor scores.

Related to technological advances, although this point remains unstudied, there is no evidence that these tests perform any differently when taken on-screen vs. in paper-and-pencil form: Both have been used indifferently. While measurement invariance between administration modalities needs empirical investigations, we could speculate that the two are equivalent. Actually, it may be more convenient in museum or virtual museum contexts to use tablets or computers for administration—smartphone screens are likely too small for properly displaying stimuli—and as we later suggest, there are psychometric advantages to using on-screen testing.

The use of computerized assessment first presents the practical advantage of allowing to reduce test length without compromising reliability, which would be desirable in assessing museum visitors. Because IRT models fit the VAST-R well (Myszkowski and Storme, 2017), researchers could use a Computerized Adaptive Testing (CAT) modified VAST-R, in which examinees would only take a subset of items that matches to their ability—re-estimated after each item—stopping assessment when such ability is estimated reliably enough (Green et al., 1984). The use of CAT is now largely facilitated by the availability of more software packages (e.g., Chalmers, 2016), and future studies may examine its usability with aesthetic sensitivity tests.

Further, as response times can be routinely collected when using computerized tests, we may suggest that recent IRT modeling advances in joint response and response time modeling could also allow to use response times as collateral information in the estimation of one's ability. Indeed, recent research (Myszkowski, 2019) suggests that there are strong dependencies between responses and response times (both related to a persons' speed and ability and to an item's difficulty and time intensity), which suggests that response times may be used to, for example, improve the accuracy of one's ability score, especially when fewer items are used (van der Linden et al., 2010). This could allow for even shorter tests, along with the improved detection of aberrant response/response times patterns (Marianti et al., 2014). As accuracy and speed are negatively correlated in the VAST-R, it has been also suggested (Myszkowski, 2019) to consider computing visual aesthetic sensitivity scores (accuracy scores) that are statistically controlled for response speed. This point is especially relevant for museum studies, because it is probably more likely to collect rushed responses from museum visitors than in experimental settings.

Finally, although we proposed that the VAST-R is the test that should currently be preferred, its content—black and white formal abstract paintings by Karl Otto Götz—remains rather narrow, and one may question the generalizability of the results of the test to other art styles and movements. We thus suggest that *ad-hoc* tests be built on a case-by-case basis using the controlled alteration procedure. One could for example use image modification software to alter artworks from the very exhibit studied and create stimuli pairs. In museum studies contexts, it would in fact probably be easier to identify subject matter experts to ensure content validity. The expert panel would then be asked which stimuli of the pair is of higher aesthetic quality, and one would select items where there is a strong or unanimous agreement (Götz et al., 1979) or keep all items and score as a function of a respondent's agreement with the expert consensus (Thorndike, 1916).

CONCLUSION

In over a century of research, visual aesthetic sensitivity testing has slowly advanced toward offering test material that finally presents encouraging—although fragile—signs of validity. Both psychometric research in visual aesthetic sensitivity testing and museum research could benefit from the implementation of these tests in museum contexts. For the former, we think that it could lead to clarifying the real-world implications of visual aesthetic sensitivity; for the latter, it could prove an important factor in the understanding of individual differences between museum visitors. While speculatory at this stage, the findings previously discussed could, for example, lead to hypothesize high aesthetic sensitivity individuals to be more engaged, reflective and attentive when visiting museums and viewing artworks, to demand more cognitive stimulation (with, for example, more contextual explanations), to make longer museum visits, to compare artworks more extensively, and to be more critical of exhibited artworks. We could thus anticipate visual aesthetic sensitivity tests to be useful in better understanding the traits of a museum's or an exhibition's audience—in both understanding who the typical visitor is, and in how different the visitors may be in their approach to art—and it thus may be useful in tailoring the museum experience to better anticipate and respond to the visitors' characteristics.

AUTHOR CONTRIBUTIONS

NM proposed and drafted the paper. NM and FZ participated in its conceptualization and FZ made important modifications to enhance the quality of the paper.

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Feeling at Home in the Wilderness: Environmental Conditions, Well-Being and Aesthetic Experience

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Environmental conditions affect one's aesthetic experience in natural environments. Understanding that effect requires accounting for the conditions affecting one's attention and experience. Rather than attempt to reduce and control environmental factors, we compare two similar groups during naturally occurring, intense and overwhelming conditions and examine the relationship between common characteristics as well as environment and group differences. Participants undertook a 5-day, winter, wilderness adventure training course designed to challenge their considerable wilderness and leadership skills under two different extreme weather conditions but within the same wilderness area (n = 47 full participation). In addition to pre- and post-adventure questionnaires, participants responded daily during the wilderness experience to briefly describe a self-selected, strong experience of nature; characterize its associated feeling states; and answer questions probing eight aesthetic aspects of the experience. Participant strong experience of nature related to hedonic and eudaimonic feelings in different ways depending upon environmental conditions. In particular, strong correlations occurred between agreement ratings with "I felt at home in nature" daily experience reports and satisfaction with life and personal growth trait measures, but primarily during sunny and cold conditions on a high plateau (PG: Pearson r = 0.51; SWL: r = 0.70) and not significantly in stormy and wet weather in a mountain forest. In addition, experience narratives that correspond to strongest agreement to feeling at home in nature were examined for shared themes and synthesized into six dimensions: focus on sensory experiences at a particular moment, self-reflection, wonder, appreciation of beauty, positive emotions, and insight of relation to nature. These findings actualize the notion of wonder, aroused by sudden feelings or by reflection, as a salient ingredient in feeling at home in wilderness. The finding of feeling at home in nature, as the most important feature relating to feelings and well-being, is discussed in relation to self-awareness, philosophical thinking, and potential ethical awareness.

Keywords: aesthetic experience, awe, beauty, natural environment, sublime, well-being, wilderness, wonder

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INTRODUCTION

When moving outdoors into the wilderness, various aesthetic experiences take place. In a sweeping landscape just moving one's head may change one's experience radically, so outdoor aesthetic experience is dynamic in a way that differs from looking at a piece of art (Chenoweth and Gobster, 1990, p. 2). In wilderness, the always shifting conditions over spatial perspectives and time result in multi-dimensional stimuli across all one's senses. By selective interest, one might choose to pay attention to shifts of environmental conditions, focus on certain objects in wilderness, attend to inner processes of mental or spiritual states, or simply struggle for satisfying needs and comfort in harsh conditions. From moment to moment, one's selective attention shifts among sensory stimuli and one's felt experience of them. William James likens one's attention to a "stream of thoughts," and one's selective interest plays a key role in understanding experience in contrast to utter chaos (James, 1890, p. 402). Wilderness adventure provides considerable potential for complex experiences, as there is room for silence, comfort, and contemplation on one hand, and challenging, even terrifying, surprising and overwhelming situations on the other. In this paper, we intend to identify core characteristics of the aesthetic wilderness experience in Norwegian winter mountains.

Studying the complex, equivocal, and perplexing phenomena of aesthetic experience and well-being in a wilderness context requires multiple perspectives including both holistic approaches–to ensure study of the actual phenomena in their long-standing historical context–and reductionist approaches to enable empirical discovery and analysis sufficient for novel insight into their enigmatic interrelationship. Although the need for such a span occurs regularly in the emerging empirical study of many complex phenomena, the examination of aesthetic experience in particular demands attention to that complexity, as the holistic-reductionist spectrum can itself be an essential aspect of the aesthetic experience.

Aesthetic experiences are important for humans as they affect mood and indirectly promote well-being (Mastandrea et al., 2019). Our approach to aesthetic experiences in nature is in line with Tomlin (2008) reflections that stress the transformative and evaluative dimensions of aesthetic experience (rather than only its analytical or defining characteristics). For Tomlin, an experience of high value gives the subject a new sort of consciousness not accessible through other experiences. "What transforms [a] kind of perception to an aesthetic experience is that it becomes an 'event'." (Tomlin, 2008, p. 7). In the process of understanding experiences to be transformative and evaluative, there are qualitative differences among several facets of the experience, and among these: the role of beauty and sublime dimensions in aesthetic experiences (different characteristics), the role of hedonic and eudaimonic experiences in well-being (different affective dimensions), and the role of stimulus-driven and goal-directed attention in the way one orients in wilderness (different involuntary and voluntary attention).

Environmental aesthetics identities that, because aesthetics depends upon attention and its evaluative and transformative effects, it also depends upon *to what* one attends. The aesthetic experience is an experience of a particular time and place, i.e., "event." There are commonalities among aesthetic experiences that enable them to be collected as "aesthetic experience," but one does not have a general experience aesthetically, one only has particular aesthetic experiences, and thus the environmental context plays a crucial role. The field of environmental aesthetics spans many approaches to how one appreciates nature (Carlson, 1998, 2000), and one crucial topic in environmental aesthetics is the relationship between aesthetic experience and aesthetic judgment (Stecker, 2005). For Stecker, these two are strongly intertwined, and for him the aesthetic experience is not only about what is pleasing, but about what one values as important. Such an approach opens up a complex understanding of what is happening in an aesthetic experience. According to Berleant (1998), environmental aesthetics needs to cover more than what is, in one sense, visual pleasing. The experience of nature, or the surrounding environment, is about several aspects, such as space, volume, time, movement, color, light, smell, sound, touch, order, and meaning. For Berleant, in environmental aesthetics the experience of beauty in nature has to be understood in a complex way as "... the pervasive aesthetic value of an environmental situation" (Berleant, 1998, p.118).

Related to aesthetic experiences in nature is the notion of wonder. Wonder is undoubtedly a complex phenomenon. One way to understand the relationship between aesthetic experiences in nature (such as beauty and the sublime) and wonder is that the former activates the latter. The experience of beauty stimulates wonder: What is this beauty I am experiencing? Why is it so? We might reflect in a similar way concerning the sublime (Sæther, 2017). Robert Fuller relates these phenomena by saying: "Wonder most frequently occurs as a response to something that strikes us as intensely powerful, real, or beautiful" (Fuller, 2012, p. 70). In one sense, as one encounters nature, one might talk about the experience of wonder, in line with experience of the sublime and beauty. However, wonder is a larger, more overreaching, profound, and subtle concept (Fuller, 2012).

Wonder has at least two dimensions: as something in nature which evokes a feeling of wonder and something motivating humans for reflection and further search for insight (Sæther, 2017). This motivation is a kind of an inner flow on the part of, for example, the scientist as described by Ralph Waldo Emerson: "Men love to wonder, and this is the seed of science." (Ledley, 2009, p. 246). We can describe this inner flow as a shared experience for everyone in one's search for understanding of the world. For Sophia Vasalou, such a flow is not only intellectual, as in a search for understanding, but also functions as a motivation for practices (Vasalou, 2012). Hence, in understanding wonder, this phenomenon can motivate toward an ethical awareness.

Both dimensions of wonder, those induced by sudden feelings and those motivated by reflection, can be explored as experiences with relevance for ethical awareness. An ethical awareness is important to feel deeply connected to nature as one of the most important virtues of our time, addressing how to respond recording to environmental crisis (Vetlesen, 2015). For Seel (1998) our aesthetic experiences in nature are pointing toward an ethical dimension of what we strive for and hope for: "... the aesthetic of nature is [...] simultaneously part of an ethics

of the individual conduct of life [. . .] for aesthetics, being concerned with specific forms of and opportunities for process-oriented activity, is generally part of an ethics of the good life." (Seel, 1998, p. 342).

Another, although closely related, way of relating aesthetics and ethical awareness is developed by Bergmann. He coined the term aesth/ethics to emphasize aesthetics as strongly intertwined with ethics (Bergmann, 2011). Bergmann shows that aesth/ethics, with the slash, indicates that ethics is embedded continuously in perception. If ethics is defined as a discursive reflection on moral problems, we cannot exclude people's mental capacities and separate aesthetic competence from moral competence, thus the perception of moral problems must be prior to their reflection and possible solution, he says (Bergmann, 2011). Bergmann's concept is to develop a specific contribution to eco-theology, and he does so by exploring three concepts, with relevance for our findings: inhabitation, *Beheimatung*, and atmosphere.

The first, inhabitation, recalls us to take seriously the perception of space and life, and works as a first step for the following two. "Beheimatung," the German word for making oneself at home, addresses the question of belonging or feeling at home. When addressing "feeling at home in nature," we need to have in mind that it might mean different things in various contexts. For Bergmann, the question one needs to ask is how to make oneself at home at "Earth, our home" which we collectively are spoiling. The "feeling at home in nature" is an experience or feeling taking place in the extension of aesthetic experiences in nature. For Bergmann, aesthetic experiences is also about a self-aware human reflection on one's living-in-particular-surroundings (Bergmann, 2006, p. 336). In addition, Bergmann's notion of atmosphere is relevant for our context, because it emphasizes the interconnectedness of the inner and outer, the bodily and the spiritual, the surrounding and the inhabitation. An awareness of who we are, and how we are interconnected with nature is of major importance. A lack of awareness creates alienation and awareness is a skill to be nourished and developed (Bergmann and Eaton, 2011, p. 3). For Bergmann and Eaton, awareness is an aspect of *how* we sense and perceive the world in a specific way. The way of seeing things is prior to the way of acting, it is about our senses and perceptions and how we actually pay attention. It includes all our senses: what we see, taste, hear, and touch. Such an aesthetic awareness influences the kinds of questions we ask, how and what we reflect upon, and ultimately how we answer our queries (Bergmann and Eaton, 2011, p. 3). Aesthetics, as the way of seeing things, is according to Bergmann a trajectory to ethical awareness.

The traditional understanding of beauty in nature relates to the pleasing dimension in experience specific objects (beauty in small scale) and the pleasing of beautiful scenery (beauty in large scale). The former is the heritage from Kant, the latter the tradition from Joseph Addison and Francis Hutcheson (Sæther, 2017). Compared to the experience of beauty we might describe the experience of the sublime as more holistic and evoking a wide range of feelings (Graves et al., 2020). John Baille argued for this back in 1747. He says the sublime is a function of the grandeur of objects (in nature), while the experience of beauty takes place in a smaller scale. Further, awe is traditionally understood as a response to the sublime. Fred D. Ledley describes the sublime as causing a sense of exaltations and awe. William Wordsworth describes such experiences as "impressions of power, feeling of apprehension, dread, fear, or wonder" (Ledley, 2009, p. 248). The sublime also includes a sense of duration in which "individuality is lost in the general sense of duration belonging to the earth itself" (Ledley, 2009). Alexander (2014, p. 52) expresses the sublime as "a pleasure in the way that nature's capacity to overwhelm our powers of perception and imagination is contained by and fuels our rational comprehension." In the extension of both the experience of beauty and the sublime, the experience of wonder is relevant to emphasize. The experiences of beauty and the sublime are intertwined with the experience of wonder. Wonder is evoked by a surprising situation, such as changes in weather, having a novel perception of something in nature.

We understand the sublime as ". . . as a pleasure in the way that nature's capacity to overwhelm our powers of perception and imagination is contained by and fuels our rational comprehension. . ." (Alexander, 2014, p. 59), and the sublime evokes "a sense of exaltation and awe, a sense of duration in which individuality is lost. . ." (Ledley, 2009, p. 248). To examine the sublime empirically, we draw upon an emerging literature on the psychology of awe, where Keltner and Haidt (2003) finds beauty the most predominant experiential theme, and Yaden et al. (2018) finds natural scenery the most predominant trigger eliciting awe. Although awe may include constructs unrelated to the sublime and the sublime has other aspects in addition to awe (Sæther, 2017), considering awe in an aesthetic context enables bridging empirical investigations of awe and aesthetics to begin creating an empirical foundation for studying experiences of the sublime. Considering levels of connectedness-to-nature as traits, the intensity of transcendent and awe-inspired experiences seems to increase (Davis and Gatersleben, 2013). However, in this latter study, connectedness-to-nature appeared to be a trait that can be trained.

Investigating traits for aesthetic nature experiences, a two-factor structure was recently identified: One relating to traditional perceptions of beauty, typically focusing on beautiful scenery, while the other relates to the sublime, typically by deeper immersion and experiences of awe (Graves et al., 2020). In the beauty-dimension (seven items), this correlated with strong relationships and communion with nature, while in the sublime-dimension (eight items), this correlated with the importance of fulfillment and peace. In the current study, we explore if sublime aspects of aesthetic nature experiences also yield *situational* wilderness experiences, and if so, how we can characterize and understand these experiences. Nature has an important impact of our overall well-being. From an environmental psychology perspective, the presence of nature is first and foremost known as having a stress reducing effect (see for example Hartig et al., 1991; Laumann et al., 2003). To be in natural environments is an effective arena for emotion regulation and important for one's everyday well-being (Johnsen and Rydstedt, 2013). Thus, daily hikes help to reduce stress and regulate emotions. Sensory experiences in nature are moreover a source of positive emotions (Ballew and Omoto, 2018) and being

more vitalized (Ryan et al., 2010). In the outdoor setting, one's social relations also improve, in being more caring for each other (Weinstein et al., 2009).

Moreover, certain activities in the natural environment feed different positive emotions: While pleasant feelings associate with life satisfaction, striving to use one's potentials or seeking meaning relates to eudaimonic well-being (Vittersø et al., 2010; Vittersø and Søholt, 2011; Vittersø, 2016). Both dimensions are important in a fully functional life. Wilderness thus carries potential for complex aspects of well-being, where aesthetic *pleasure* might associate with life satisfaction and aesthetic *interest* might associate with personal growth. Awe, as a positive emotion taking place in aesthetic nature experience, transforms us toward a reorientation of our lives, goals, and values (Fuller, 2012; Sæther, 2017). While the function of emotions to some degree is known in well-being research (Vittersø, 2016), the identification of intentionality: when and why these emotions occur in the natural environment, are less known. Both aesthetic pleasure and aesthetic interest are identified during wilderness experiences, whereas aesthetic interest most typically can be interpreted to the active approach to valuing the natural environments as sacred, construction of new meaning, and feeling a connection with the powerful unseen forces of wild nature (McDonald et al., 2009), which could correspond to understanding the sublime.

The distinction between the influence of aesthetic nature experiences and the mere presence of nature is hard to draw, as our attention shifts between paying attention to sensory stimuli and intentionality, by selective interest. In the brain, there appears to be at least two systems connected to attention: the role of the attention shift by the *orienting network* and the role of focusing attention by the *alerting network*. In addition, an executive network makes the overlap and selection between the different systems (Posner, 2008). These different attention systems are connected to the stimulus driven attention and the goal directed attention (Corbetta and Shulman, 2002). Although both systems interact in a situation of normal sensory experience, there is a selection process switching from one system to the other, called the "attention shift" (Broadbent, 1956), which is dependent on the competition of the different system processing network. This insight can be related to aesthetic nature experiences as these are embedded in perception, which according to Bergmann and Eaton is about seeing in a specific way, i.e., awareness and to pay attention (Bergmann and Eaton, 2011).

In the wilderness, it is likely that both the orienting and alerting networks provide aesthetic experiences in visual, hearing, smelling, tasting, and touching sensory experiences – both as basic qualities of nature and as sudden shifts or movements, what identifies as involuntary attention called "soft fascination" (Kaplan and Kaplan, 1995). Moreover, there could be more goal-directed attention in seeking for some special qualities, for example in looking for rare plants or animals or in striving to use skills to keep warm and dry, or even in striving to achieve a state of well-being, for example in being mindful. During a winter day in the snow, with skis and backpack, one may have all kinds of emotional experience, shifting from one moment to another. However, some experiences might be more important, as we pay attention to some aspects of the adventure when thinking of strong experiences of nature. Intense experiences in nature moreover carries the potential for rare, life changing experiences in the deep interpretation of peak-experiences (Maslow, 1976). The intense environmental context for the studies necessarily becomes a factor in the investigation enabling study of the relationship between environment and aesthetic experience of nature.

Outdoor environment provides many health promoting ingredients. For example, coastal landscape provides therapeutic values in experiencing emotional, embodied and often shared connections with the coast (Bell et al., 2015). There might be differences in personality traits and preference of places, whereas introverts prefer mountains more than extroverts, and introverts are happier in wooded landscapes than in open areas (Oishi et al., 2015). Emotional experiences of landscapes were moreover enhancing the relationship between place-identity and well-being in Swedish mountains (Knez and Eliasson, 2017). The more bonded one felt with the place, the better well-being. Taking these differences account, there might be differences in how the forest adventure differs from mountain adventure in understanding aesthetic nature experiences.

In mountain areas, there are many weather changes that could influence the overall judgment of the experience. Experiencing cold and wet circumstances could result in low scores on hedonic well-being but these experiences could be less relevant to eudaimonic well-being. Strong winds, heavy rain or snow or extremely cold could moreover influence our judgments and what we choose to attend to. As we tend to remember events based on experiences of peak, ends and specific emotions in our overall judgment (Fredrickson, 2000), weather issues might influence our perceptions of peak, ends and specific emotions, or they are less relevant. We assume that weather issues are important in the overall experiences of the wilderness adventure, but we do not know to what degree weather issues influence aesthetic nature experiences.

Our aim is to explore how the dimensions of aesthetics and well-being characterize *situational* experiences during 5-day, winter, wilderness adventures. Based on data collection from two, similar yet distinct, environmental conditions, we wish to identify structures that are common and divergent through these adventures. In addition, we found feeling at home in nature to be a very important dimension for aesthetics and well-being in our study, and we investigate that further.

We explore three complementary questions that relate aesthetic experience and well-being within a wilderness environment:

1. What characterizes core aesthetic dimensions in wilderness?
2. How do those aesthetic experiences affect well-being?
3. What is the role of aesthetics and its affective aspects associated with feeling at home in nature?

We do this by analyzing the core aesthetic dimensions and well-being measures using quantitative methods, identifying the

significance of feeling at home in nature, and explore the aesthetic and affective dimensions of belonging predominantly using qualitative methods.

MATERIALS AND METHODS

The holistic-reductionist methodological complexity needed for studying aesthetics and well-being in a natural environment affects at least two aspects of the present study. First, our empirical approach uses mixed methods with quantitative analysis of survey data and experience reports as well as qualitative text analysis of experience report narratives. Second, our theoretical approach focuses narrowly on how the aesthetic experience in wilderness adventure affects well-being and also branches out philosophically to include not only the narrow experience of beauty in nature but also the sublime, its associated feelings of awe and wonder, and feelings of interconnectedness, communion, and belonging in the wilderness experience. This multifaceted approach enables careful investigation of the full aesthetic experience and its interrelationship with a richer conception of well-being.

We examine one's aesthetic communion with nature and strong experiences in an expansive and attention-demanding wilderness setting, in particular its effect on overall well-being. Toward that end, we examined students undergoing training to guide wilderness expeditions before, during, and after a 5-day, intense wilderness adventure designed to challenge their considerable wilderness and leadership skills. The students do not yet have skills that would be considered as expert or exemplary as leaders. Examining a participant pool with greater outdoor adventure skills than a typical adult, hopefully yields insight into the same phenomena experienced by numerous people during shorter and/or less intense wilderness adventures.

Mixed Methods

A combination of quantitative measures and qualitative narratives were used to detect and explore details in the aesthetic experience of nature. Moments of subjective experiences identified by each participant as "strong experiences of nature" were narratively described and quantified using aesthetic and affective measures for the intensity of aesthetic dimensions and feelings. Using the participant's rating of intensity for the experiences and feelings, corresponding narratives were selected to analyze using qualitative methods, to expand the research paradigm not only to include close-ended, but also open-ended data (Merriam and Tisdell, 2016). An iterative process was used in classifying the selected, high-intensity, experience reports, first investigating the total sample, and second, investigating similarities and differences between the two different contexts. Third, as quantitative methods identified feeling at home as a significant experience, thematic analysis was used to characterize feeling at home in the wilderness. By focusing on the daily moment chosen by participants as a strong experience and using the quantitative aspects of the experience reports to select narratives for qualitative analysis, mixed methods are well integrated (Teddlie and Tashakkori, 2009). In addition, questionnaires regarding aesthetic traits and well-being were conducted before and after each expedition, described below.

Participants and Environmental Research Contexts

Because of the key role environmental context plays in *in situ* study of aesthetics, we describe a study with identical experimental design and similar participants undertaken in two different environmental contexts. The analytical methods remain the same between both studies, and because (pre- and post-adventure) trait instruments taken in a controlled (classroom) environment showed no differences between the participant groups, we can relate differences between groups to the environmental context.

Total Sample

Within the context of a formal education program in leading extreme outdoor wilderness adventures, a group of students from a University College in Norway were followed through their 5-day expedition to the winter mountains in 2017 in Norway (n = 26, M_{age} = 26.1 years, 42.3% females). 24 students reported on the pre- and post-tests, before and after the wilderness experience (92.3%), while 21 volunteered to answer questions during trip (81%). The following year, an additional study was conducted with a new group of students from the same University College in the same mountain area. From a group of 43 students (M_{age} = 24.5 years, SD = 2.6, 51.2% females), 37 students reported on the pre- and post-tests, before and after the wilderness experience (86%), while 26 students volunteered to answer questionnaires during trip (60% participation). Altogether 62 students out of 67 reported on pre- and post-measures of the wilderness expedition. Forty-seven of 67 reported on experience reports.

Environmental Context 1: Forest-Stormy

During the first wilderness expedition, there was a full storm for 4 days, and it was necessary for safety reasons to discontinue the plan to reach the high-altitude plateau over the tree line. As a consequence, the whole expedition took place in the forest. The student group was divided in three smaller independent groups, with three leaders (one female leader). They all moved in the same area, but in separate camps, not in sight of each other. Students lived in self-built snow caves some of the days. For simplicity we call this group "forest-stormy."

Environmental Context 2: Plateau-Cold

During this wilderness expedition, it was sunny, but the temperature was very low (minus 25°C). This time, the groups succeeded in reaching the high-altitude plateau, and moved for a longer distance in the mountain. They lived in self-built snow caves some of the days. The group of 43 students were divided into four groups, each group with a leader (one female leader). The groups moved in a wide area, not in sight of each other. For simplicity we call this group "plateau-cold."

Instruments for Psychological Traits

Students were given (pre- and post-adventure) trait instruments in a classroom environment, including measures of satisfaction with life and personal growth.

Satisfaction With Life Scale

Five items for Satisfaction With Life Scale (SWLS; Pavot and Diener, 1993) were used on a Likert scale from 1 to 7 (e.g., "In most ways my life is close to my ideal," "I am satisfied with my life").

Personal Growth

We used a personal growth composite based on four different dimensions, each measured by three items: Curiosity (Amabile et al., 1994) (e.g., I enjoy to deal with new tasks presented for me), Absorption (Kashdan et al., 2004) (e.g., When I participate in an activity, I have a tendency to be so involved that I "forget time"), Complexity (e.g., I like to hear about new ideas), and Competence (e.g., I like to meet challenging tasks). Complexity and Competence were based on California Psychological Inventory (CPI) from International Personality Item Pool (IPIP, 2002; HPI Science ability HIC). Each item was measured on a bipolar scale from 1 to 5, ranging from "disagree" to "fully agree." This measure of personal growth is used in other publications (Kopperud and Vittersø, 2008; Straume and Vittersø, 2015).

Instruments During Nature Experiences

During the wilderness experience, participants were asked to record questionnaire responses in a hand-written diary.

Strong Experiences of Nature

Inspired by the Day Reconstruction Method (DRM; Kahneman et al., 2004) and Event Reconstruction Method (ERM; Grube et al., 2008), each student was asked to describe a strong experience of nature daily in a diary made especially for the data collection. The instruction was: "Thinking about this day in the mountains, select one event when you felt a strong experience of nature. Describe this strong experience." Five lines with open space were available for the answer. Based on this strong experience, we asked students to report quantitatively on questionnaires regarding aesthetical nature experiences and feeling states. This diary was distributed at the start of the wilderness expedition and collected at the end of the expedition. Students were asked to report on the same questions for 5 days.

Feeling States

In relation to the self-selected episode, students were asked to report how intensely they felt during the episode. Three hedonic feelings (satisfaction, pleasure, and happiness) and three eudaimonic feelings (interest, engagement, and enthusiasm) were gauged on Likert scales (1–7) based on an adjusted version of the Basic Emotion State Scale (Vittersø et al., 2005).

Aesthetic Situational Nature Experiences

As we were unaware of a suitable questionnaire to examine aesthetic experience in nature, we tested eight novel aesthetic theory-generated questions: (1) I experienced beautiful scenery, (2) I was aware of small details in nature, (3) I appreciated variety in nature, (4) I felt everything was connected in nature (or: I felt everything in nature was connected), (5) I felt at home in nature, (6) I felt nature evoked wonder, (7) I felt beauty in nature evoked wonder, and (8) I felt nature evoked awe and respect. These questions do not operate as a scale to measure one phenomenon but give an opportunity to find empirical evidence to theory-driven questions capturing different dimensions of aesthetics. Each item was asked in Norwegian translation (the native language of participants) and measured on a Likert scale 1–7. To ensure similar meaning between English and Norwegian, the questions were based upon aesthetics literature available in English but formulated in Norwegian. The Norwegian questions were back translated into English and from this translation a new translation into Norwegian by an independent Norwegian-English speaking researcher was made.

Human Subjects Review

Students were invited to participate during a regularly scheduled, wilderness leadership course. They were informed in writing that they could withdraw from the project at any time and for no reason. The data would then be deleted. Data was collected by paper and pencil, with no personally identifiable information, as only a participant-generated id was used. Students were asked to use an anonymous code (not identifiable for the researchers) to group the questionnaires together. Following national rules of personal information safety by the Norwegian Centre for Research Data (NSD), no additional written consent was necessary, given the process used to collect and store data. The project also was reviewed for appropriate informed consent though the university college where the study took place.

Design and Procedures

Pre- and post-questionnaires of traits were distributed in ordinary classes the week before and the week after the wilderness expedition. As these classes were obligatory to join the wilderness expedition, all students had the opportunity to participate in the survey.

During each expedition, students reported daily on their experiences in a diary, collected afterward by the researcher and their research assistants, who were also wilderness leaders. Students were friendly reminded in the evenings to fill out their daily experiences after they had come safely into their sleeping bags in the evenings, using head torch and pencil to fill out the questions.

Quantitative Analysis

Descriptives

Collapsed measures of the 5 days experience sampling on each question of the aesthetic situational nature experience were calculated to find mean scores and standard deviations for the wilderness experience at group level (see **Table 1**). Three analyses were performed: the entire sample and the split forest-stormy and the plateau-cold samples. Analyses were performed in SPSS, version 25.

Correlations

Hedonic and eudaimonic feelings were correlated with eight different items of the aesthetic nature experience. Satisfaction with life and personal growth from the post-measure of the wilderness expedition were correlated with "felt at home in nature."

Qualitative Analysis

The coding from subthemes (events) and main themes (context) toward synthetic dimensions was discussed and agreed upon by two investigators. Experience reports were selected for closer investigation when participants also answered the question of "felt at home in nature" with the strongest Likert response. Only quotes that were also reported as 7 on the Likert Scale 1–7 were included. With this selection, 13 quotes from the forest-stormy-sample, and 26 quotes from the plateau-cold-sample satisfied the selection criteria, suitable for narrative investigations. First, all narratives were read through and coded by two independent researchers. Next, dimensions across the narratives were agreed upon, based on thematic understanding of the narratives. Third, the researchers analyzed each narrative in terms of synthetic dimensions, which were deduced based on shared themes in the narratives. The inductive analysis process follows the strategy of theme-oriented analysis (Braun and Clarke, 2006).

RESULTS

Descriptives

Mean scores for each of the items from the questions of aesthetic situational nature experiences indicated similarities and differences on group level between the forest-stormy- and the plateau-cold-sample. Calculated with the two-sample *t*-test, the first question "I experienced beautiful scenery" was reported as stronger in plateau-cold than in forest-stormy. This finding was close to significant ($p = 0.051$). Changes in other scores were not significant between these small samples (see **Table 1** for more details). All data was checked to be normally distributed.

TABLE 1 | Means for situational aesthetic nature experiences.

Aesthetic situational nature experiences	Forest-stormy Valid ($n = 12$)		Plateau-cold Valid ($n = 20$)	
	M	*SD*	*M*	*SD*
I experienced beautiful scenery	4.63	1.18	5.45	0.87
I was aware of small details in nature	5.17	0.92	5.19	0.94
I appreciated variety in nature	5.45	1.12	5.47	0.96
I felt everything was connected in nature	4.79	0.81	4.77	0.94
I felt at home in nature	4.89	1.06	5.14	1.03
I felt nature evoked wonder	4.81	1.49	4.92	1.19
I felt beauty in nature evoked wonder	4.33	1.60	4.67	1.25
I felt nature evoked awe and respect	5.05	0.92	4.87	1.58

Only respondents with no missing were included.

Feeling States

For hedonic feelings, reliability tests showed a Cronbach's alpha $\alpha = 0.80$ (in forest-stormy) and $\alpha = 0.96$ (in plateau-cold). For eudaimonic feelings, $\alpha = 0.95$ (in forest-stormy) and $\alpha = 0.95$ (in plateau-cold).

Correlations

In the hedonic and eudaimonic measures of how the strong experience of nature felt, there were similarities between the two environmental conditions on some items, but others differed in their correlation to aesthetic questions. For example, "beauty in nature evoked wonder" felt more hedonic in forest-stormy while more eudaimonic in plateau-cold. To be more aware of details in nature (item 2), felt more hedonic in forest-stormy and more eudaimonic in plateau-cold. The most affective dimension of the aesthetic nature experience related to "felt at home in nature" (item 5), which had the highest correlations with both hedonic and eudaimonic feelings for the whole sample. During plateau-cold, this item correlated highly with both hedonic feelings (Pearson $r = 0.82$, $p < 0.001$) and eudaimonic feelings ($r = 0.91$, $p < 0.001$), while in forest-stormy, this dimension correlated with hedonic feelings ($r = 0.63$, $p = 0.011$) but not eudaimonic feelings ($r = 0.22$, $p = 0.459$) (see details in **Table 2**).

Five items had higher correlations with hedonic feelings during forest-stormy than plateau-cold, but these differences did not reach the level of significance. Similarly, seven of the items had higher correlations with eudaimonic feelings during plateau-cold than forest-stormy. "Felt at home in nature" reached significance ($z = 3.16$, $p < 0.01$), as did "felt nature evoked awe" ($z = 2.54$, $p < 0.05$).

Hedonic and eudaimonic feelings were related to well-being in different ways, too. In the whole sample, hedonic feelings correlated with personal growth ($r = 0.42$, $p = 0.015$). Looking closer to forest-stormy, hedonic feelings were important for personal growth, but did not reach a level of significance ($r = 0.38$, $p = 0.184$). Eudaimonic feelings were also relevant for personal growth ($r = 0.34$, $p = 0.260$). Satisfaction with life was not related to either hedonic ($r = 0.04$, $p = 0.896$) nor eudaimonic feelings ($r = -0.13$, $p = 0.677$). In plateau-cold, hedonic feelings correlated with both satisfaction with life ($r = 0.47$, $p = 0.033$) and personal growth ($r = 0.51$, $p = 0.022$). Eudaimonic feelings did not reach levels of significance for correlation with satisfaction with life ($r = 0.28$, $p = 0.229$) but correlated with personal growth ($r = 0.49$, $p = 0.033$).

The question of feeling at home in nature from the experience reports was correlated with life satisfaction and personal growth. In forest-stormy, personal growth correlated with feeling at home, approaching levels of significance ($r = 0.49$, $p = 0.073$). In plateau-cold, feeling at home in nature correlated with both life satisfaction ($r = 0.70$, $p < 0.001$) and personal growth ($r = 0.51$, $p = 0.022$).

Regression Analysis

In the combined sample, a regression analysis of the *in situ* aesthetic nature experiences for all eight items were used as the independent variables of the post-measure of personal growth.

TABLE 2 | Correlations between aesthetic nature experiences and feeling states.

	Total sample		Forest-stormy		Plateau-cold	
	Hedonic	***Eudaimonic***	***Hedonic***	***Eudaimonic***	***Hedonic***	***Eudaimonic***
I experienced beautiful scenery	0.58*	0.40*	0.68**	0.59*	0.54*	0.46*
I was aware small details in nature	0.42*	0.55**	0.60*	0.45	0.33	0.60*
I appreciated variety in nature	0.45*	0.53**	0.55*	0.48	0.40*	0.61*
I felt everything was connected in nature	0.29	0.40*	0.75**	0.41	0.45*	0.68*
I felt at home in nature	0.75**	0.61**	0.63*	0.22	0.82**	0.91**
I felt nature evokes wonder	0.43**	0.43*	0.42	0.27	0.44*	0.59**
I felt beauty in nature evoked wonder	0.48**	0.51**	0.64*	0.48	0.38	0.60*
I felt nature evoked awe and respect	0.27	0.35	−0.05	−0.5	0.37	0.46*

*$p < 0.05$, **$p < 0.01$.

This model had an explained variance of $R^2 = 42.4$, $p = 0.151$. Only item 8 "I felt nature evoked awe and respect" was significant in the model, as a negative predictor ($t = -2.4$, $p = 0.03$). A second model was tested based only upon the almost significant item 5 "felt at home in nature" as the independent variable, which explained less variance, $R^2 = 13.1$, $p = 0.04$, but in this model, "felt at home in nature" was a significant predictor ($t = 2.2$, $p = 0.04$).

Qualitative Analysis

Narratives that corresponded to "felt at home in nature" (= 7 on the Likert scale) were extracted from SPSS and copied into a word file. Next, the first and second author read independently through the material and some common characteristics appeared: looking at phenomena of light, such as stars, aurora borealis, the sun, and campfire. Participants also frequently observed phenomena related to fauna and flora, such as trees and traces of animals. Many report experiences of silence in nature. Some narratives also report of some sort of "movement" as strong experience. This movement is either when they are moving through a particular environment, e.g., the forest, or a movement from one local environment to another, expressing a transition, e.g., moving from the forest into the high mountain. Further, the narratives were related to some broader synthetic dimensions after a full theme-oriented analysis. See an extraction of this analysis in **Table 3** (full data available in **Appendix 1**).

Narratives analyzed by synthetic dimensions were: (1) Description of a certain moment with focus on sensory experiences: e.g., "To come through the pine forest and feel the sun warming in the face and the sound of the wind whizzing in the trees"; (2) Description of self-reflection: e.g., "The feeling of being alone in the pine forest"; (3) Description of wonder: e.g., "Met on some fresh animal tracks"; (4) Description of a certain moment of appreciation of beauty: e.g., "We walked past a lovely old pine tree. The branches and trunk twisted around in a stylish way"; (5) Situations focusing positive emotions, e.g., "When I had time to enjoy breakfast with the morning sun in the middle of me"; and (6) Insight of relation to nature: e.g., "Walk through the woods of skiing, with everything you need to survive on your back makes you feel strongly connected to nature." Some of the narratives included more than one synthetic dimension among these six synthetic dimensions.

DISCUSSION

Strong experiences of nature inform our well-being in complex ways. In wilderness, strong experiences of nature relate to personal growth, and sometimes also satisfaction with life. "To feel at home in nature" arises as the most important feature relating to aesthetic nature experience. This feature includes sensory experiences as well as reflections, which actualize the notion of wonder. In order to understand aesthetic nature experiences in the wilderness, the study of winter expeditions yields some clarity into the effect of environment on aesthetic experience and well-being as well as opportunities for theoretical insights. There appear to be both some stable elements and some context-dependent elements within the aesthetic nature experience that require careful analysis.

Core Characteristics of Aesthetic Experiences in the Wilderness

When interpreting the results from the combined winter expeditions, the eight questions regarding aesthetic nature experience account for 42.4% of the variance of personal growth. Although the regression analysis in the small sample did not reach the level of significance, aesthetic nature experiences seem to be powerful in understanding this aspect of well-being. However, the items seem to vary, and dividing participants into their two different environmental contexts thus informs about similarities and differences in some of the items. In order to understand more of the sublime dimension, which we strongly identify with personal growth (Graves et al., 2020), a deeper approach is necessary.

In both contexts, strong experiences of nature included same levels of "awareness of small details in nature" and "appreciations of variety in nature," indicating that these dimensions were equally important across the different contexts. The groups differed in intensity of experiencing beautiful scenery, which in forest-stormy was different due to wind and snow. On other typical qualities, there were some slight differences, such that "felt at home in nature" was more intense during the plateau-cold sample. Also, both questions of wonder were more intense during

TABLE 3 | Example of the analysis process and developing sub-, main-, and synthetic dimensions.

Environmental context	Narratives	Sub-themes (event)	Main themes (context)	Synthetic dimensions
Forest-stormy	Come through the pine forest and feel the sun warming in the face and the sound of the wind whizzing in the trees	Sun warming, sound, forest	Sounds of wilderness	Description of a certain moment with focus on sensory experiences
Plateau-cold	When all the lights from the headlamp were extinguished and the stars appeared	Stars. Light	Contrast darkness/light	
	Look at the stars with a friend while we melted snow in 20 minus	Stars. Light. Cold		
Forest-stormy	The feeling of being alone in the pine forest	Being alone, forest	Forest reflection/alone	Description of self-reflection
	Met on some fresh animal tracks	Animal tracks	Forest, surprise	Description of wonder
Plateau-cold	Look at animal tracks in the forest			
	Saw many animal tracks			
	Ice-covered bench	Ice fascination	Fascination of details, surprise	
	Blackcock (big bird) that flew up	Bird		
Forest-stormy	Snow cave. How amazing is it that you can build something so nice, cozy and warm by snow? Totally insanely nice and an aha experience	Snow cave	New snow experience	Description of a certain moment of appreciation of beauty
	We walked past a lovely old pine tree. The branches and trunk twisted around in a stylish way	Tree, forest	Fascination and aesthetic judgment of details/forest	
Plateau-cold	When we walked between pine and birch and sang "In the forest I am free"	Walking and singing. Forest	Enjoyment	Situations focusing positive emotion
	When I had time to enjoy breakfast with the morning sun in the middle of me	Warmth from sun. Light	Pleasure	
	Walk through the woods of skiing with everything you need to survive on your back makes you feel strongly connected to nature	Connection to nature, moving, carrying backpack, forest	Reflection on relation to nature when moving	Description of a certain moment with focus on sensory experiences and insight of relation to nature

the plateau-cold sample. On the other hand, awe and respect were stronger during the first, forest-stormy year. Although these differences were informative, the sample sizes (of participants who rated belonging Likert = 7) were too small for the differences to reach significance.

Affectively, there were also some similarities and differences in the two different winter expeditions. All eight aesthetic items relate to positive emotions, but in different ways. For example, while the feeling that everything was connected in nature and feeling at home was hedonic during forest-stormy, it turns out to be more eudaimonic during plateau-cold. One explanation could be that during forest-stormy, students had to work hard in order to keep warm and dry, and when they succeeded in this, they felt connected to nature, which is a hedonic feeling. During plateau-cold, focus was much larger than keeping warm and dry, as during this expedition they skied for a long distance and could feel connected to nature in more complex ways, both hedonic and eudaimonic. During plateau-cold, "felt at home in nature" felt more eudaimonic than during forest-stormy. During forest-stormy, "felt nature evoked awe and respect" was not related to affect, as it correlated neither with hedonic nor eudaimonic feelings. These findings add more fine-grained knowledge about where and when hedonic and eudaimonic feelings occur during wilderness adventure. As there are similarities and differences between one group during forest-stormy and another group during plateau-cold, there is much more to understand than preference into different landscapes (Oishi et al., 2015). Also, as all students were presented with a new landscape, the bonding effect based on former experiences (Knez and Eliasson, 2017) could not explain the connection between place and well-being. In neither of the groups, students had been in this particular environment before. Rather, the finding that the sublime dimension has both context dependent and general features informs how to understand awareness and how to pay attention (Bergmann and Eaton, 2011) to this complex and powerful phenomenon.

Affective, Experiential, and Philosophical Aspects Associated With "Feeling at Home in Nature"

The item that has the strongest affective relevance is the item "I felt at home in nature." This was felt more intense during plateau-cold than during forest-stormy, with very high correlations during plateau-cold on both hedonic and eudaimonic feelings, while only hedonic feelings in forest-stormy. Interestingly, feeling at home in nature, as a theoretically strong argument for aesthetic

nature experience, turned out to be the most affective item in the plateau-cold sample. Students were emotionally activated when they recalled an experience that they felt at home in nature. Informing strong affective aesthetic nature experiences, post measures of well-being correlated strongly with this item. During plateau-cold conditions, feeling at home correlated strongly with satisfaction with life, but this was not found during forest-stormy. On the other hand, personal growth was correlated with feeling at home in nature during both adventures. The finding supports that life satisfaction and personal growth needs to be understood separately as different facets of well-being (Vittersø, 2016). Moreover, it is informative that both expeditions related personal growth to feeling at home in nature, but life satisfaction was only related to feeling at home in nature during plateau-cold. Feeling at home in nature was felt affectively different during forest-stormy and plateau-cold. These are differences on group level, informing about contextual differences and identifying core characteristics across the groups. Nevertheless, the strong finding of feeling at home in nature as the most important feature, as it is felt strongest and alone predicted personal growth, leads to the connection of "Beheimatung" and "atmosphere" (Bergmann, 2011), which carries an awareness of who we are and how we are interconnected with nature, at least as an intense feeling and as an expression of personal growth.

The thematic analysis of narratives corresponding to "felt at home in nature" displays synthetic dimension relevant for our discussion. We recognize how the notion of "feeling at home in nature" and the interconnectedness in nature corresponds to descriptions of a certain moment with focus on sensory experiences, certain moments of appreciation of beauty, self-reflection, wonder, and situations focusing positive emotions (and even moments with combinations of these dimensions).

First, situations of feeling at home in nature take place when there is a certain moment with focus on sensory experiences. Revisiting the role of attention, feeling at home in nature includes narratives that follow some meaningful patterns in both samples, patterns that include attentional dynamics from the orienting and alerting network. Situations of feeling at home include perceptions of wilderness, such as contrasts of darkness/light and other visual sensory experiences as well as tactile ones, exemplified by sudden sights of stars, moon or northern lights, the warmth from the camp fire or the silence in forest. These examples of focused experience relate to the orienting network and can be explained as "soft fascination" (Kaplan and Kaplan, 1995).

One other synthetic dimension is appreciation of beauty. This dimension relates to appreciation of certain qualities, such as certain trees or landscapes, or the perception inside the snow cave, such as "insanely nice and an aha-experience." Parsons (2008) says our experience of beauty is, bottom line, about our love to something. Talking about beauty in nature, he says, is about how people have strong feelings of love and attachment to certain places and things. Thus, the experience of beauty in nature is about much more than a disinterested contemplation.

Feeling at home strongly relates to positive emotions, with correlations to both hedonic and eudaimonic feelings. Three of the narratives associated directly to positive emotions, where two of them describe situations of movement in hedonic interpretations, like downhill skiing, walking and singing, and also enjoying breakfast. It is likely that eudaimonic feelings associated with feeling at home in nature thus include an active interpretation of a sensory experience, identified in the other synthetic dimensions, but there is also possible that this dimension is not fully understood in this explorative study. However, the strong connection between positive emotions and feeling at home in nature is observed. Positive emotions build our action repertoire and build resources to see the world in a more complex manner (Fredrickson, 2004). This could be a two-way process of (i) positive emotions empowering the feeling of being at home in nature and (ii) feeling at home, as a safe or inspiring moment, causing positive emotions, which in both cases promote our well-being. Feeling at home, as the strongest positive emotion, relates to Kaplan and Kaplan (1995, p. 193) interpretation of compatibility in finding a special resonance between natural environment and human inclinations. This resonance includes being away from civilization, living with less effort, supporting psychological well-being, but wilderness experience also leads to "a sense of awe and wonder and, at the same time, relatedness" (Kaplan and Kaplan, 1995, p. 194).

Feeling at home is also experienced when (i) a moment of self-reflection takes place, (ii) the experience of wonder is articulated and (iii) gaining insight of relation to nature. These dimensions are reflexive and philosophical by nature and could be related to each other. Description of self-reflection and gaining insight of relation to nature corresponds to the latter dimension of wonder, as evoking reflection on what we perceive and experience (e.g., being alone in the forest). The former dimension of wonder, evoked by something in nature, corresponds to the synthetic dimension of wonder which includes the experience of surprise and fascination of nature. Thus, in this context wonder, which is an active approach using the alerting network, takes place in in a fascination of trees, or experience a bird flying up. These synthetic dimensions correspond to self-reflection as one of the central components in wonder (Sæther, 2017), while sensory experiences and positive emotions, that also could relate to wonder, display as separate dimensions. Interestingly, in looking for experiences that correspond to feeling at home in nature, these wonder-experiences seem to be of the same characters in the two different contexts, but they had higher frequencies during plateau-cold.

Wonder spans over a wide range of meanings and is indubitably a complex phenomenon. Wonder can at least be distinguished in two ways: as something in nature which evokes a feeling of wonder and something motivating humans for self-reflection and further search for insight (Sæther, 2017). The former dimension of wonder has some similarities with the experience of beauty and the sublime. Experiences of beauty and sublime can take place as something striking you surprisingly from "the outside." On the other hand, the latter experience of wonder takes place as a kind of reflection on what we perceive. Deane-Drummond (2009, p. 128) says: "... wonder is an even broader term than beauty and could be said to be prior to its recognition." The comprehensiveness of wonder, broadly understood, is articulated by Schindler (2013, p. 163), describing

wonder as ". . . a final state, as that-than-which-nothing-further-ought-to-be-sought."

We also recognize complex experiences as we find combinations of the previous synthetic dimensions, such as both sudden feelings *and* reflection, which underscores that we cannot differentiate too categorically between the different dimensions. Even within the different dimensions, we find complex phenomena, such as wonder. Although we have to navigate carefully in such complex experiences in the wilderness, we will address one line of thought which displays the ethical relevance for feeling at home in nature (which include aesthetic experiences in nature, wonder and awareness). According to Robert Fuller (2012), wonder has some similarities with awe as experience. Awe transforms us toward a reorientation of our lives, goals, and values, he says. Further, awe evokes a feeling in us for being part of a larger whole. For Fuller, both wonder and awe are caused by novel and unexpected stimuli, challenging our given conceptual categories.

In light of the experiences of beauty and the sublime (awe) in wilderness, wonder as an experience can be understood as taking place together with, and in the extension of, beauty and awe (Sæther, 2019). When one experiences the beauty and the sublime in nature, this experience might evoke wonder (Ledley, 2009). Matravers (2012) characterizes this type of wonder as a reflective state. For Matravers, the experience of beauty and the sublime in nature evokes a first-order non-cognitive state, and the resulting feeling can be described as astonishment. Thus, wonder is about a duration of awareness, and corresponds to our theoretically unpacking of awareness, feeling at home, and how to pay attention to our surroundings – in Bergmann's terms "living-in-particular-surroundings." Therefore, our analysis of narratives informs about complex relationships when feeling at home in nature, where sudden feelings have hedonic and eudaimonic variation depending on context, and reflection seem to rise across many of the wilderness situations. Here, we recognize a trajectory from aesthetic experiences, through wonder, toward a potential ethical awareness. Such a trajectory corresponds to Bergmann's notion of aesth/ethics, including his reflections on inhabitation and "Beheimatung."

Feeling at home is also touched upon by García-Rivera (2009). According to him, in light of our environmental crisis, we need to address the question of being at home in the cosmos. For García-Rivera, an emphasis on "place" helps us to understand what this home or connectedness to nature might take shape, which corresponds to Bergmann's notion of inhabitation. The narratives of feeling at home in the wilderness adventure identify several important places where feeling connected to nature are expressed directly, such as when being alone, looking at the stars or skiing in the forest. García-Rivera says place expresses both an inner as well as an outer dimension, and the experiences of such a place – in our context the experience of feeling at home in nature – is about an intimate immensity actual in space and time. Thus, aesthetic experiences of nature open for experiences of feeling at home which addresses deeper emotions involving belonging, interconnectedness. A recognition of such complex experiences might evoke ethical awareness.

Strengths and Limitations

The empirical investigation of aesthetic wilderness experiences is based on experience reports from 47 individuals in a Norwegian study program. Strengths of the study design in understanding aesthetic wilderness experiences includes mixing quantitative measures as well as personal narratives as well as the examination of challenging environmental conditions. The utilization of mixed methods seems to be optimal in exploring deep connections in a complex field, as the integration of methods leads to more pinpointed knowledge: Quantitative measures inform intensity of aesthetic dimensions and feelings connected to these, while qualitative investigations gave feeling at home, identified as a quantitative finding, a much richer description and deeper interpretation (i.e., Løvoll, 2019).

One weakness with the current study was the hard work filling out the questionnaire in the evening, with cold fingers and in an uncomfortable condition. Consequently, we missed some participants, especially from the plateau-cold group, and also some narratives were very short. Nevertheless, we consider reliability as good, in comparison to other methods like using observational data or only retrospective data collection after adventures (Merriam and Tisdell, 2016).

Our two research contexts include one expedition with worse weather condition (forest-stormy) than the other (plateau-cold). As one of the contexts was under the tree line and the other above the tree line, landscape is one dimension of the context, and the other is the impact of weather, such as wind, temperature and snow. In the current analysis, we were not able to distinguish between other possible combinations of landscape and weather such as plateau-stormy or forest-cold.

To move forward, the study should be replicated with other groups and other contexts, including those outside Norway. Series of studies can produce empirical data for meta-analysis, calculating power for context dependent and context independent dimensions of the aesthetic wilderness experience. Moreover, more studies are needed to enable generalizing about the strong connection we found between feeling at home in nature and well-being.

Implications

The findings have implications for theoretical and practical didactical reasons. In understanding the role of environment for aesthetic experiences, it is important to pay attention to wilderness, as the non-human-built environment offers a unique understanding of how aesthetic experiences appear and how those experiences connect to feelings and well-being. In this way, the knowledge of aesthetic wilderness experiences can offer a reference knowledge enabling comparison to aesthetic experiences within arts and built environments.

The finding that "feeling at home" is a very informative aesthetic dimension in being positively felt as well as important for well-being. This relates to belonging in a much wider sense, which also theoretically connects aesthetics to ethics. For the outdoor leader, there is a potential in identifying, dwelling, and cultivating what it is like to feel at home in nature, as this aesthetic dimension has individual importance, as well as a potential

for ethical reflection. When considering learning outcomes in outdoor events or adventures, this dimension should not be under communicated or overlooked. In a contemporary context, where the UN's climate report, and other initiatives, strongly call for human action in the face of global climate change, the connection between aesthetics and ethics is an important aspect in identifying, savoring and cultivating what "feeling at home in nature" actually means, in a global context, especially with an understanding of the role of wonder. Also, in a practical didactical context, the findings give impetus to focus on aesthetic wilderness experiences, as they provide strong emotional experiences as well as importance for well-being.

CONCLUSION

This article has explored three complementary questions that relate aesthetic experiences and well-being within the wilderness environment. First, main dimensions of beauty and the sublime were identified as core features in situational wilderness experiences. The classical notion of beauty was more important in the plateau-cold condition.

Second, we found that "beauty in nature evokes wonder" was hedonic in forest-stormy and eudaimonic in plateau-cold. The item "felt at home in nature" had very high correlation on both hedonic and eudaimonic feelings during plateau-cold. In forest-stormy, this item only correlated with hedonic feelings. Hence, we find aspects of this feature to be context dependent. Feeling at home in nature correlated with both satisfaction with life and personal growth during plateau-cold while only with personal growth during forest-stormy.

Third, when exploring feeling at home in nature as an intense experience, six synthetic dimensions were identified through the narratives. These six dimensions relate to theories of wonder in different ways. To feel at home in nature can be understood as a non-intentional experience but also as an intentional experience when being self-aware. Our findings contribute to a more refined and systematic understanding of the characteristics of how wilderness experiences create aesthetic experiences and well-being. We accentuate that aesthetic experiences generate feelings of nature as our home and, further, creates an ethical awareness of the value of wilderness.

DATA AVAILABILITY STATEMENT

The datasets generated for this study are available on request to the corresponding author.

ETHICS STATEMENT

Ethical approval was not provided for this study on human participants, because there was no person identifiable information in the collection of data. Details about the process is described in the Human Subjects Review section of the article. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2020.00402/full#supplementary-material

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OPINION
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Communication and Meaning-Making Are Central to Understanding Aesthetic Response in Any Context

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Conceptions of aesthetic experience extend beyond beauty to include any evaluative judgment or emotion experienced in response to an artwork. In this opinion piece, we discuss the nature of artistic communication and how it might be facilitated inside and outside of museum settings.

AESTHETIC AFFORDANCES AND COMMUNICATION

Many conceptions of aesthetic experience begin with perception. Gibson (1986) argued that an object is perceived in terms of its affordances, which represent potentials for action—like the handle of a coffee mug inviting a grip. Design principles are built around the idea that objects suggest appropriate behaviors (Withagen et al., 2012). Beyond objects' pure functionality, the perception of affordances also involves cognitive, emotional, and aesthetic processes, which emerge via interaction (Xenakis and Arnellos, 2013).

Art objects like paintings do not show physical affordances, like coffee mugs. However, art is a potent source of other kinds of affordances—aesthetic and social—which involve a communicative process and invite a search for meaning. We interact with art objects with the implicit awareness that they were created by other people. As social creatures, our evolutionary survival depended on an ability to communicate and share meaning with others. This habit carries over into our interactions with works of art. Artworks are perceived as extensions of their creators (Newman et al., 2014).

Many factors—including features of artworks, viewers, and physical contexts—impact people's interaction with artworks, both in the lab and in more ecologically valid settings (Pelowski et al., 2017). Empirical studies have also examined more specific facets of artistic communication. These include the extent to which abstract marks can communicate particular emotions (e.g., Takahashi, 1995), the detection of high-quality abstract paintings with reference to perceived artistic intention (Hawley-Dolan and Winner, 2011), and the influence of contextual information—often wall labels in museums—on aesthetic appreciation (Russell, 2003).

GRICEAN PRINCIPLES OF CONVERSATION APPLY TO VISUAL ARTWORKS

An overarching question is how to characterize the nature of artistic communication. Communication is a meaning-making process, a search for understanding and relevance, and a way of establishing common ground and connecting with another's experience. We argue that principles of communication in everyday conversation also apply to communicative exchanges

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between artworks and viewers. Specifically, we have proposed (Grice, 1975) maxims of conversation as a promising framework for aesthetic communication in visual art (Dolese et al., 2014).

The Gricean framework is an *intentionalist* model of communication. It presupposes an underlying *cooperative principle*, whereby those involved in an interaction do so with the goal of being understood and arriving at some form of meaning. This plays out via four conversational maxims: *quality* (be truthful), *quantity* (be informative), *relation* (be relevant), and *manner* (be clear). When the maxims are adhered to, or even when they are intentionally unfulfilled (Mooney, 2004), the meaning of a speaker's utterance can be inferred by the listener. When maxims are violated, a speaker is perceived as no longer cooperative, negative emotions arise, and the conversation ends. The Gricean framework is thus useful in characterizing both *direct* and *indirect* communication—that is, not only the choice of words to facilitate straightforward information-sharing, but more broadly in how interlocutors negotiate and develop a shared understanding.

Gricean principles can be translated into the domain of visual art, if one regards aesthetic encounters as a conversation between the artwork-as-extension-of-its-creator and the viewer. For instance, quality can be construed as the artist's sincerity and skill in expression; quantity, as conveying an appropriate level of visual complexity; relation, as a sense of an artwork being relevant to one's experience; manner, as the stylistic and compositional aspects of a work that clearly convey an intended meaning (Dolese et al., 2014).

The divergent experiences of viewers faced with challenging artworks can readily be understood in Gricean terms. Knowledgeable viewers, who share common communicative ground with such works, can easily negotiate deliberate violations of the maxims. For instance, they may appreciate Cubist works that appear to flout the maxim of quality, Minimalist works whose simplicity seems to undercut quantity, or conceptual pieces whose interpretive ambiguity looks as if it would violate manner. In contrast, when inexperienced viewers are confronted by works that violate their expectations, and they have no means of establishing common ground that would allow indirect communication, their response involves negative aesthetic emotions like disgust or hostility (Silvia and Brown, 2007), or, as we note here, alienation—precisely the attitudes that would terminate in-person conversations.

IMPLICATIONS OF THE GRICEAN FRAMEWORK FOR AESTHETIC COMMUNICATION

Beyond serving as a mere theoretical model for understanding the nature of artistic communication, a Gricean perspective also has practical implications. Here we focus on three substantive issues where it might provide scientific traction and pragmatic impact: (1) facilitating heightened aesthetic engagement and understanding, especially in museum settings, (2) emphasizing the maxim of *relation* as a means of engaging and empowering viewers, again in museum settings, and (3) better understanding the nature of peak, transformative aesthetic experiences through a Gricean lens.

USING GRICEAN PRINCIPLES TO HEIGHTEN AESTHETIC ENGAGEMENT

A key element of the Gricean framework is the necessity of shared common ground as a basis for any communication. To the extent that some viewers don't "get" a work or style of art, one might attribute this to missing common ground. This Gricean diagnosis suggests a straightforward remedy: provide additional relevant information, as part of museum walls texts, audio guides, or educational outreach programs that would begin to provide such common ground in an explicit way. Content and stylistic information appears to improve viewers' ratings of the meaningfulness and interest of artworks (Cupchik et al., 1994), though the effect of additional information on aesthetic emotion may be more muted (Dolese and Kacinik, 2019). Thus, information specific to artists' communicative goals, rather than just background content information, may lead to more fulfilling aesthetic experiences.

Establishing common ground becomes more urgent in cases of more challenging artistic styles. For instance, many viewers react negatively to abstract art—even renowned works by famous painters—on the basis, arguably, of not realizing an intentional violation of the quality maxim. However, the finding that even naïve viewers can detect traces of intentionality, which distinguish professionally produced abstract paintings from visually similar works by animals or children (Hawley-Dolan and Winner, 2011), suggests a nucleus of potential common ground that could be developed, particularly in a museum setting.

While such practices could be useful for bootstrapping common ground for aesthetic communication, there may be limits on the usefulness of methods that are *too* explicit. Consider processing fluency, whereby aesthetic response reflects how easily a viewer processes the stimulus of an artwork: easier processing, a more positive response. Hedonic responses appear higher if the source of fluency in processing is unknown to the viewer and the experience comes as a surprise (Reber, 2012). The uneasy relation between explicit knowledge that promotes aesthetic response, and too much information that might potentially dampen it, is a provocative area of research that can mutually inform both Gricean and processing fluency accounts. Clearly, museum contexts would play a major role in future studies addressing these questions.

THE MAXIM OF RELATION IS CRUCIAL FOR ENGAGING AND EMPOWERING VIEWERS

The preceding discussion of how Gricean maxims can be deployed in visual art have only used examples from quality, quantity, and manner. We have deliberately withheld a deeper discussion of the maxim of relation until now, as we believe it has special status for informing viewers' perceived representation in settings like museums, which can smack of an elitist ethos.

Viewers often dislike artworks not because of specific objectionable content, but because they seem devoid of meaning. Viewers are thus unable to find a personal connection that makes the work relevant to their concerns and experiences. Indeed, in a series of studies, Landau and colleagues (Landau et al., 2006) found that when forced to confront their mortality, people—especially those with a high need for personal structure—show a decreased liking for modern art that appeared meaningless. Notably, this effect could be offset by imbuing a work with a meaningful title or inducing a personal frame of reference to interpret the work via viewers' own experiences.

In general, viewers have a felt sense of ownership over artworks, an expectation of understanding or meaning-making that should not necessarily require special training or knowledge. This attitude may be compounded by the fact that so much art is found in public venues, which serve to house the memories of the communities it represents: "these institutions show us who we are, who we were, and who we might become" (Smith, 2014, p. 1). Museums have a responsibility to represent the experiences of diverse groups of people and to make clear how these pieces represent individual experience and our common humanity, to honor diversity but also to connect. Visitors frequent museums for information and understanding, meaning, and connection. Those who don't attend often cite a feeling that they don't belong. Art objects can invite movement into institutional spaces by signaling an affordance of belonging, a sense that displayed objects represent visitors, who can thus feel welcomed.

MEANING-MAKING IS THE ENDGAME OF AESTHETIC RESPONSE

The process of artistic communication is ultimately geared to the creation of meaning by the viewer. This is a critical aspect of aesthetic response, present in some form in many models of aesthetic appreciation (Pelowski et al., 2016), but whose details and dynamics remain elusive. It is unlikely that artists create work with a very specific point of meaning to communicate—in contrast to someone who, say, creates a visual infographic to represent data. The ambiguity inherent in indirect Gricean communication permits a useful balance between the viewer suspecting that *something* is there to be communicated but then having to work to achieve a meaningful interpretation. Great artworks that communicate indirectly are thus more potent stimuli for aesthetic response and individual meaning-making than any direct, unambiguous communication ever could be.

The process of meaning-making in artistic contexts is not well-understood. Often, it is construed simply as a viewer "getting" a basic understanding of some aspect of a particular artwork—a nice, but decidedly non-peak experience, akin to "mini-c" creativity (Kaufman and Beghetto, 2009) or an aesthetic "experience" tantamount to mild positive affect (Silvia, 2012). Such transient—but not transcendent—moments are not why we care about art.

In contrast to such facile and limited characterizations, other accounts of meaning-making focus on its existential aspects—in confronting and coping with devastating situations of loss, illness, or death (e.g., Frankl, 1946/2006). Meaning-making, in various guises, has sometimes been construed as a central feature of high-level aesthetic response: (Dewey, 1934) view of art as experience (Johnson, 2007), emphasis on embodiment as a vehicle of artistic meaning-making (Konečni, 2005), trinity of peak aesthetic experiences (Vessel et al., 2012), research on intense aesthetic experience and the default mode network, and Pelowski and (Pelowski and Akiba, 2011) discussion of aesthetic experiences that are fundamentally transformative and that can change the way people view themselves.

Articulating the nature of aesthetic communication in more robust, testable terms and with a focus on the endgame of peak aesthetic experience has great potential to inform neglected but vital questions. In-person, museum-based studies of encounters with great art will be necessary to bring this line of inquiry to fruition.

CONCLUSION

Understanding how Gricean principles operate should allow us to more effectively engage the process of artistic communication, curating exhibits and environments with the intention to be more relational, communicative, and inclusive, and to spur more intense and meaningful aesthetic responses among viewers. Art is a stimulus for many important modes of human experience: semantic knowledge about culture and the world, aesthetic pleasure in the processing of sensory patterns, interpersonal or social bonding over shared appraisals, and existential meaning-making. Empirically grappling with these themes under the umbrella of artistic communication has extraordinary potential to inform both theoretical and practical aspects of aesthetic engagement, in any context.

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Viewing Art in Different Contexts

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While aesthetic experiences are not limited to any particular context, their sensorial, cognitive and behavioral properties can be profoundly affected by the circumstances in which they occur. Given the ubiquitous nature of contextual effects in nearly all aspects of behavior, investigations aimed at delineating the context-dependent and context-independent aspects of aesthetic experience and engagement with aesthetic objects in a diverse range of settings are important in empirical aesthetics. Here, we analyze the viewing behavior of visitors (N = 19) freely viewing 15 paintings in the 20th-century Australian collection room at the Art Gallery of New South Wales. In particular, we focus on how aspects of viewing behavior including viewing distance in the gallery condition and eye gaze measures such as fixation count, total fixation duration and average fixation duration are affected by the artworks' physical characteristics including size and image statistics properties such as Fourier amplitude spectrum, fractal dimension and entropy. In addition, the same artworks were viewed in the laboratory, either scaled to fit most of the screen (N = 22) or to preserve their relative size as in the museum condition (N = 17) to assess the robustness of these relationships across different presentation contexts. We find that the effects of presentation context are modulated by the artworks' physical characteristics.

Keywords: eye movements, museums, art, image statistics, gaze patterns

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INTRODUCTION

It is well-established that context affects aesthetic experience and that investigations in authentic and ecologically-valid settings such as art museums are important in empirical aesthetics (for a review see Pelowski et al., 2017). Since the seminal work by Locher et al. (1999, 2001), studies in empirical aesthetics conducted in naturalistic settings have proliferated, afforded by new methods and techniques that have become available. Furthermore, in recent times the way we engage with art has changed dramatically, owing to the proliferation and accessibility of digital information sources and online art repositories. According to Groys (2016), art institutions nowadays use digital platforms as the main place of information distribution about exhibitions and other art events. Museum websites and image repositories of their collections have become an extension of the museum, thus allowing people from around the globe to have access to images of the artworks. Styliani et al. (2009) argue that technology also provides solutions to contemporary issues, such as art gallery exibition and storage space limitations by creating virtual environments with an infinite exhibition and storage capacity. In fact, museums have not only created repositories of their collections visitors can scroll through when looking at works of art in the traditional way, but virtual exhibitions, where avatars mimic navigation in real museums, have become popular in recent years. For example, museums such as the Louvre, the Guggenheim (NYC), and the British

Museum, among others, provide 3D tours of temporary and permanent shows on their websites. The University of Hamburg developed a virtual replica of *Alt-Segeberg Bürgerhaus* museum that enables people to visit the museum by using a virtual reality headset remotely, which aims to provide a more "real" experience that includes body movements in the tour (Kersten et al., 2017). Finally, the Google Art Project (GAP) is an ambitious long-term venture that aims to digitize at the highest possible resolution museum collections from all over the world. In 2011, Beth Harris, the director of Digital Learning at the Museum of Modern Art in New York, argued that the GAP will help make the art experience more pleasant by avoiding "crowds, physical fatigue and self-consciousness" (Proctor, 2011). In summary, it is clear that digital availability of artworks has a substantial presence in the art field, making it important to continue investigating contextual factors in aesthetic experience and engagement with artworks in contexts ranging from museums and laboratories to tablets and cell phones.

Pelowski et al. (2017) comprehensive review of studies comparing the experience of museum-based art to that of digital reproductions in the laboratory noted a number of important contextual effects. For example, artworks are rated as more "immediate" and "pleasant" when viewed in museums (Locher et al., 1999) and, conversely, viewers perceive artworks displayed on computer screens as less interesting, less arousing, more ambiguous and less memorable than the same works exhibited in the gallery (Brieber et al., 2014, 2015). Different presentation contexts have also been reported to result in different viewing behaviors. Empirical studies utilizing mobile eye-tracking have reported longer viewing times (Brieber et al., 2014; Balbi et al., 2016) as well as more widespread distribution of fixations (Quiroga et al., 2011; Walker et al., 2017) for artworks viewed in the museum context compared to the digital reproduction in laboratory.

However, the differences in art experience in different contexts are not always as pronounced. For example, Locher et al. (1999) found significant differences across different contexts evident in only four of the 16 rating scales (sparse-dense, distant-immediate, similar-contrasting, and unpleasant pleasant). The evaluations related to physical, structural and compositional characteristics of artworks were virtually indistinguishable across presentation formats. In subsequent studies, Locher et al. (2001) and Locher and Dolese (2004) found that the ratings of symmetry, heterogeneity, randomness, complexity and clutter were very similar across the original and different reproduction formats (ranging from slide projections to postcards) and did not differ between naïve and more sophisticated viewers. Based on these results, Locher et al. (1999) proposed the notion of "pictorial sameness" and argued that under some conditions, the reproduction can be as perceptually valuable as the original, with the viewers exhibiting "facsimile accommodation" and the ability to "look beyond" the limitations of the medium.

The facsimile accommodation hypothesis notwithstanding, Locher et al. (1999, 2001) were careful to emphasize that the reproduction of a painting is not the same as the original, and that the authentic art context certainly has the potential to enhance the art appreciation. Though extremely plausible, this assertion was tested by Brieber et al. (2015) who noted that in most of the studies of contextual effects on art experience, the effects of genuineness (authenticity or originality) and context were confounded in that participants always view the genuine artworks in museums and the reproductions in the laboratory. In an attempt to dissociate the effect of genuineness from the physical context they tested liking, interest, arousal, valence and understanding of both genuine and reproduced artworks in both gallery and laboratory (Brieber et al., 2015). Surprisingly, they found that neither physical context, nor genuineness had an effect on participants' evaluations of artworks and argued that the inconsistencies across studies could be related to the differences in the nature of materials used across different studies (i.e., photographs vs. conceptual installations; thematic focus of the entire exhibition etc.) and personal relevance of the work to the observer (not always high or meaningful to often used psychology students).

What Causes Difference in Art Experience and Viewing Patterns in Different Contexts?

The many reported differences in the experience and engagement with art between the museum and laboratory contexts play an important role in recent claims regarding the gap between empirical aesthetic science and aesthetic experience (Makin, 2017). Given that most aesthetic research is still conducted in laboratories without access to real artworks, overlooking the contribution of context in which art is typically experienced and appreciated, it is becoming increasingly important to be able to identify the most influential factors associated with different contexts.

Of course, this is not an easy task, since a myriad of particular characteristics define different contexts and differences between them. In a comprehensive review of the characteristics of museum experience, Pelowski et al. (2017) identify three broad groups: (1) features of the artwork; (2) characteristics of the viewer; and (3) characteristics of the presentation context. Features of artworks comprise both physical (size, texture, physical presence, and remnants of the artist's touch and effort) and perceived features (seeing objects as "art" and perceived authenticity). Characteristics of the viewer include personal characteristics such as age, wealth, art expertise, motivations and expectations and group characteristics such as group size and between group differences. Finally, characteristics of the presentation context include physical and cultural aspects of the museum, display/hanging, frame, lighting, art labels, furniture, movement, viewing distance, viewing time and museum fatigue. While all of these factors might be contributing to differences between art experience in museum and other contexts, to date, the majority of them have remained underexplored (Bitgood et al., 2013; Minissale, 2013; Tröndle et al., 2014; Carbon, 2017).

In addition, the majority of studies to date have compared museum and laboratory contexts by aggregating the measures of art experience and viewing behavior across all artworks under consideration, even though the artworks may vary in a number

of important physical characteristics, without providing a finer-grained analysis of the role these characteristics play in both the museum and laboratory contexts.

THE PRESENT STUDY

The museum component of this study was conducted in a room containing 20th-century Australian artworks at the Art Gallery of New South Wales (AGNSW) in Sydney, Australia. The two important issues that we aim to explore in this study are the effect of the context on viewing behavior (i.e., museum vs. laboratory) and the influence of characteristics of the artwork on viewing behavior in both contexts.

While studies considering the experience of artworks in different contexts often utilize the explicit ratings of artworks to directly measure various aspects of aesthetic experience, we opted to focus on the viewing behavior as an index of spontaneous engagement with such objects. Preferential looking at artworks in an exhibition space is not only a defining feature of an art museum visit but, arguably, can be taken as an immediate and objective index of our engagement with such objects. This idea is not only central to the preferential looking paradigm in general, but has also received support in the aesthetics domain (Holmes and Zanker, 2012; Brieber et al., 2014).

The fine-grained analysis of precisely what and how participants look at art exhibits still remains a topic of enormous theoretical and practical interest, especially for visitor-centered art institutions such as art museums and galleries. While it has been well-established that allocation of attention in any physical context is a complex interplay between "top down" (viewer-centered) and "bottom up" (stimulus-driven) factors, our approach is aligned with the attempts to explore the role of physical, statistical properties in the perception of and interaction with images, including artworks. The physical characteristics of the artworks considered were physical size, and image statistical properties such as Fourier amplitude spectrum, fractal dimension and entropy. All these are general physical characteristics of objects and images known to be effective in capturing attention (Berlyne, 1971; Treisman and Gelade, 1980), or influencing perceived complexity, predictability and/or aesthetic appeal (Redies, 2007; Spehar and Taylor, 2013; Mather, 2014, 2018; Redies, 2015; Viengkham and Spehar, 2018) but have seldom been investigated in studies considering different presentation contexts and viewing behavior (eye movements).

The present study explores the viewing behavior of gallery visitors freely viewing paintings with a particular focus on how the aspects of viewing behavior, including viewing distance and eye gaze measures such as fixation count, total fixation duration and average fixation duration are affected by the artworks' physical characteristics including physical size and image statistics properties.

Physical Size

While the studies of visitor behavior in museums have acknowledged that larger artworks are generally more effective in attracting and holding attention (Bitgood, 1993; Bitgood et al., 2013), relatively few studies have systematically investigated the effect of physical size on aesthetic evaluation. One of the rare exceptions is a recent study by Seidel and Prinz (2018), who found that merely altering physical scale of a painting (small vs. large) influenced aesthetic judgment. Participants evaluated larger reproductions more postively, regardless of whether the painting was high in complexity (Picasso's *Three Musicians*) or low (Joan Miro's *Blue II*).

The physical size of artworks has also been found to affect viewing distance. Clarke et al. (1984) varied the size of projected art images and asked their participants to choose the distance from which either the artworks "look best" or felt the most comfortable. While there was considerable variability in the preferred viewing distance, all participants chose to view the larger artworks from a greater distance, regardless of instruction. Moreover, Clarke et al. also found that viewing time increased with the projection size but there was no effect of either stimulus size or viewing distance on ratings of how pleasant or interesting the artwork appeared. More recently, in a real art gallery setting, Carbon (2017) confirmed a high positive correlation between the artwork size and viewing distance: the larger the artwork, the greater the viewing distance observed.

Image Statistics

Despite the apparent heterogeneity and even randomness, artworks, like natural scenes, have characteristic, and regular structure related to the degree of spatial redundancy they exhibit. The spatial redundancy is related to the extent to which the surface properties at any locations can be predicted by the known values at nearby locations, and is intimately coupled with the notions of both spatial information and the scale-invariant, fractal-like properties of both artworks and natural scenes (Redies, 2007; Graham and Field, 2008; Mather, 2018). Here we use three widely-known indices of spatial redundancy: the Fourier spatial frequency amplitude spectrum ($1/f^a$), fractal dimension (FD), and Shannon Entropy (SE).

The Fourier Amplitude Spectrum

The Fourier amplitude spectrum measures the relative contribution of different spatial frequencies in an image as whole. In particular, the slope "alpha" of the $1/f^a$ amplitude spectrum quantifies contribution of coarse spatial structure (low spatial frequency) vs. fine spatial detail (high spatial frequency) in an image and has a value of approximately 1 for both natural scenes and artworks (Graham and Redies, 2010). This particular property of natural scenes and artworks is taken to reflect the scale-invariance of natural scenes, or the notion that approximately equivalent amount of spatial structure exists at different spatial scales. Images with high values of a contain a higher degree of similarity in luminance intensity across image regions and thus a higher degree of spatial redundancy and predictability of intensity variations across an image. Conversely, images with low values of a are associated with a higher degree of intensity variations and thus lower predictability of intensity variations across an image.

Fractal Dimension

The scale invariance of spatial patterns can also be expressed by a geometric scaling parameter known as the fractal dimension (FD) which can be used to describe and quantify patterns which exhibit self-similarity in geometrical-spatial structure at different levels of magnification (Mandelbrot, 1967). Fractal dimension (FD) measures the degree to which a pattern is broken up (or fractured) into a finer and finer spatial structure. Images containing coarse spatial structures with lack of fine spatial detail are associated with low FD values, whereas images with high levels of intricate and fine spatial detail would have high FD values. FD is inversely related to the slope a of the Fourier amplitude spectrum (higher a values are equivalent to low FD values and vice versa) and the relationship between them has been both established mathematically and validated empirically (Graham and Field, 2008; Forsythe et al., 2011; Spehar and Taylor, 2013; Bies et al., 2016).

Shannon Entropy (SE)

Shannon entropy (SE) measures the degree to which an image or a spatial form vary unpredictably, or randomly and is inversely related to the notion of spatial redundancy (Mather, 2018). Those images which vary highly unpredictably (or randomly) have a high SE value (or low redundancy), or conversely, images with similar intensity values across the spatial extent would have a low SE value (or high redundancy).

Our selection of these measures of statistical structure was motivated as follows. Firstly, these measures have been used to investigate and characterize the spatial structure of a wide range of different artworks with findings indicating a remarkable similarity in Fourier-based image statistics of artworks from different regions or time periods (Graham and Field, 2007, 2008; Redies, 2007; Graham and Redies, 2010). Most recently, a longitudinal statistical study by Mather (2018) showed that FD and SE remained relatively stable over a period of 500 years, from the 14th–19th century, with marked variations coinciding with the beginning of the Modern Art movement.

More importantly, all three measures exemplify the objective measures of complexity, a notion that belongs amongst the most influential in empirical aesthetics: from Fechner (1876) concept of the aesthetic middle to the Birkhoff (1933) definition of beauty as the ratio of an object's order (simplicity) and its complexity, and Berlyne (1971) modeling of the relationship between complexity and preference as an inverted U-shape. Our own work and that of others has established that variations in fractal dimension and/or Fourier amplitude spectrum characteristics are highly correlated with the perceived complexity of both synthetic and art images as well as preference for those images (Forsythe et al., 2011; Spehar et al., 2016; Viengkham and Spehar, 2018). However, there has been a relative paucity of investigations into the influence of image statistics properties on engagement with artworks in museum settings.

Painting Style

Artworks are often analyzed or classified as belonging to a particular style, typically based on a period, country, cultural group, or art movement. In addition to these predominantly art historical considerations, different art movements are often associated with distinctive visual qualities, which in turn can be associated with their physical features and statistical properties (Mather, 2018). Our study location, a single room in the 20th-century Australian Art section of the Art Gallery of New South Wales in Sydney afforded the opportunity to consider painting styles, non-Indigenous and Indigenous Australian, as an additional characteristic of interest to our study. However, we want to emphasize that these groupings are based on the available sample of artworks, and do not intend to suggest that either group is homogeneous in style or symbolism. For example the Indigenous grouping includes famous works from the Western and Central desert regions and styles and non-Indigenous includes figurative and abstract works. **Figures 1**, **2** show the artworks belonging to the non-Indigenous and Indigenous Australian artworks, respectively, with the details of these paintings displayed in **Table 1** (non-Indigenous artworks) and **Table 2** (Indigenous artworks).

Viewing Contexts

In addition to the AGNSW museum condition, the same artworks were viewed on computer monitors in our laboratory, either scaled to preserve their relative size or presented to fit most of the screen in order to assess the robustness of the effect of artworks' physical characteristics across different presentation contexts. The details of physical dimensions of both artworks and their digital reproductions are shown in the Method section.

Across the three presentation conditions (museum; on-screen relative size; and on-screen full size) we compare the average number of fixations (NF), average total fixation duration (TFD), and average fixation duration (AFD) with mixed effects ANOVA with the presentation condition as the between-subject and Paintings as the within-subject factor. In each presentation condition we also perform regression analyses with the average NF, TFD and AFD as dependent variables and the artwork physical size, Fourier amplitude spectrum and fractal dimension as predictors.

METHOD

Participants

In-Museum Condition

A total of nineteen AGNSW visitors (11 female) volunteered to participate in this study. All participants reported normal or corrected-to-normal vision. All participants were over 18. Eleven participants were Sydney residents, two were interstate visitors and six participants were international visitors. Sixteen out of 19 participants reported a university degree or postgraduate studies as their highest level of education. Participant recruitment and all other procedures for the in-museum study were approved by the University of New South Wales, Human Research Ethics Advisory Panel B- Arts, Humanities and Law (Approval No. HC180466).

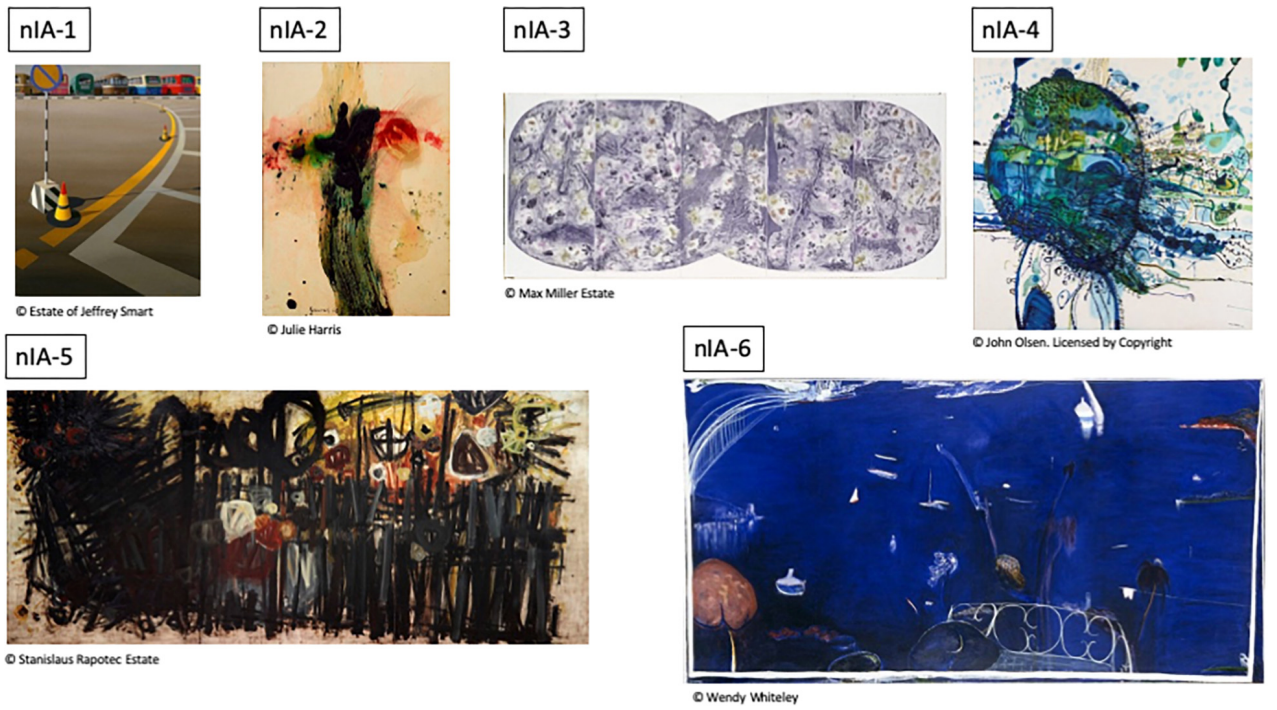

FIGURE 1 | Non-Indigenous Australian paintings used in this study. For detailed description of artworks see **Table 1**.

FIGURE 2 | Indigenous Australian paintings used in this study. For detailed description of artworks, see **Table 2**.

On-Screen Laboratory Conditions

Thirty-nine UNSW students (25 female) volunteered to participate through the UNSW online SONA system in exchange for course credit or a small monetary reward of AU$5). All subjects reported normal or corrected-to-normal vision and were over the age of 18. Participants were randomly assigned to either on-screen full size (22) or on-screen relative size (17) condition. Participant recruitment and all other procedures were approved by the University of New South Wales, Human Research Ethics Advisory Panel C- Psychology (Approval No. 3052).

TABLE 1 | Non-Indigenous paintings.

Non-indigenous australian	n-IA1	**Jeffrey Smart (Italy; Australia, b.1921, d.2013) *Bus terminus* (1973)** Synthetic polymer paint and oil on canvas, 92.0 × 81.0 cm stretcher; 109.0 × 90.4 × 4.4 cm frame Art Gallery of New South Wales; Bequest of Mrs. John Minter 1998 Photo: Brenton McGeachie, AGNSW, 251.1998 © Estate of Jeffrey Smart
	n-IA2	**Peter Upward (Australia, b.1932, d.1983) *Surry Hills Green* (1960)** Oil, synthetic polymer paint on hardboard, 162.2 × 120.5 cm Art Gallery of New South Wales; Purchased 1986; Photo: Jenni Carter, AGNSW 149.1986 © Julie Harris
	n-IA3	**Max Miller (Australia, b.1940) *Pure land — Henso* (1989)** Soft ground etching, aquatint, printed in blue, purple, brown and green ink from five zinc plates on five sheets of white wove paper, 99.6 × 249.5 cm Art Gallery of New South Wales; Purchased with funds provided by the Young Friends of the Art Gallery Society of NSW 1990; Photo: Ray Woodbury, AGNSW 25.1990.1.a-e © Max Miller Estate
	n-IA4	**John Olsen (Australia; England; Spain; Portugal, b.1928) *Five bells* (1963)** Oil on hardboard, 264.5 × 274 cm Art Gallery of New South Wales; Purchased with funds provided by the Art Gallery Society of NSW 1999; Photo: Mim Stirling, AGNSW 133.1999 © John Olsen. Licensed by Copyright Agency
	n-IA5	**Stanislaus Rapotec (b.1913, d.1997) *Meditating on Good Friday* (1961)** triptych: oil on board, 183 × 412 cm Art Gallery of New South Wales; Purchased with funds provided by the Gleeson O'Keefe Foundation 2016; Photo: Jenni Carter, AGNSW 427.2016.a-c © Stanislaus Rapotec Estate
	n-IA6	**Brett Whiteley (Australia; England, b.1939, d.1992) *The balcony 2* (1975)** Oil on canvas, 203.5 × 364.5 cm Art Gallery of New South Wales; Purchased 1981 Photo: Christopher Snee, AGNSW 116.1981 © Wendy Whiteley

The sample size in the two viewing conditions is quite small due to both convenience sampling and time limited chance to collect data. Nevertheless, in the museum condition the number of participants in our study is either comparable to or higher than in other eye tracking studies (Quiroga et al., 2011; Brieber et al., 2014; Walker et al., 2017). As such, we do recommend viewing the current findings as exploratory.

Materials and Stimuli

Study Location

The Australian Art gallery at the Art Gallery of New South Wales measures 9.5 × 27.3 m room and contains 15 paintings, as shown in **Figure 3**.

Paintings

The physical dimensions and image statistics of artworks are shown in **Table 3**.

Image Statistics

We note a high degree of variability in physical size and image statistic measures between individual paintings, both within and between the two painting style groups. The average image statistic values for the two groups are detailed and compared in **Table 4**. The difference in the average painting area between the non-Indigenous and Indigenous painting style groups was not statistically significant (t_{13} = 1.849, p = 0.087), nor was the difference in Shannon Entropy (t_{13} = −1.395, p-0.187). The two groups differed with respect to their average Fourier slope (t_{13} = 4.435, $p < 0.001$) and fractal dimension (t_{13} = −3.301, p-0.006) values. In particular, the Indigenous paintings have a lower average Fourier amplitude spectrum slope and higher average fractal dimension value, consistent with the high level of fine spatial detail (dots) in these artworks.

In **Figure 4**, we show the scatterplots between different image statistics measures for all paintings which show that the only significant negative correlation existed between the amplitude spectrum slope (a) and fractal dimension values (r = −0.841, $p < 0.001$). Importantly, there were no significant correlations between the painting area and image statistic measures.

Physical Size of Artworks in Different Viewing Contexts

Given the very large differences in the area of individual paintings [the area of the largest painting (IA9: 8.74 m^2) was approximately 65.5 times larger than the area of the smallest painting (IA1 = 0.13 m^2)], keeping the relative sizes in the on-screen condition true to the physical sizes would have been impossible as the smallest paintings would be virtually impossible to resolve.

The determinations of the relative size were constrained by the screen dimensions which were 55.7 cm × 31.3 cm or 46.4 deg × 27.1 deg of visual angle (VA), viewed at a distance of 65 cm. In

TABLE 2 | Indigenous paintings.

Indigenous australian	IA1	Papunya/Northern Territory/Australia **Timmy Payungka Tjapangati (Australia, b.circa 1940, d.2000) *Children's goanna dreaming* (1974)** Gouache and polyvinyl acetate on plywood, 45.2 × 29.5 cm Art Gallery of New South Wales; Purchased 1997; Photo: Ray Woodbury, AGNSW 267.1997 © Estate of artist licensed by Aboriginal Artists Agency Ltd.
	IA2	Yei Yei Bore/Papunya/Northern Territory/Australia **Unknown (Australia) *Dreaming journey* (1974)** Poster paint and PVA glue on three ply, 29.5 × 45.5 cm Art Gallery of New South Wales; Purchased 1997; Photo: Ray Woodbury, AGNSW 271.1997 © Licensed by Aboriginal Artists Agency Ltd.
	IA3	Papunya/Northern Territory/Australia **Uta Uta Tjangala (Australia, b.circa 1926, d.1990) *Untitled* (1972)** Synthetic polymer powder paint and natural earth pigments on hardboard, 62.6 × 50.7 cm Art Gallery of New South Wales; Purchased under the terms of the Florence Turner Blake Bequest and with funds provided by the Don Mitchell Bequest Fund 1999; Photo: Felicity Jenkins, AGNSW 138.1999 © Estate of artist licensed by Aboriginal Artists Agency Ltd. Unable to display image due to cultural restrictions.
	IA4	Yei Yei Bore/Papunya/Northern Territory/Australia **Charlie Tararu Tjungurrayi (Australia, b.circa 1921, d.1999) *Love story of a man and the moon* (1974)** Poster paint and PVA glue on threeply, 45.5 × 50.5 cm Art Gallery of New South Wales; Purchased 1997; Photo: Ray Woodbury, AGNSW 266.1997 © Estate of the artist. Licensed by Aboriginal Artists Agency Ltd.
	IA5	Yei Yei Bore/Papunya/Northern Territory/Australia **Charlie Tararu Tjungurrayi (Australia, b.circa 1921, d.1999) *Frog spirit dreaming* (1974)** Synthetic polymer paint and polyvinyl acetate on hardboard, 45.4 × 50.7 cm Art Gallery of New South Wales; Purchased 1997; Photo: Ray Woodbury, AGNSW 265.1997 © Estate of the artist. Licensed by Aboriginal Artists Agency Ltd.
	IA6	Yei Yei Bore/Papunya/Northern Territory/Australia **Unknown (Australia) *Dreaming journey west of Papunya* (1974)** Poster paint and PVA glue on three-ply, 45.5 × 51.5 cm Art Gallery of New South Wales Purchased 1997; Photo: Ray Woodbury, AGNSW 269.1997 © Licensed by Aboriginal Artists Agency Ltd
	IA7	Papunya/Northern Territory/Australia **Clifford Possum Tjapaltjarri (Australia, b. circa 1932, d.2002), Tim Leura Tjapaltjarri (Australia, b. circa 1929, d.1984) *Warlugulong* (1976)** Synthetic polymer paint on canvas, 168.5 × 170.5 cm Art Gallery of New South Wales Purchased 1981; Photo: Christopher Snee, AGNSW 321.1981 © Estate of the artists licensed by Aboriginal Artists Agency Ltd.
	IA8	Papunya/Northern Territory/Australia; Papunya Tula Movement **Dick Pantimus Tjupurrula (Australia, b.circa 1940, d.1983) *Water and wallaby dreaming* (1981)** Synthetic polymer paint on linen, 181.3 × 182.6 × 2 cm Art Gallery of New South Wales; Gift of the Art Gallery Society of NSW 1995; Photo: Christopher Snee, AGNSW 487.1995 © Estate of artist licensed by Aboriginal Artists Agency Ltd.
	IA9	Docker River/Northern Territory/Australia **Uta Uta Tjangala (Australia, b. circa 1926, d.1990) *Untitled (Jupiter Well to Tjukula)* (1979)** Synthetic polymer paint on linen canvas, 230 × 380 cm Art Gallery of New South Wales; Purchased with funds provided by the Art Gallery Society of NSW 2004; Photo: Mim Stirling, AGNSW 160.2004 © Estate of artist, licensed by Aboriginal Artists Agency Ltd.

order to ensure the relative visibility of the smallest painting, we have limited its size to 10.7 cm × 7 cm corresponding to the visual angle of 9.5 deg × 6.2 deg VA. The biggest paintings occupied most of the full-screen area and the remaining paintings were scaled relative to these two anchors. This ratio was approximately 17:1 in the relative size on-screen condition and 3:1 in the full-size on-screen condition.

We have provided these dimensions in both cm and deg or visual angle for each painting in **Table 3**. We have also provided scatterplots of each painting's width and height dimensions in all three conditions in **Figure 5**, top row. The bottom row plots these values in degrees of visual angle in all three viewing contexts. The visual angles for the museum condition were estimated based on the average mean distance measured for every painting.

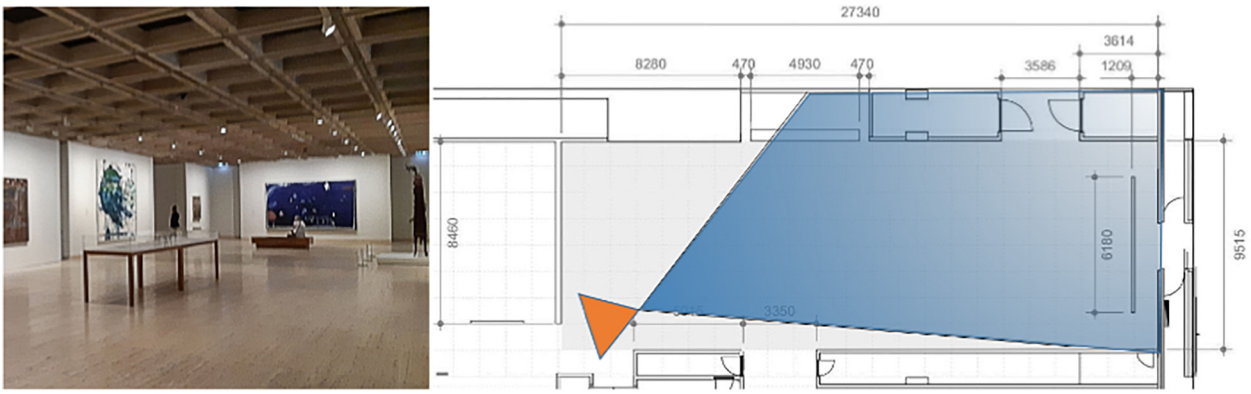

FIGURE 3 | The 20th Century Australian Art room at the Art Gallery of New South Wales: **(top)** photograph; plan indicating the field of the view of the photograph. Adapted from a plan supplied by AGNSW.

TABLE 3 | Physical dimensions and image statistic properties of artworks used in this study.

	ID	Size (cm)	Amplitude spectrum (α)	Fractal dimension	Entropy	Screen -equal size dimensions (cm) visual angle	Screen -relative size dimensions (cm) visual angle
Non-indigenous australian	NIA1	109 × 90.4	1.7	1.17	6.77	*31.2× 25.9*	*15.4× 12.8*
						27.1 × 22.7	13.6 × 11.3
	NIA2	162.2 × 120.5	1.37	1.28	7.32	*31.2× 23.2*	19.1 × 14.2
						27.1 × 20.4	16.8 × 12.5
	NIA3	106.3 × 253.8	1.2	1.45	7.26	23.5 × 55.4	12.5 × 29.6
						20.5 × 46.4	11.1 × 25.8
	NIA4	265.74 × 274	1.14	1.36	7.64	31.2 × 32.1	31.2 × 32.1
						27.1 × 27.9	27.1 × 27.9
	NIA5	183 × 412	1.28	1.33	7.15	24.4 × 55.4	21.6 × 49
						21.4 × 46.4	18.9 × 41.5
	NIA6	210.9 × 372.2	1.13	1.39	5.63	31 × 54.7	24.9 × 43.9
						26.9 × 45.8	21.7 × 37.5
Indigenous australian	IA1	45.2 × 29.5	0.89	1.65	7.47	31.2 × 20.4	10.7 × 7.0
						27.1 × 17.9	9.4 × 6.2
	IA2	45.5 × 29.5	0.98	1.44	7.2	31.2 × 20.2	10.7 × 6.9
						27.1 × 17.8	9.5 × 6.2
	IA3	62.1 × 36.8	1.1	1.43	7.3	31.2 × 18.5	14.6 × 8.7
						27.1 × 16.3	12.9 × 7.7
	IA4	45.4 × 50.5	0.97	1.49	7.32	31.2 × 34.7	10.7 × 11.9
						27.1 × 30.1	9.5 × 10.5
	IA5	45.5 × 50.5	1.08	1.43	7.1	31.2 × 34.6	10.7 × 11.9
						27.1 × 30.0	9.4 × 10.6
	IA6	45.5 × 51.5	0.91	1.38	7.19	31.2 × 35.5	10.7 × 12.2
						27.1 × 30.7	9.5 × 10.8
	IA7	168.5 × 170.5	0.85	1.73	7.17	31.2 × 31.6	19.9 × 20.1
						27.1 × 27.4	17.4 × 17.7
	IA8	181.3 × 182.6	0.91	1.69	7.74	31.2 × 31.4	21.4 × 21.6
						27.1 × 27.3	18.7 × 19.0
	IA9	230.0 × 380.0	0.9	1.58	7.25	31.2 × 51.5	27.1 × 44.8
						27.1 × 43.3	23.6 × 38.2

TABLE 4 | Average image characteristics of Indigenous and non-Indigenous paintings used in this study.

		Non-indigenous paintings	Indigenous paintings	Student's *t*-test
Area (m^2)	Mean	4.71	1.79	$t_{13} = 1.849$, $p = 0.087$
	Median	4.97	0.23	
	SD	3.16	2.89	
Fourier slope (α)	Mean	1.303	0.954	$t_{13} = 4.435$, $p < 0.001$
	Median	1.240	0.910	
	SD	0.214	0.087	
Fractal dimension (D)	Mean	1.330	1.536	$t_{13} = -3.301$, $p = 0.006$
	Median	1.345	1.490	
	SD	0.097	0.130	
Shannon entropy (SE)	Mean	6.962	7.304	$t_{13} = -1.395$, $p = 0.187$
	Median	7.205	7.250	
	SD	0.710	0.195	

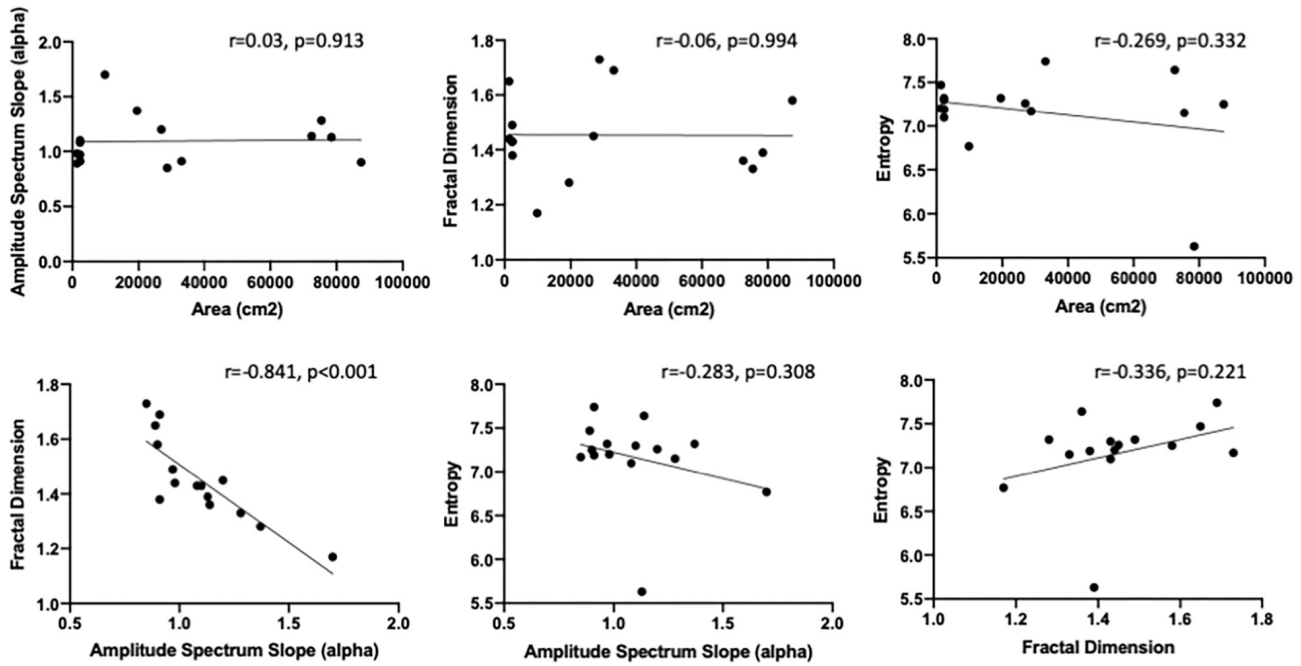

FIGURE 4 | Scatterplots between different image statistics for the 15 paintings used in this study: **(top row)** Painting area vs. Amplitude spectrum slope **(left panel)**, Fractal dimension **(middle panel)** and Shannon entropy **(right panel)**; **(bottom row)** Amplitude spectrum slope vs. fractal dimension **(left panel)**, and Shannon entropy **(middle panel)**, Fractal dimension vs. Shannon entropy **(right panel)**.

Eye-Tracking Hardware and Software

In Museum Condition

A Tobii Pro Glasses 2 mobile eye-tracking system was used to record eye gaze while participants freely explored the gallery room. Gaze behavior was sampled with a frequency of 100 Hz by four cameras (two for each eye). The viewed scene was captured with an extra camera with a visual angle of 82° × 52°. The recorded data were captured and stored via the Tobii Pro Glasses Controller software. For the detailed data analysis, the data were exported to the Tobii Pro Lab Analyser software with integrated Real-World Mapping tool, which scans scene camera video recordings to identify defined areas of interest (AOI) from different perspective angles. Consequently, all fixations allocated in the AOI are aggregated allowing us to extract the following metrics: Number of Fixations (NF), Total Fixation Duration (TFD) and Average Fixation Duration (AFD).

With the Tobii Pro Glasses 2 system eye position (x, y) and gaze vectors (z) are calculated from the eye images using a 3D eye model that gives positions and angles in a coordinate system with its origin in the center of the scene camera. The gaze point is calculated as the vergence point between the two gaze vectors for the left and the right eye. The vergence point indicates how far away the user is looking: the error in estimated distance is small at short distances and increases with distance. We are aware that this is a crude estimate of the distance and in our calculations have eliminated z-values greater than 7 m. In addition, for each

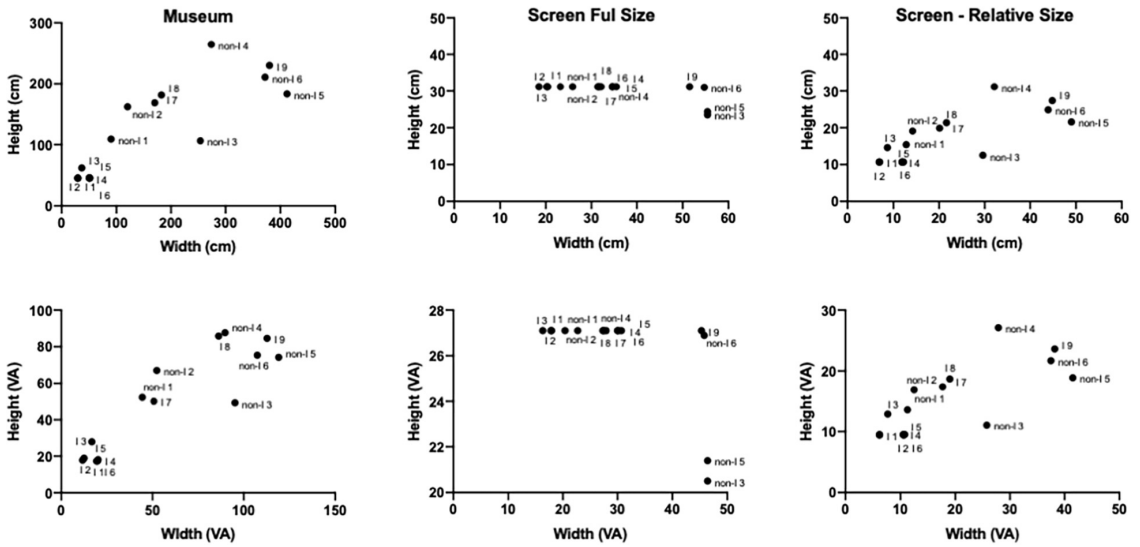

FIGURE 5 | Scatterplots of width and height dimensions in cm **(top row)** and degrees of visual angle **(bottom row)** of paintings in all three conditions. The visual angles in the museum condition were calculated based on the average mean distance estimates for every painting.

participant and each painting we calculated different measures of central tendency (mean, mode, and median) in order to be able to rely on a multiple types of viewing distance estimates. We are aware that these estimates are affected by a number of extraneous factors (head orientation, height, etc.) but still considered it useful to use these estimates as a pilot set of measurements.

Laboratory On-Screen Conditions

In the two on-screen conditions a Tobii TX300 desk top system was used to record eye gaze in the two on-screen conditions. The stimulus presentation and data analysis were done with the Tobii Studio software to extract the same metrics as was done in the in-museum condition.

Procedure

In Museum

AGNSW visitors were recruited in the foyer of the museum. After providing informed consent, participants were fitted with the Tobii Pro Glasses 2 at a research table in the same location. A calibration procedure was performed in order to ensure accuracy of eye movements recording. Participants were then invited to "visit that room [*pointing out the 20th− century Australian Art room, the entrance to which was visible about 25 metres away*] and look at the paintings as you would normally do. Take as long as you wish. When you finish, please come back to us." In order to preserve the museum condition as natural as possible, the experimenter was not present in the exhibition room. For the same reason, there were no attempts to control the crowd density in the exhibition room.

Laboratory On-Screen Conditions

The laboratory conditions were conducted in the School of Psychology at UNSW. All participants in the laboratory on-screen condition volunteered to participate through the UNSW SONA system in exchange for course credit, or a small monetary reward ($5). All participants read the subject information sheet and signed the informed consent form before starting the experimental session. They were seated with their chins placed on a rest to avoid abrupt head movements. The chin-rest was positioned 65 cm in front of the screen. The experimental session started with a 9-point target calibration procedure followed by the two practice art images (the *Mona Lisa* and Van Gogh's *Starry Night*) to experience the self-paced nature of the experiment. Later, instructions appeared on the screen which informed participants that they would be shown a series of 15 paintings which they could view at their own pace without any time constraints and that they should press the spacebar to go to the next painting. The digital reproductions of the 15 paintings from the museum condition were then presented in random order.

RESULTS

Museum Condition

Total Visit Duration

For the in-museum condition we firstly determined the Room Visit Duration (RVD), defined as the period of time between crossing the threshold to enter the room and crossing it again to leave. Five out of 19 participants left the exhibition room to visit other rooms and then returned to it. Multiple visits were included in calculation of total visit duration. The shortest visit lasted 120 s, the longest 1284 s (2 and 21.4 min). On average, participants spent 521 s (8.68 min) in the room (SD = 257 s), with a median of 412 s (6.87 min). On average, 84.5% of the total visit duration was spent viewing paintings (48.7%) and reading labels (35.8%). Participants in our sample also spent, on average, 4.8 % of their total visit time looking at their mobile phones and 2% of the total visit time looking at other people.

Number of Visited Paintings

Eleven out of 19 participants (57.9%) looked at all 15 paintings, with four participants (21.1%) and three participants (10.5%) looking at fourteen and thirteen paintings, respectively. One participant (5%) only looked at ten paintings. On average, there was no difference in the average proportion of participants who viewed the paintings between the two painting style groups: the Indigenous Australian paintings were viewed on average by 94% of participants (SD = 7%) while the non-Indigenous Australian paintings were viewed on average by 95% of participants (SD = 5%).

Across all paintings there was a significant correlation between the average proportion of participants who viewed the painting and the painting physical size (r = 0.568, p = 0.0271, 95% CI 0.079–0.837) but this relationship was more pronounced for the contemporary non-Indigenous (r = 0.808, p = 0.051, 95% CI −0.0106–0.978) than for the indigenous paintings (r = 0.537, p = 0.136, 95% CI −0.197–0.885). There were no significant correlations between the average proportion of participants who viewed the paintings and their image statistics measures.

Viewing Distance

For each painting, the viewing distance was estimated by tracking the combined z-coordinate of gaze position for each fixation in the scene camera coordinate system. These fixation-based gaze positions were aggregated for all paintings and all participants with the mean, median and mode extracted as the complementary measures of central tendency for further analysis.

The average mean viewing distance across all paintings was 1.37 m (SD = 0.195), ranging from 0.97 to 1.8 m. The average median viewing distance across all paintings was 1.09 m (SD = 0.199), ranging from 0.71 to 1.57 m. Finally, the average mode distance equaled 1.03 m (SD = 0.234), ranging from 0.77 to 1.43 m. When the results were split according to the painting style, both the average mean, and median viewing distances for the non-Indigenous paintings were shorter than those for the Indigenous paintings. The mean and median viewing distances for the non-Indigenous paintings were 1.241 and 0.957 m, respectively, while the corresponding distances for the Indigenous paintings were 1.4 and 1.178 m, respectively. The paired samples t-test revealed a statistically significant difference in the average median distance between the two conditions (t_{18} = −2.276, p = 0.035, Cohen's d = −0.522), while the difference between the average mean distances did not reach statistical significance (t_{18} = 1.907, p = 0.07, Cohen's d = −0.437).

Figure 6 shows the average mean, median and mode distances for every painting plotted as a function of the painting area for all paintings together (left panel) and separately for the two painting styles, the non-Indigenous (middle panel) and Indigenous (right panel). For each painting, the mean, median and mode viewing distances were estimated for every observer. These three individual estimates of central tendency were averaged for each painting and the means with the standard error of the means are shown in **Figure 6**. When all paintings are considered together, the correlations between the painting area and mean, median and mode viewing distances are non-significant ($r_{\text{mean distance}}$ = −0.199, p = 0.477; $r_{\text{median distance}}$ = −0.351, p = 0.200 and $r_{\text{mode distance}}$ = 0.092, p = 0.742). When the non-Indigenous paintings are considered separately, the pairwise correlations all become positive but fail to reach significance due to low power ($r_{\text{mean distance}}$ = 0.783, p = 0.066; $r_{\text{median distance}}$ = 0.553, p = 0.255 and $r_{\text{mode distance}}$ = 0.606, p = 0.204). With the Indigenous paintings, the correlations between the painting area and mean, median and mode distances become negative, though also non-significant ($r_{\text{mean distance}}$ = −0.282, p = 0.463; $r_{\text{median distance}}$ = −0.276, p = 0.472 and $r_{\text{mode distance}}$ = −0.268, p = 0.485).

The two image statistics measures correlated significantly with the viewing distance: Shannon Entropy was negatively correlated with all measures of viewing distance with Indigenous paintings ($r_{\text{mean distance}}$ = −0.798, p = 0.010; $r_{\text{median distance}}$ = −0.738, p = 0.023 and $r_{\text{mode distance}}$ = −0.691, p = 0.039). In addition, across all paintings, the amplitude spectrum slope was also negatively correlated with the average median viewing distance ($r_{\text{median distance}}$ = −0.524, p = 0.045).

In summary, while our measures of viewing distance are arguably noisy, our findings suggest the strong mediating role of the painting style, with the pattern of results obtained for the non-Indigenous paintings similar to that reported by Carbon (2017). The significant negative correlation between the amplitude spectrum slope and mean viewing distance across all paintings seem to suggest that the participants tend to move away from the patterns that have greater presence of high spatial frequency information and/or greater degree of spatial variegation. The negative correlation between Shannon entropy and viewing distance for the Indigenous paintings may be related to the relationship between "amount of information" and visual

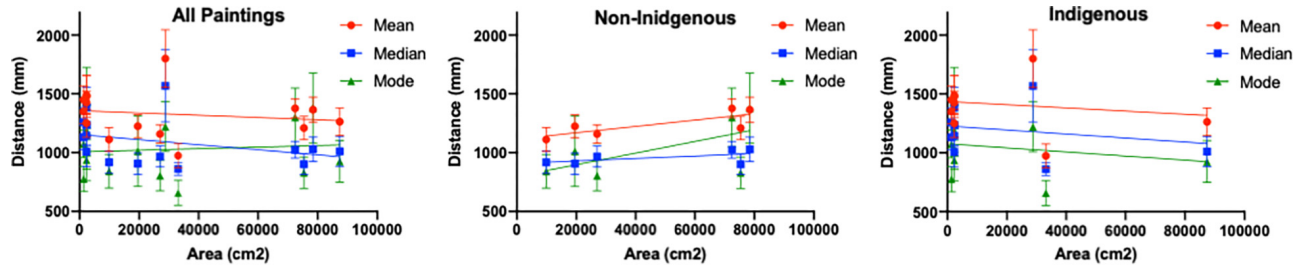

FIGURE 6 | The average mean, median and mode viewing distance as a function of painting area. The error bars represent SEM.

interest, however, in the absence of any direct psycho-physical measures of the components of aesthetic experience (such as visual interest), this assertion remains speculative.

Analysis of Gaze Metrics in the Museum

For each participant we determined the total number of fixations (NF), total duration of fixations (TFD) and average fixation duration for each painting viewed. These data are shown per painting for the three gaze pattern metrics in **Figure 7**. Each symbol represents one participant's data for a given painting. The data corresponding to the non-Indigenous and Indigenous paintings are shown in blue and orange colors, respectively (successive paintings in each category are ordered by the area from the smallest to the largest).

On average, participants made 44.24 fixations per painting (median = 42.9; *SD* = 21.07), with an average total fixation duration of 12.44 s (median = 11.24; *SD* = 7.42), and an average length of 0.270 ms (median = 0.254; *SD* = 0.005). To test whether there were statistically significant differences in the gaze measures between different paintings we performed separate mixed-effect models (REML) with Paintings (15 levels) as a repeated measures factor. These analyses revealed significant main effect of Paintings for the number of fixations [$F_{(4.87,\ 82.13)} = 9.371$, $p < 0.001$], the total fixation duration [$F_{(4.37,\ 73.68} = 6.200$, $p < 0.001$], as well as the average fixation duration [$F_{(4.97,\ 83.77} = 3.207$, $p = 0.011$]. To explore whether there was a systematic difference in the three eye gaze measures across the two painting style categories, we averaged these metrics across all non-Indigenous and Indigenous paintings, respectively. Paired t-tests revealed significant difference in the number of fixations ($t_{18} = 3.074$, $p = 0.006$) and the total fixation duration (TFD) ($t_{18} = 2.263$, $p = 0.036$) between the two groups of paintings: the non-Indigenous artworks received higher number of fixations (59.18) with longer total fixation durations (16.22 s) compared with Indigenous artworks (33.14 fixations and 9.557 fixation duration). The difference in the average fixation duration (AFD) between the two groups was not significant ($t_{18} = 1.065$, $p = 0.309$).

It is likely that these differences are related to the aforementioned general relationship between the painting size and the proportion of visitors. It seems that not only are the smaller paintings less likely to be visited at all, but, even when they are, they receive fewer fixations and are not looked at for as long as the larger paintings.

Image Statistics as Predictors of Eye Gaze Behavior

To examine the extent to which image statistics measures can be used to predict variance in eye gaze measures we performed three separate multiple regression analyses (enter method) with the number of fixations, total fixation duration and average fixation duration as dependant variables with the area, amplitude spectrum slope, fractal dimension and Shannon entropy as predictors in each case. These analyses show that the area ($\beta = 0.799$, $t = 7.025$, $p < 0.001$), fractal dimension ($\beta = 0.643$, $t = 3.11$, $p < 0.011$) and amplitude spectrum slope ($\beta = 0.556$, $t = 2.752$, $p < 0.020$) were significant predictors of number of fixations [$F_{(4,\ 10)} = 18.556$, $p < 0.001$]. The same was the case for the total fixation duration [$F_{(4,\ 10)} = 13.638$, $p < 0.001$] with the area ($\beta = 0.762$, $t = 5.860$, $p < 0.001$), fractal dimension ($\beta = 0.667$, $t = 2.83$, $p < 0.018$) and amplitude spectrum slope ($\beta = 0.548$, $t = 2.376$, $p < 0.039$) as significant predictors. None of the image statistics measures were significant predictors of the average fixation duration [$F_{(4,\ 10)} = 0.858$, $p = 0.521$].

Laboratory Conditions

Analysis of Gaze Metrics in the Museum

As with the gaze data in the museum condition, the total number of fixation (NF; left panels), total duration of fixations (TFD; middle panels) and average fixation duration (AFD, right panels) for each painting are shown in **Figure 8**. The top row shows the data from the full-screen condition in which the longest dimension for each painting (either horizontal or vertical) was made to till the screen while the bottom row shows the data from the relative-screen condition in which the relative size differences were preserved between the paintings. Each symbol represents data from one participant and the data corresponding to the non-Indigenous and Indigenous paintings are shown in blue and orange colors, respectively (successive paintings in each category are ordered by area from the smallest to the largest). In order to test whether there were significant differences in three gaze metrics between the two on-screen presentation conditions we performed two way mixed-effect models (REML) with paintings (15 levels) as within and on-screen presentation condition (full-size vs. relative-size) as between subject factors, respectively.

Number of fixations.

The mean number of fixations per painting was 49.9 in the full-screen condition, compared to the mean of 27.03 for the relative size condition. The two-way mixed-effect model (REML) revealed the significant main effect of paintings [$F_{(6.235,230.7)} = 5.856$, $p < 0.001$] and the significant paintings x on-screen presentation condition interaction [$F_{(14,518)} = 2.375$, $p = 0.003$]. However, the main effect of on-screen presentation condition was not significant [$F_{(1,37)} = 2.985$, $p = 0.0924$].

Total fixation duration.

The mean fixation duration per painting was 13.39 s in the Full-screen condition, compared to the mean of 7.44 s for the relative size condition. The two-way mixed-effect model (REML) revealed the significant main effect of paintings [$F_{(7.043,260.6)} = 5.018$, $p < 0.001$]. The main effect of on-screen presentation condition was not significant [$F_{(1,37)} = 2.947$, $p = 0.0944$], nor was the paintings' x on-screen presentation condition interaction [$F_{(14,518)} = 1.599$, $p = 0.0751$].

Average fixation duration.

The mean fixation duration per painting was 0.273 s in the full-screen condition, compared to the mean of 0.296 s for the relative size condition. The two-way mixed-effect model (REML) revealed the significant main effect of paintings [$F_{(3.585,\ 132.4)} = 3.712$, $p < 0.009$], as well as the significant paintings x on-screen presentation condition interaction [$F_{(14,517)} = 2.567$, $p = 0.0014$]. The main effect of on-screen presentation condition was not significant [$F_{(1,37)} = 1.533$, $p = 0.223$].

Image Statistics as Predictors of eye Gaze Metrics

As for the in-museum condition, in order to examine whether the image statistics measures can be used to predict variance in eye gaze metrics we performed three separate multiple regressions (enter method) with the area, amplitude spectrum slope, fractal dimension and Shannon entropy as predictors.

Full-size on-screen presentation condition.

Even though there were no major changes in the area, or the visual angle subtended by different paintings in this condition, the area was kept as one of the predictors to keep the parameters of regression analyses comparable across different presentation conditions. The results show that none of the image statistics measures were significant predictors of the average number of fixations [$F_{(4,\ 10)} = 1.212$, p = 0.365) and the same was observed for the total fixation duration [$F_{(4,\ 10)} = 3.309$, $p = 0.057$]. However, the Shannon Entropy (b = −0.861, $t = -5.589$, $p < 0.001$) was the significant predictor of the average fixation duration [$F_{4,\ 10)} = 18.556$, $p < 0.001$]. The same was the case for the total fixation duration [$F_{(4,\ 10)} = 10.413$, $p < 0.001$]. Negative standardized b coefficient suggests that the average fixation length was shorter for the paintings with higher entropy values.

Relative-size on-screen presentation condition.

The results show that none of the image statistics measures were significant predictors for the number of fixations [$F_{(4,\ 10)} = 2.430$, $p < 0.116$], fixation duration [$F_{(4,\ 10)} = 1.171$, $p = 0.380$], or average fixation length [$F_{(4,\ 10)} = 2.193$, $p = 0.143$].

Comparison Between Museum and On-Screen Conditions

To compare the gaze metrics between all three presentation conditions we performed two-way mixed-effect ANOVA with painting style (non-Indigenous, Indigenous) as a repeated measures and presentation condition (museum; screen, full size; screen, relative size) as a between-subject factor. The mean number of fixations, total fixation duration and average fixation length for each presentation condition and the painting style groups are depicted in **Figure 9**.

Number of Fixations

The main effect of presentation condition did not reach significance [$F_{(2,\ 55)} = 2.080$, $p = 0.1347$], but the interaction between the presentation condition and painting style was significant [$F_{2,\ 55)} = 8.358$, $p < 0.001$]. The main effect of painting style was also significant [$F_{1,\ 55)} = 10.35$, $p = 0.002$]. The significant interaction indicates that the difference in number of fixations for the two painting styles was pronounced only in the museum condition.

Total Fixation Duration

The main effects of presentation condition [$F_{(2,\ 55)} = 1.927$, $p = 0.1553$] and painting style [$F_{(1,\ 55)} = 3.924$, $p < 0.053$] did not reach significance, but the interaction between the presentation condition and painting style was significant [$F_{(2,\ 55)} = 5.532$, $p = 0.006$]. Analogous to the pattern with number of fixations, the difference in the total fixation duration for the two painting styles was visible only in the museum condition.

Average Fixation Duration

The main effect of painting style was significant [$F_{(1,\ 55)} = 9.125$, $p < 0.004$] such that overall the average fixation duration for the Indigenous paintings was longer than for the non-Indigenous paintings. This trend seems to be more pronounced in the museum and in the on-screen relative size conditions, but the interaction between painting style and presentation condition was not significant [$F_{(2,\ 55)} = 0.349$, $p = 0.707$]. The main effect of presentation condition was not significant [$F_{(2,\ 55)} = 1.237$, $p < 0.298$].

Fixations Location Heatmaps for Artworks in Different Viewing Contexts

In order to provide further qualitative and quantitative insights in viewing behavior across the three different contexts used in our study, we have generated heatmaps of total fixations for each artwork in each condition. They are summarized for the non-Indigenous and some of the Indigenous paintings in **Figures 10**, **11**, respectively. The bigger and

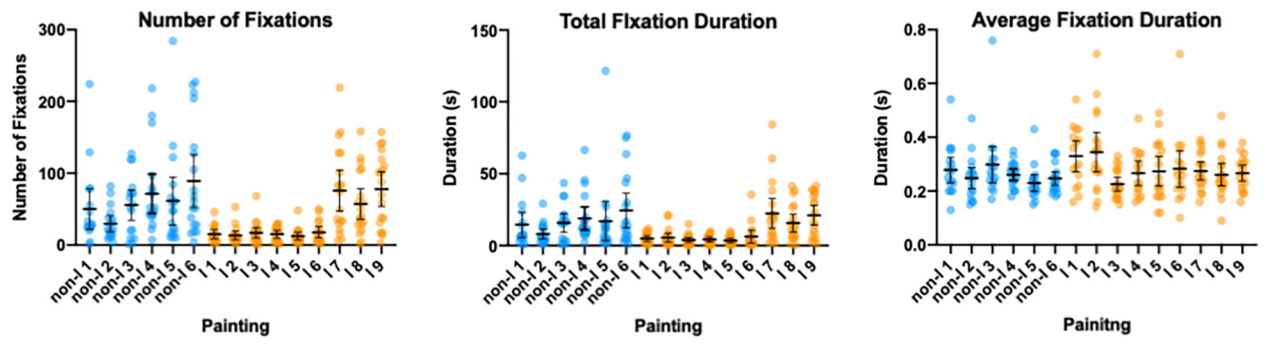

FIGURE 7 | Number of fixations **(left panel)**, total fixation duration **(middle panel)** and average fixation duration **(left panel)** shown per each painting. Each dot represents data from one participant with the mean with 95%CI for each painting superimposed in black color. The data corresponding to the non-Indigenous and Indigenous paintings shown in blue and orange color, respectively. The paintings in each group are ordered from the smallest to the largest in area for that group. The error bars represent 95% CI.

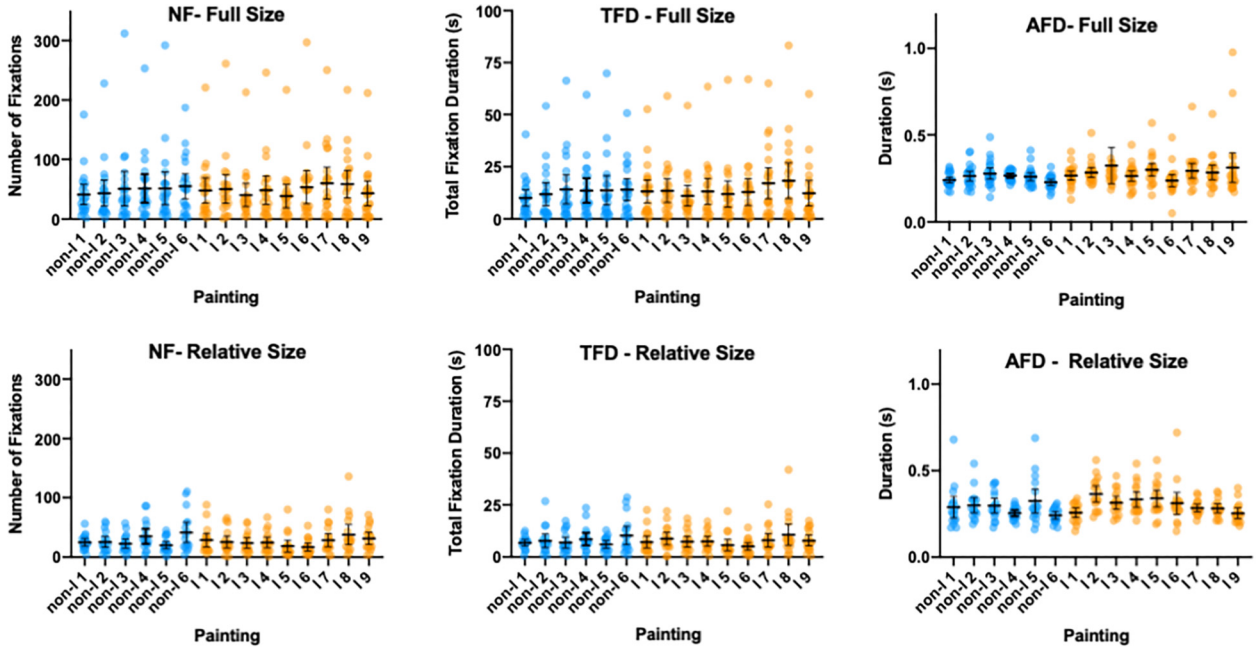

FIGURE 8 | Number of fixations **(left panels)**; total fixation duration **(middle panels)**; and average fixation duration **(left panels)** shown for each painting in the full-size screen condition **(top row)** and the relative size screen condition **(bottom row)**. Each dot represents data from one participant with the mean with 95% CI for each painting superimposed in black color. The data corresponding to the non-Indigenous and Indigenous paintings shown in blue and orange color, respectively. The paintings in each group are ordered from the smallest to the largest in area for that group. The error bars represent 95% CI.

higher quality heatmaps for each painting can be found in **Supplementary Materials**.

To provide a low-level visual baseline we computed an objective, visual saliency map of each image using the Graph-Based Visual Saliency method (Harel et al., 2007) which are shown in **Figures 12**, **13**. They are computer-generated saliency analyses of the original images' low-level visual features (e.g., luminance, color, orientation, contrast, edge, etc.) represented as a heat map, the warmest color indicating the areas of highest image-based saliency. For most, if not all of the images, they seem in a good agreement with the fixation heatmaps though we do not have any quantitative measures of comparison.

Though differing in the overall number of fixations, the spatial layout of fixated locations is remarkably similar across the three different contexts in which the artworks were viewed from different distances, for different durations, at different visual angles and in different mediums. This similarity is consistent with the two-stage model proposed by Locher (1996) according to which, exploration of a painting starts with a rapid global survey of the pictorial field to acquire an initial structural gist of the composition,

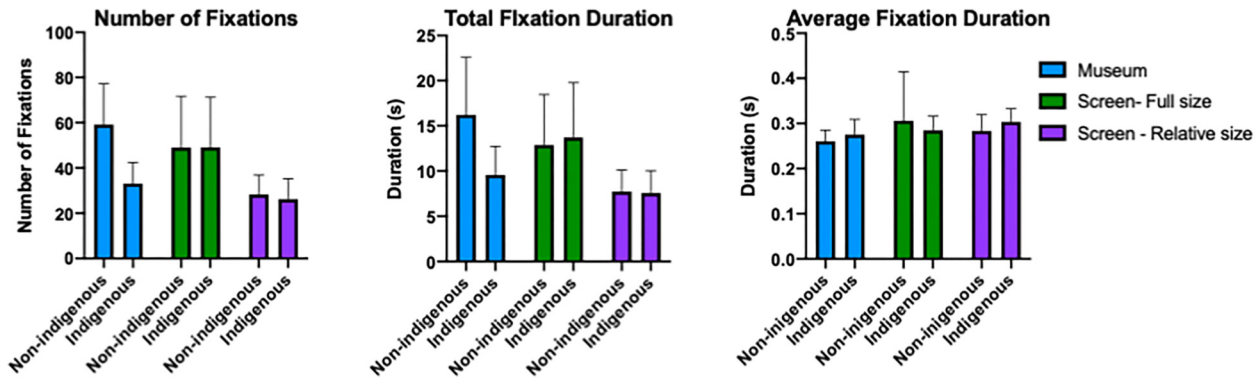

FIGURE 9 | Mean number of fixations, total fixation duration and average fixation length for Indigenous and non-Indigenous paintings in the three presentation conditions (museum; screen, full size; screen, relative size). The error bars represent 95% CI.

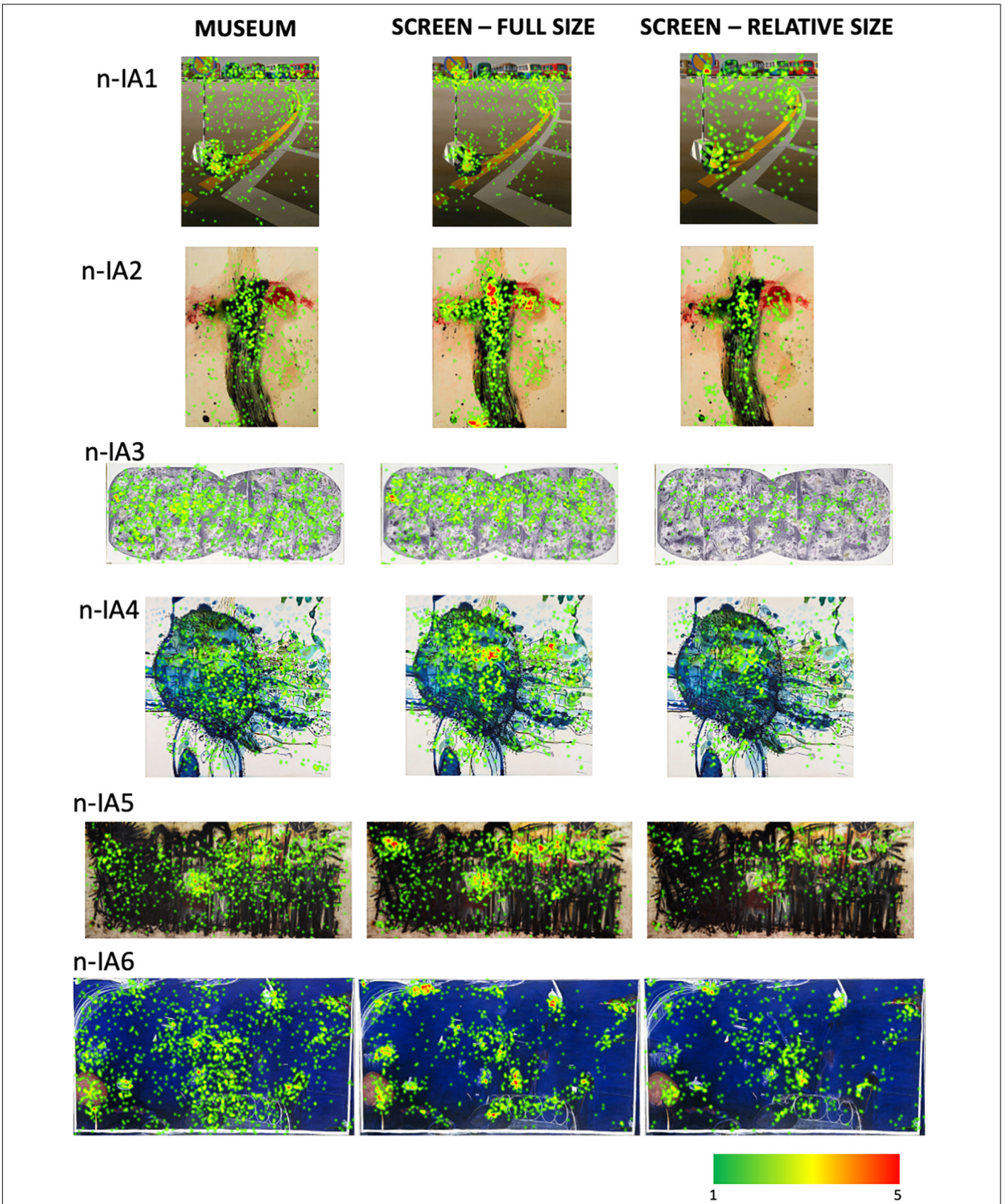

FIGURE 10 | The heatmaps of total fixation counts for the non-Indigenous Australian paintings in the three viewing conditions. See **Supplementary Material** for bigger, higher-quality versions of these heatmaps.

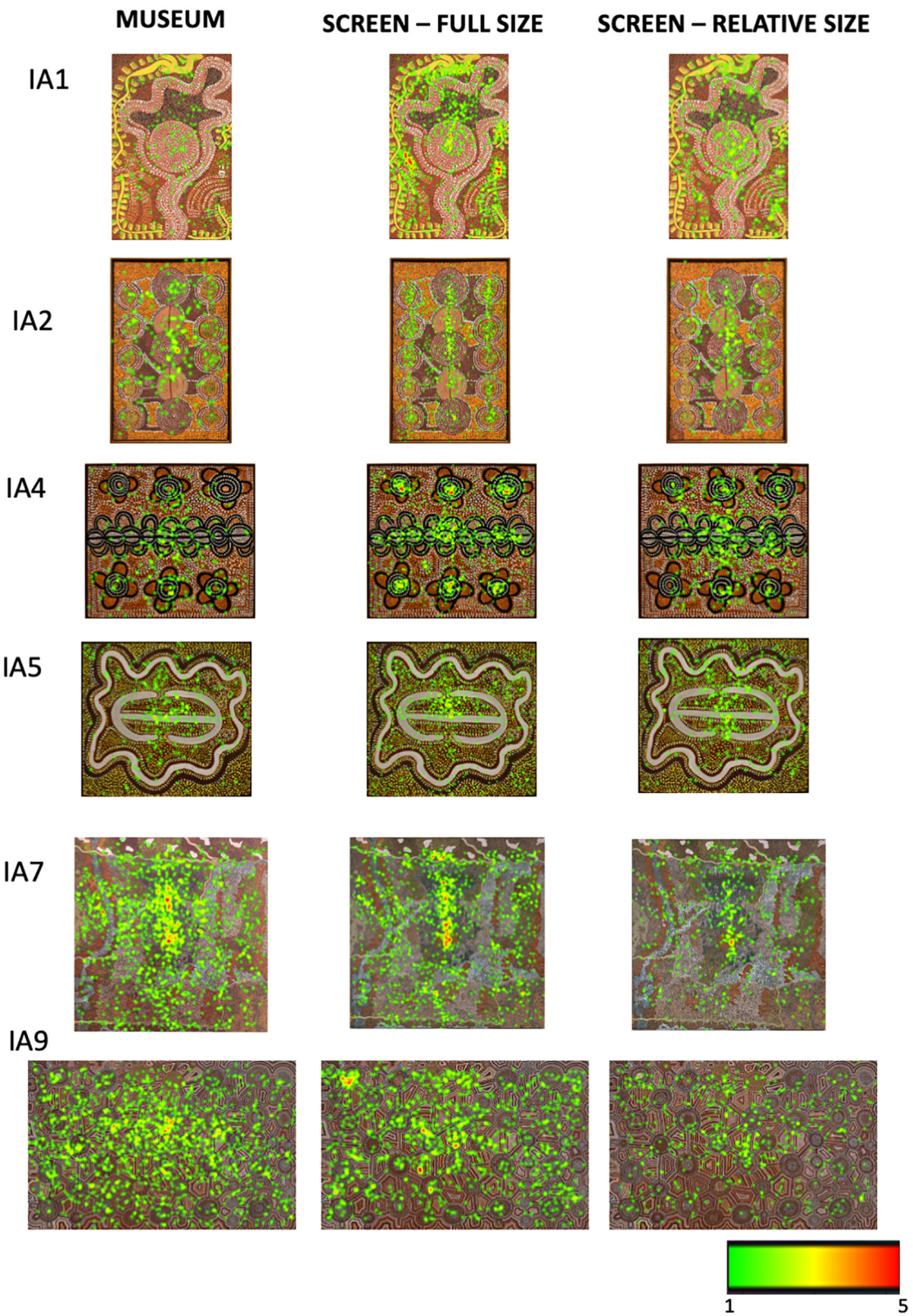

FIGURE 11 | The heatmaps of total fixation counts for some of the Indigenous Australian paintings in the three viewing conditions. See **Supplementary Material** for the heatmaps for all Indigenous Australian paintings.

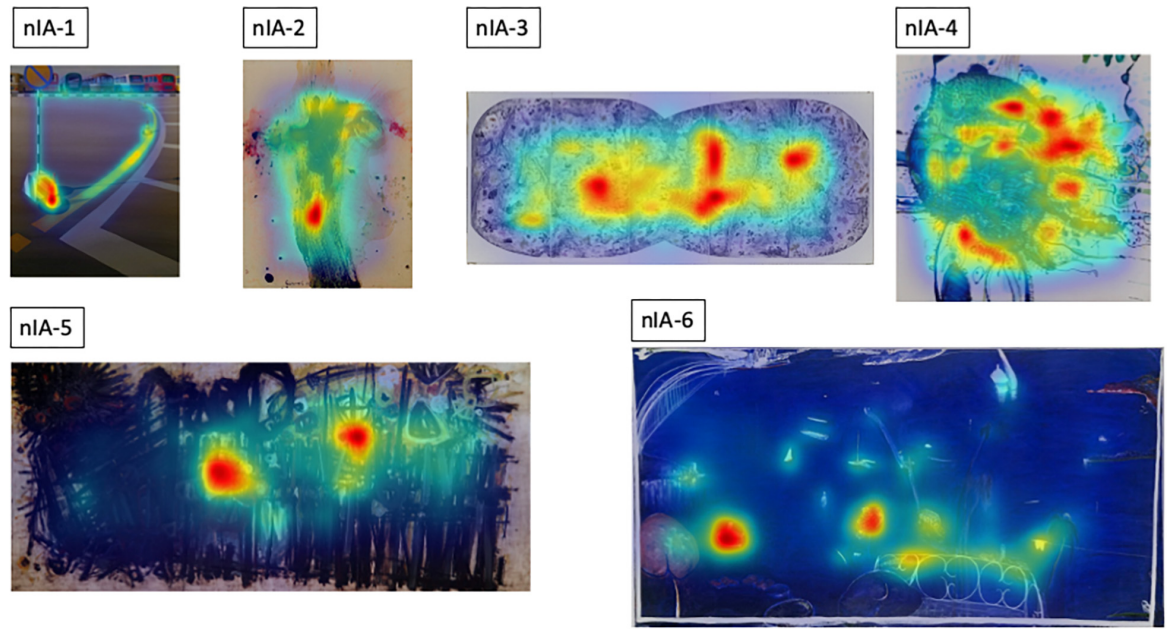

FIGURE 12 | Graph-based Visual Saliency maps (Harel et al., 2007) for the non-Indigenous Australian paintings.

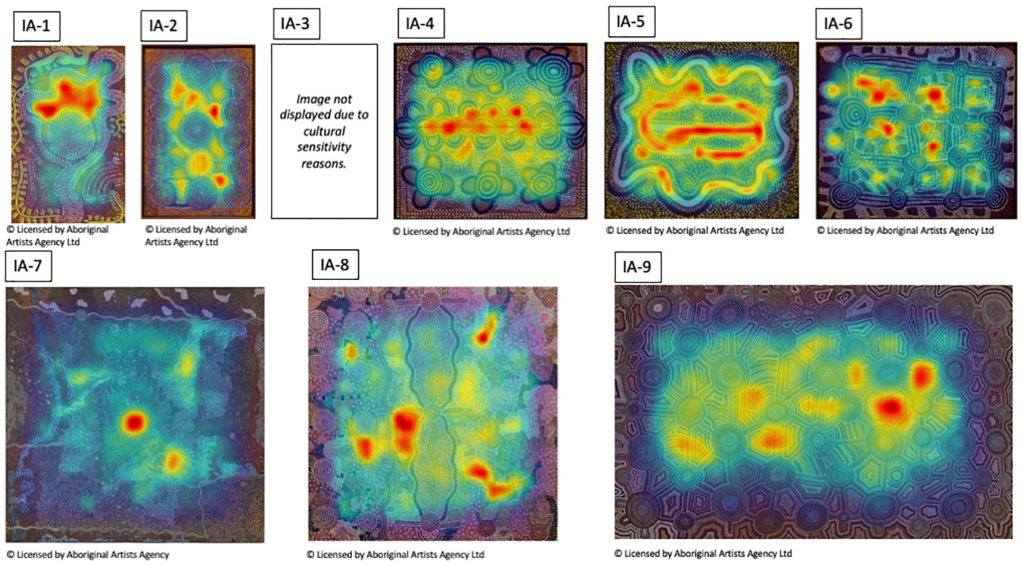

FIGURE 13 | Graph-based Visual Saliency maps (Harel et al., 2007) for the Indigenous Australian paintings.

followed by the second phase of visual scrutiny of interesting pictorial features.

Interindividual Similarity in Viewing of Artworks in Three Conditions

used a ScanMatch MatLab toolbox (Cristino et al., 2010) to quantify the similarity in fixation sequences between different participants in each viewing condition. In ScanMatch the individual fixation sequences are spatially and temporally binned to create a sequence of letters that retains fixation location, time and order information. The algorithm then uses the Needleman-Wunsch sequence alignment procedure to compare the coded sequences and, based on the inverse Euclidian distance of each fixations pair, calculates a similarity score (0–1). For each painting, we calculated similarity scores for all pairwise combinations between participants who viewed the painting in each of the three conditions. Based on the pairwise similarity scores for all possible pairings between participants, we calculated an average similarity score for each painting in three conditions.

DISCUSSION

In this study we investigated the viewing behavior of visitors (N = 19) freely viewing 15 paintings in a room containing 20th-century Australian artworks at the Art Gallery of New South Wales. We examined how aspects of viewing behavior including viewing distance in the gallery condition and eye gaze measures such as fixation count, total fixation duration and average fixation duration are affected by the artworks' physical characteristics of size and image statistics properties such as Fourier amplitude spectrum, fractal dimension and entropy. Given the diversity of artworks in the collection, we have also considered the painting style, Indigenous Australian vs. non-Indigenous Australian as an additional characteristic of interest in our study.

On average, the participants spent 8.68 min in the gallery room and looked at 94% of the paintings. We observed a significant correlation between the average proportion of participants who viewed a painting and the painting's physical size. This relationship was more pronounced for the contemporary non-Indigenous compared to Indigenous paintings. The average mean viewing distance across all paintings was 1.37 m, with the shorter average viewing distance for non-Indigenous (1.24 m) compared to Indigenous paintings (1.4 m). There was also a positive relationship, although only for the non-Indigenous paintings, between the painting area and viewing distance, as observed by Carbon (2017). With Indigenous paintings, there was a negative relationship between viewing distance and Shannon entropy coefficient. In addition, across all paintings, the slope of the Fourier amplitude spectrum was negatively correlated with the median viewing distance. In summary, while our measures of viewing distance are arguably noisy, our findings suggest the strong mediating role of the painting style on the viewing distance. The significant negative correlation between the amplitude spectrum slope and mean viewing distance across all paintings seem to suggest that the participants tend to move away from the patterns that have greater presence of high spatial frequency information and/or greater degree of spatial variegation.

Our eye gaze measures in the gallery condition revealed that on average participants made 44.24 fixations per painting with an average total fixation duration of 12.44 s and fixation length of 0.270 ms. Although the total fixation duration observed in our study is shorter than the average viewing times reported in earlier studies (Locher et al., 1999, 2001; Smith and Smith, 2001; Brieber et al., 2014, 2015; Carbon, 2017), our values include fixations only and do not reflect the total duration that the participants might have spent in front of paintings. There was also a significant effect of painting style with higher number of fixations and longer fixation durations for non-Indigenous compared to Indigenous paintings. We believe that these differences are related to the effects of painting size: not only are the smaller paintings less likely to be visited at all, but, seemingly, even when they are, they receive fewer fixations and are not looked at for as long as bigger paintings. Indeed, the multivariate regression analyses have revealed significant effect of area, fractal dimension and amplitude spectrum slope on both number of fixation and fixation duration.

However, when the same artworks were viewed in the laboratory, either scaled to fit most of the screen or to preserve their relative size as in the museum condition, none of the image statistics measures could be used to predict the average number of fixations and fixation duration. The only exception was Shannon entropy, which correlated negatively with the fixation duration and length, suggesting the shorter fixation duration and average length for paintings with higher entropy values.

Overall, when museum and on-screen presentation conditions were directly compared, our results reveal a strong interaction between presentation conditions and the effect of painting style and associated physical characteristics of artworks. We suggest that in order to be able to fully characterize the effect of presentation context in engaging with aesthetic objects, a finer grained analysis of their physical characteristics seem promising.

CONCLUSION

In conclusion, our study indicate that individual paintings exert a strong influence of viewing behavior. Some of that influence can be attributed to the paintings' physical and statistical image properties, especially when these properties coincide with differences in painting style. However, the experience of artworks in different contexts remains a complex question that requires a more robust and parametric manipulation of these factors. Concurrent measures of aesthetic experience should also be incorporated in future studies in this area.

DATA AVAILABILITY STATEMENT

The datasets generated for this study are available on request to the corresponding author.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the University of New South Wales Human Research Ethics Advisory Panel B (Arts, Humanities and Law) and Panel C (Psychology). The participants provided written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

VE-G, MG, SE, and BS contributed to the conception and design of the study. VG-E, MG, and SE contributed to the data collection at the AGNSW. VG-E and BS contributed to the data collection in laboratory and analyzed data. All authors contributed to the writing of the manuscript and approved its submission.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2020.00569/full#supplementary-material

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Ecological Art Experience: How We Can Gain Experimental Control While Preserving Ecologically Valid Settings and Contexts

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One point that definitions of art experience disagree about is whether this kind of experience is qualitatively different from experiences relating to ordinary objects and everyday contexts. Here, we follow an ecological approach that assumes art experience has its own specific quality, which is, not least, determined by typical contexts of art presentation. Practically, we systematically observe typical phenomena of experiencing art in ecologically valid or real-world settings such as museum contexts. Based on evidence gained in this manner, we emulate and implement essential properties of ecological contexts (e.g., free choice of viewing distance and time, large scale of artworks, and exhibition-like context) in controlled laboratory experiments. We found, for instance, that for large-scale paintings by Pollock and Rothko, preferred viewing distances as well as distances inducing the most intense art experiences – including Aesthetic Aha insights – were much larger than typical viewing distances realized in laboratory studies. Following Carbon's (2019) terminology of measurement strategies of art experience, the combined use of "Path #1" (real-world context) and "Path #2" (mildly controlled, still ecologically valid settings and contexts) enables us to understand and investigate much closer what is really happening when people experience art.

Keywords: empirical aesthetics, ecologically valid testing, art and perception, art experience, museum, gallery, real world

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INTRODUCTION

Nearly all empirical research on aesthetics and most research on art experience are conducted in the context of experimental laboratories. Indeed, laboratory settings provide ideal conditions for setting up experiments in a standardized and rigorous way: they do, however, also create a specific context that is far from any typical context people encounter when they experience art in everyday life; for example, museums, art galleries, art happenings, or installations (Carbon, 2019). For an overview on the general problems of experimental, especially neuroexperimental, research about art experience, I would like to refer to a recent position article by Kubovy (2020).

The essential differences between typical experimental laboratory and ecological settings are manifold. In a very general sense, experimental laboratory settings might provide perfect systematic experimental conditions, but lack "ecological validity" (Brunswik, 1956) – see also

"psychological ecology" (Lewin, 1943, p. 306) and "Lebensnähe" (English: "being close to real life," see Lewin, 1927, p. 419). This lack of ecological validity comprises potentially reduced involvement (Deniaud et al., 2015) and decreased emotional processing (Schmuckler, 2001) – in the last consequence, we might even witness a lack or even loss of meaningfulness (Neisser, 1976). Specifically, in the field of art experience, it is quite evident that there are substantial differences in approaching, perceiving, and processing artworks in ecological contexts versus laboratory contexts. First, laboratory research is most often restricted to presenting copies of artworks, but not original artworks – simply because original artworks are not available for laboratory research because of their immense price and the fact that they would have to be transported out of the secured museum or stacks (Wolz and Carbon, 2014). Whether the originality factor has a great impact is still under debate. Results are quite mixed (Locher et al., 1999). One research group claims that their studies do not show an essential difference between the experience of art in the museum versus the laboratory (Brieber et al., 2015a), but they also present results that indicate influences on valuation and memory (Brieber et al., 2015b). Further research showed that the quality of experience is clearly changed with context (Wolz and Carbon, 2014; Pelowski et al., 2017). One reason for differences in the experience of art in different contexts could be related to the sample rather than the context itself: Often, museum visitors recruit from specific social groups (Hanquinet, 2013) that are not typically represented by participants attending a laboratory experiment, so studies researching context effects using a between-participants design might be biased in this respect (see Muth et al., 2017).

It should be noted that in specific cases the experience of art and art reproductions could be even better, richer, and deeper in a non-museum context. As was recently shown in a survey study by Bertamini and Blakemore (2019), high-quality reproductions allow a direct and close inspection of the artworks that is not possible in many art museums due to security issues. Additional promising results stem from preliminary studies in the domain of virtual reality testing (Janković et al., 2019). Importantly, the positive aspects of using copies cannot be emulated by presenting minimized versions of artworks on ordinary computer screens – we need, it seems, life-sized pictures printed in high quality.

A series of articles addressed the parameters of size, quality, and originality. Most of them actually concluded that they all influence the experience of art. Reproductions in original size are, for instance, considered more interesting, surprising, and pleasant by the participants (Locher et al., 2001), but they are also interpreted as being less complex (Locher et al., 1999). Large-scale (original) pictures additionally provoke a specific eye scanning behavior marked by a pronounced concentration on the central areas of the picture (Locher et al., 2008), and image size seems to modulate the observer's viewing distance (Carbon, 2017) – at least in settings where this is possible, that is, mainly in real art-museum contexts.

Quality of depiction is still a rarely investigated topic in the field of art experience, but most originals provide a three-dimensional (3D) quality with canvas texture, protruding colors, and distinctive brush strokes (Carbon, 2016). This additional quality is mostly lacking in reductionistic laboratory research using common computer screens (see Locher et al., 2010), which narrows the overall experience to mostly plain visual stimulation and less pleasurable perception (Norman, 2002). Regarding originality, researchers have often found indications for a higher appreciation of original artworks: Viewers particularly appreciate the uniqueness of such works (Wolz and Carbon, 2014), and they are often well aware of the status of the artist who personally touched and created it (Newman and Bloom, 2012).

When directly observing museum visitors, it is quite evident that their viewing and inspection behavior is very different to what is found in typical laboratory contexts. First, most inspection in the laboratory is rather passive, but in the museum is typically active and explorative. We also freely choose the time we spend and the distance we take in to inspect pieces of art in the museum. These parameters and our specific pattern of approaching artworks are thus substantially, and probably qualitatively, different from the laboratory in their environmental setting. In a now classical study, Smith and Smith (2001) systematically investigated the visitors' behavior while attending six masterpieces from the collection of the Metropolitan Museum of Art. The mean time visitors spent on viewing was 27.2 s. Subsequent studies with a similar methodological approach confirmed such long viewing times, for example, 28.6 s for viewing pieces from the permanent collection of The Art Institute of Chicago (Smith et al., 2017) and 32.9 s for viewing pieces from a temporary exhibition of Gerhard Richter's work at the Neues Museum Nürnberg (Carbon, 2017). A study by Tröndle and Tschacher (2012), which analyzed visitors' movement behavior covering much larger parts of a museum (Kunstmuseum St. Gallen) and much more diverse pieces of art, revealed much shorter average viewing times of about 10 s; some artworks, however, yielded viewing times similar to those found in the other studies (e.g., 34.5 s for the work "Antibild" by Günther Uecker made in 1974). Viewing times certainly depend on several factors such as the size of the observed picture (with larger pictures being viewed longer, see Carbon, 2017) or the social setting of where the artworks are attended (with people in a group looking at art longer than as an individual, see Carbon, 2017; Smith et al., 2017). Furthermore, viewing time is also modulated by reading or not reading the appending label (with visitors who read the label attending the artwork much longer – but only because they read the labels – and so effectively for a shorter period regarding the observation of the artwork as such, see Smith et al., 2017), or by the sheer number of artworks in an art show to be visited (Brieber et al., 2014).

Overall, there is overwhelming evidence that the context and the way of presenting artworks make a difference, especially regarding the richness of experience, the memory traces that are made, and the pleasure that is gained. When people are observed in the original habitat of experiencing artworks, for example, art galleries, museums, or special art shows, they behave qualitatively differently than in laboratory contexts. For instance, in a museum, they optimize their observation space, mostly taking in a much larger viewing distance and also using different viewing distances while constantly watching the artwork. Typical museum visitors also use far more time to inspect an artwork,

and they return to many artworks after having fleetingly visited them before (Carbon, 2017). According to Brunswik (1956), we will not get "fully representative" (p. 67) research with laboratory-oriented research that ignores such typical viewing and inspection behavior, but we probably have at least a chance to go for "close-to-life systematic research" (p. 67) if we implement essential conditions by more ecologically valid study designs.

THE PRESENT STUDY

In the present work, we consequently emulate and implement essential properties of the ecological-valid contexts of art perception (e.g., large scale, variable viewing distance, unrestricted inspection time, exhibition flair) within an experimentally controlled procedure. We thus follow the Path #2 approach proposed by Carbon (2019). We emulated a typical art gallery context by showing large-scale, high-quality reproductions printed on linen-like canvases, enabling large degrees of freedom of viewing with a very wide range of viewing distances. Participants approached the pictures one after another. During the inspection, no other person was attending the scene except the experimenter standing in the background. This should provide the ideal setup for the participant to fully concentrate on the artworks with no time limit and no time pressure. To gain a rich picture of their art experience, we employed this experience as a multidimensional construct as suggested by Faerber et al. (2010) for aesthetic appreciation. For the present study on abstract art, we employed the following variables: (1) *liking* (German: Gefallen), (2) *power(fulness)* (Kraft), (3) *interesting(ness)* (interessant), (4) *emotional (value)* (emotional), and (5) *3D impression* (3D Wirkung); finally, we asked whether an Aesthetic Aha insight moment occurred while viewing the artwork. *Liking* assesses how personally pleasing an artwork is for the participant; this variable is employed in most aesthetic studies addressing preferences (Faerber and Carbon, 2012; for an overview of operationalization of this variable, see Faerber et al., 2010; Marin et al., 2016; e.g., Muth and Carbon, 2013). *Powerfulness* (Pepperell, 2011) was employed to reflect the other classical axis of preference besides pleasantness (Ortlieb et al., 2016), which is often discussed in aesthetic theories such as those of Edmund Burke or Immanuel Kant to describe how impressive an artwork is. *Interestingness* represents the important component of aesthetic experience, which triggers the motivation for a deep inspection (Silvia, 2005b,c). However, this variable is often neglected or suppressed in aesthetic research because of biased reliance on aspects of beauty or pleasantness (Turner and Silvia, 2006; Silvia, 2008; Muth et al., 2015a). *Emotional (value)* represents the personal assessment of how emotional the impression of an artwork was and corresponds to the facet *valence* from the aesthetic appreciation concept of Faerber et al. (2010). It primarily reflects the affective response of a person. *3D impression* was specifically employed for the abstract expressionist paintings by Marc Rothko and Jackson Pollock used in the present exploratory study. Works by these artists are often described as triggering experiences of visual depth that immerse the viewer (Emmerling, 2003). Last but not least, *Aesthetic Aha* represents a sudden insight into perceptual Gestalt (Muth and Carbon, 2013). The Aesthetic Aha (as a concept) is a part of a typical experience of artistic epiphany (Carbon, 2019), which typically leads to an increased liking of the artifact from which the person had the insight (Muth and Carbon, 2013) and can even lead to transformative effects (Pelowski, 2015). Just as an example: When we enter the titular church of San Pietro in Vincoli, Rome, Michelangelo Buonarroti's *Moses* – sculpted 1513–1515 of the finest Carrara marble – makes a clear impression on us by its sheer size of more than 2 m in height. But only by close inspection do we become aware of the lively and energetic character of Moses. After some time, many visitors recognize female body shapes in the swirling beard – they perceive gestalts instead of background information. Strong experiences such as having an Aesthetic Aha are particularly interesting to investigate in ecologically valid contexts because the deeper effects of aesthetic experience are quite rare in standard laboratory contexts, and therefore their existence might even be questionable if we always carry out our aesthetic research in laboratory settings that are mostly far from reality.

EXPERIMENT

Methods

Participants

We tested 10 participants (eight female, M_{age} = 26.1 years) who had no special training in the arts, but were mostly interested in art (M = 5.1 on an eight-point scale from 0 = no interest at all to 7 = very high interest). As the study used paintings by Mark Rothko and Jackson Pollock as material, we specifically asked for the participants' knowledge of both artists via two separate eight-point scales ranging from 0 = no knowledge at all to 7 = very high. Most of the participants had no particular knowledge of Rothko (only one participant indicated knowledge greater than 4 on this scale), whereas Pollock was somewhat more well-known (three participants indicated knowledge about Pollock as greater than 4 on the respective scale). Participants were invited to join a "small art show organized by the department" – we did not provide explicit knowledge, neither on the artists involved nor any other information about the paintings. The participants were recruited from several lectures. They were mainly psychology students, and they received course credit for their participation. All participants had normal or corrected-to-normal vision, as tested by the Snellen Eye chart test. Normal color vision was shown by all participants through fully correct responses in a short self-fabricated version of the Ishihara Color test.

Stimuli

Six large-scale abstract expressionist paintings (**Table 1**), three by Marc Rothko (an American painter of Jewish–Litvak descent who lived from 1903–1970, mostly known for his abstract expressionist paintings) and three by Jackson Pollock (an American painter who lived from 1912 to 1956 and was a major figure in the abstract expressionist movement) were used as stimulus material.

TABLE 1 | List of artworks used in the present study, printed on linen-like canvases and mounted on wooden stretcher frames.

Artist	Title	Year	Original and used size
Mark Rothko	No. 7 (Dark Brown, Gray, and Orange Brown)	1963	162.5 × 175.5 cm [106.8 × 117.0 cm]
	No. 21 (Red, Brown, Black, and Orange)	1951	162.5 × 241.5 cm [106.8 × 162.0 cm]
	Untitled (Yellow and Blue)	1954	186.7 × 242.9 cm [106.8 × 140.0 cm]
Jackson Pollock	Number 1A	1948	264.2 × 172.7 cm [167.0 × 106.8 cm]
	Blue Poles (Number 11)	1952	488.9 × 212.1 cm [242.0 × 106.8 cm]
	Full Fathom Five	1947	76.5 × 129.2 cm [106.8 × 189.5 cm]

Sizes are shown as width × height. Realized sizes in the experiment are indicated within brackets.

Procedure

The study comprised two major experimental blocks. Both blocks were characterized by six sub-blocks devoted to one artwork each. The order of artworks was randomized for each person and was fixed across blocks. All instructions were given in German. In both blocks, participants had to evaluate their experience of each artwork on a series of five seven-point Likert scales (1 = very weak, 7 = very strong) representing different dimensions of aesthetic experience: (1) liking (German: Gefallen), 2) power(fulness) (Kraft), (3) interesting(ness) (interessant), (4) emotional (value) (emotional) and (5) 3D impression (3D Wirkung). Additionally, we asked the participants whether they had experienced an Aesthetic Aha insight (Muth and Carbon, 2013) while viewing the artworks – if so, they were requested to describe the aha experience in their own words. In the first block ("assigned distances" condition), the experimenter situated the participants at various predefined distances in front of the paintings (the experimenter guided them to the respective subtly marked positions on the floor by hand; they were instructed to inspect the painting from these positions and evaluate it according to the questions provided while staying there) – the empirical distances were also registered and measured exactly later on, as participants tend not to fully fix their positions to those assigned. The order of the eight predefined distances was randomized for each sub-block and for each participant. The range of distances was from very near to far, that is, 0.5, 1.0, 1.5, 2.0, 3.0, 4.0, and 5.0 m, which are typical distances that can be observed in real museum contexts (Carbon, 2017), plus

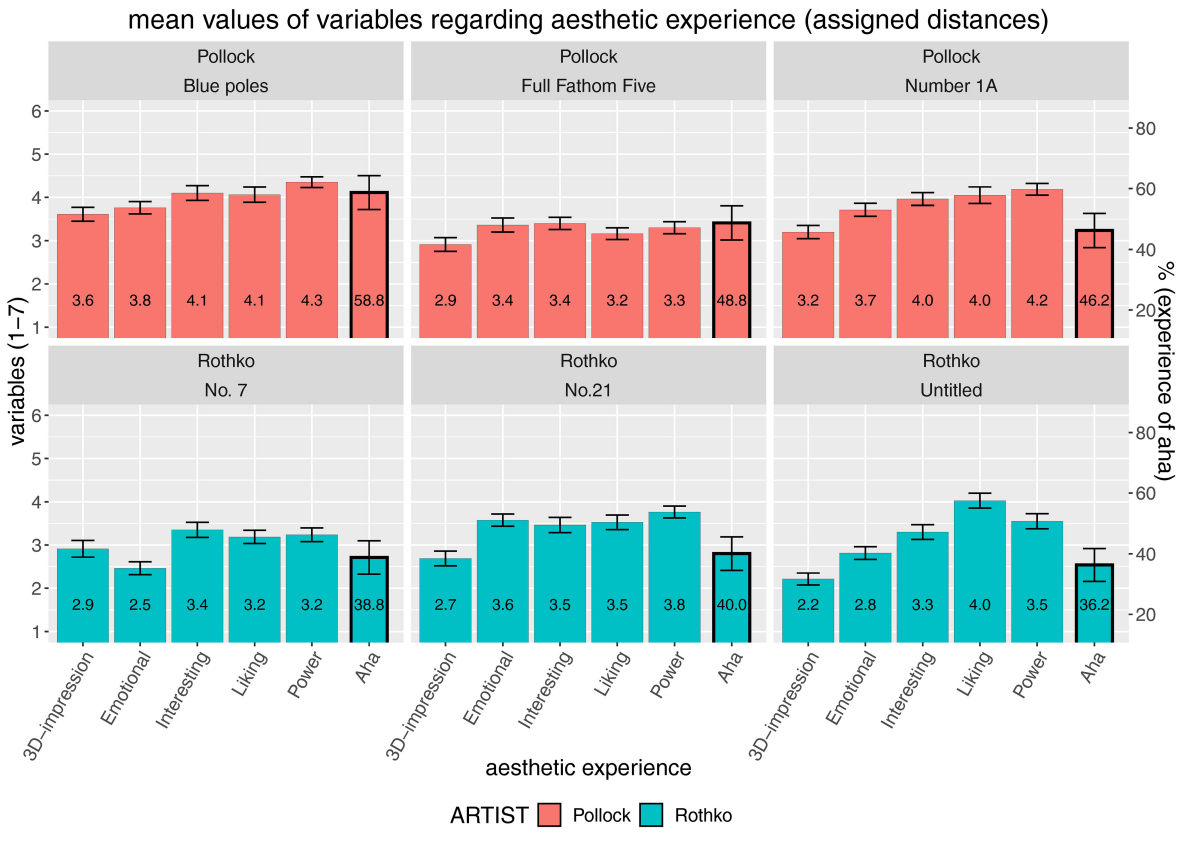

FIGURE 1 | Evaluations with assigned distances: mean values for aesthetic experience comprising five different quantitative variables (3D impression, emotional value, interestingness, liking, and powerfulness) plus the percentage of having experienced an Aesthetic Aha insight, all split according to artist (paintings by Pollock in the top row and paintings by Rothko in the bottom row). Error bars indicate standard error of the mean (SEM).

a very far distance of 10.0 m. In the second block ("self-chosen distance" condition), after having been massively familiarized with the presented artworks, participants were asked to make their own, preferred choice of distance to finally view each painting in an optimal way. For all trials, we let participants view the respective artwork as long as they wanted; there was no time pressure and no time limit, so that participants had the opportunity to deeply process each artwork. In order to assist this deep processing and to reduce any distraction, the participants' assessments were verbally requested and were then written down by the experimenter.

Prior to the experimental session, written informed consent was obtained from each participant. Additionally, we conducted a personality test concerning the Big Five, based on 21 items [Big Five Inventory short version (BFI-K), Rammstedt and John, 2005]. After the experiment, participants were fully informed about the background of the study and allowed to ask questions. Persons who did not consent were not included in the study – but this did not happen in the course of the study. All data were collected anonymously. The entire procedure took 2–3 h per person.

Results and Discussion

We were mainly interested in gaining insight into three aspects: (1) how viewing distance changes the aesthetic experience of large-scale artworks, (2) how Aesthetic Aha insights modulate the aesthetic experience, and (3) how liking of an artwork can best be predicted by other qualities of aesthetic experience. The data were processed by RStudio 1.2.5001 with *R* 3.6.1, using the *R* toolbox *psych* for calculating effect sizes. Linear mixed-effects analysis was conducted via toolbox *lme4* (Bates et al., 2015).

Data Basis

We registered no loss of data for any of the participants yielding 324 data points per person, that is, 5 + 1 [Aha] = 6 data points per picture and distance in blocks yielding 6 × 8 × 6 = 288 data points for Block 1, and 5 + 1 [Aha] = 6 data points per picture yielding 36 further data points for Block 2. All in all we obtained 324 data points per person, so 3,240 overall.

Strategy of Analyzing the Data

The analysis of data will start with the mean data from Block 1, where we let the artworks be experienced at specifically assigned

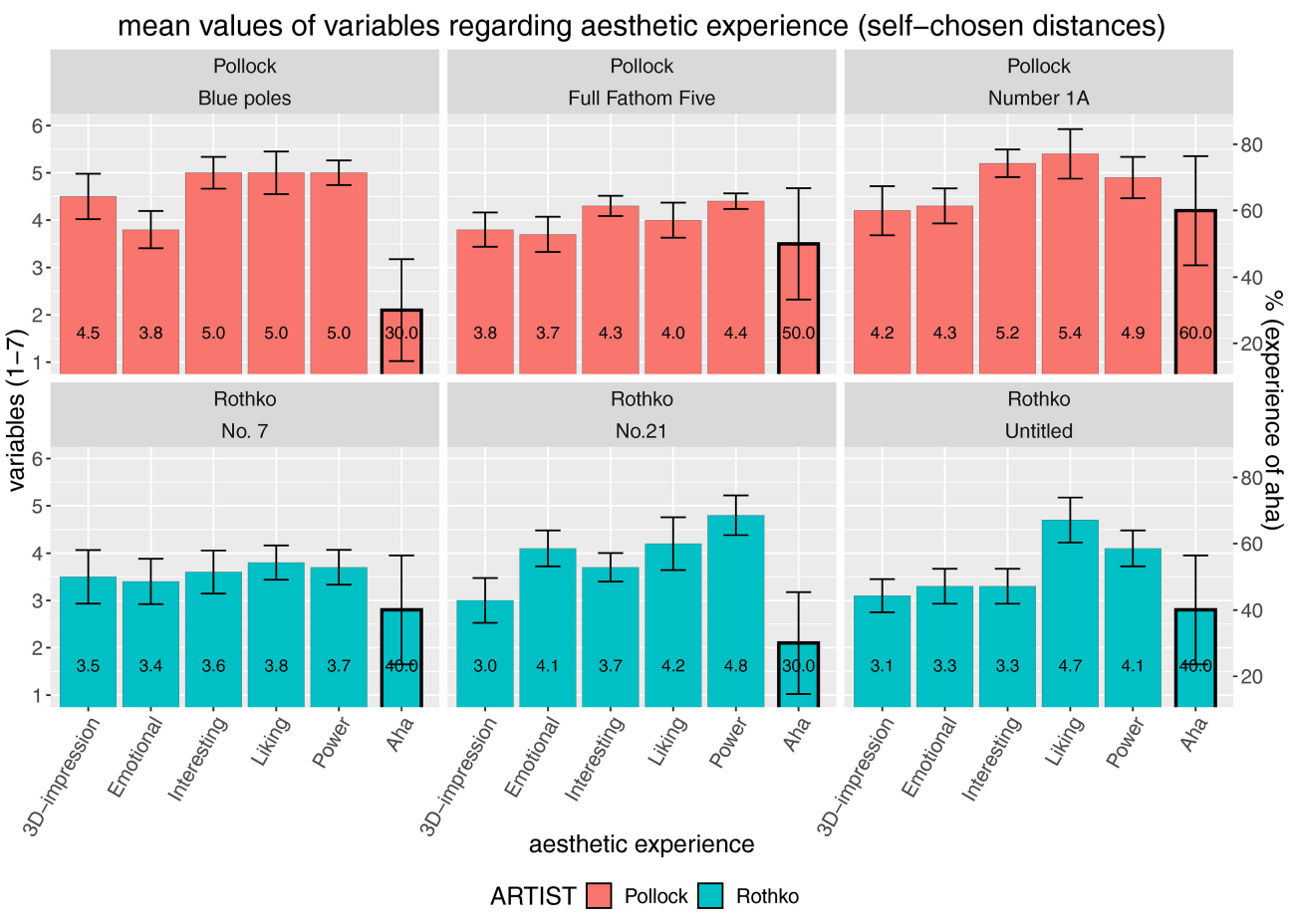

FIGURE 2 | Evaluations with self-chosen distances: mean values for aesthetic experience comprising five different quantitative variables (3D impression, emotional value, interestingness, liking, and powerfulness) plus the percentage of having experienced an Aesthetic Aha insight, all split according to artist (paintings by Pollock in the top row and paintings by Rothko in the bottom row). Error bars indicate standard error of the mean (SEM).

viewing distances. After that, we will focus on the data of Block 2 where we let the participants find the optimal viewing distance for each artwork. The mean data of both blocks will be compared via linear mixed effects to reveal any benefit of the mode of how viewing distance is established – fixedly assigned (Block 1) versus self-chosen (Block 2). We then explicitly analyze the relationship between assigned distance and the quality of art experience. We will do this by looking at all artworks differently as we believe that certain artworks ask for specific viewing distances; for instance, larger-scale pictures often implicitly need greater distances to fully appreciate them (Carbon, 2017). All these analyses include the five focus variables of aesthetic experience (3D impression, emotional, interesting, liking, and power) plus the quality of whether an Aesthetic Aha effect takes place when inspecting the artwork. In order to find out whether viewing distance is more a general factor or a viewer-specific one, we will furthermore test viewing distance within linear mixed models as fixed versus random slopes. As liking is a central variable in art experience, we will then focus on this specific target variable when looking at the impact of viewing distance. For the self-chosen distances, we will also look at the histogram of viewing distances to get an impression of how single viewers differ in their idiosyncratic interpretation of an optimal distance for specific artworks. Lastly, we will analyze the trials in which an Aesthetic Aha happened in comparison with trials where such Aesthetic Ahas were not available – here we were especially interested in the impact on the other five variables capturing the concept of art experience.

TABLE 2 | Linear mixed-effects analysis of different models in comparison to a simple base model (Model #0).

Dependent variable/tested model	df	AIC	logLik	R^2	$p(\chi^2)$
3D impression					
#0: *Base* (random intercepts)	4	1,783	−887	0.187	
#1: + FS distance	**11**	**1,764**	**−871**	**0.238**	**<0.0001**
#2: + RS distance (by artists)	13	1,766	−870	0.241	0.4051, n.s.
Emotional value					
#0: *Base* (random intercepts)	**4**	**1,664**	**−828**	**0.221**	
#1: + FS distance	11	1,671	−824	0.232	0.4113, n.s.
#2: + RS distance (by *artists*)	13	1,675	−824	0.232	0.8516, n.s.
Interestingness					
#0: *Base* (random intercepts)	4	1,705	−848	0.235	
#1: + FS distance	**11**	**1,703**	**−840**	**0.258**	**0.0264**
#2: + RS distance (by *artists*)	13	1,706	−840	−259	0.7332, n.s.
Liking					
#0: *Base* (random intercepts)	4	1,790	−891	0.173	
#1: + FS distance	**11**	**1,759**	**−869**	**0.242**	**< 0.0001**
#2: + RS distance (by *artists*)	13	1,763	−869	0.242	0.9604, n.s.
Powerfulness					
#0: *Base* (random intercepts)	4	1,638	−815	0.207	
#1: + FS distance	**11**	**1,632**	**−805**	**0.238**	**0.0045**
#2: + RS distance (by artists)	13	1,634	−804	0.240	0.5418 n.s.

For each dependent variable, the best-fitting model, while being parsimonious, is indicated by bold face. FS, fixed slopes (fixed factors); RS, random slopes (random factors); df, degrees of freedom; R^2, coefficient of determination, based on the likelihood-ratio test; $p(\chi^2)$, probability of accepting a significant effect despite a non-existent difference regarding the more complex versus the one-step less complex model.

Overview of Aesthetic Experience Data Including Aesthetic Aha

For an initial inspection of the data, we examined the mean values of aesthetic experience and the mean percentage of having experienced an Aesthetic Aha insight (Muth and Carbon, 2013). First, we analyzed the mean data of the first experimental block where fixed distances were assigned to the participants (**Figure 1**). From the mere visual inspection of these mean values (averaged across distances), it is clear that the aesthetic profiles differed among the artworks and that Pollock paintings in particular generated Aesthetic Aha insights quite often, on average, in approximately half of all inspections within a range of 46.2–58.8% of all cases.

Second, we analyzed the mean data of the second experimental block where the distances were self-chosen by the participants (**Figure 2**). The data were similar – but obviously, aesthetic experience was at a higher level in general when participants were allowed to choose the viewing distance on their own. Note: We have to be cautious in interpreting this higher level as a direct outcome of the assigned distance versus self-chosen distance condition, because the self-chosen condition was always executed after the assigned distance condition. Thus, this effect can also be explained by a deeper elaboration as such. It is, nevertheless, important to stress that this effect was probably not caused by mere exposure (Zajonc, 1968) as we did not find an effect of

TABLE 3 | Mean values of aesthetic experience variables for assigned (experimental Block 1) versus self-chosen (Block 2) distances.

Variable	*M* (assigned)	*M* (self-chosen)	*p*	Cohen *d*
3D impression	2.92	3.68	<0.0001	0.370 "small to medium"
Emotional	3.28	3.77	0.0025	0.263 "small"
Interestingness	3.60	4.18	0.0005	0.303 "small to medium"
Liking	3.67	4.52	<0.0001	0.400 "small to medium"
Powerfulness	3.73	4.48	<0.0001	0.418 "small to medium"
Aha	0.448	0.417	0.6172, n.s.	–

Statistical tests were conducted by means of linear mixed-effects analyses, employing models with random intercept effects for participants and artworks and the respective target variable as fixed slope effects. Effect sizes (expressed as Cohen d) are qualified according to the suggestions of Cohen (1988).

trial number in the assigned distance condition on liking [linear mixed Model #0 from **Table 2** tested against the same model with additional trial number as fixed slope, $p(\chi^2(7)) = 0.2268$, not statistically significant (n.s.)] – thus, the mere frequency of having inspected an artwork did not significantly yield higher aesthetic appreciation.

We tested the differences between both viewing conditions (assigned vs. self-chosen distances) by means of linear mixed-effects analyses as shown in **Table 3**. With the exception of Aesthetic Aha, all aesthetic experience variables showed higher values in the self-chosen viewing distance condition than in the assigned distance condition.

This finding is particularly interesting as it shows that taking an own, optimally suiting viewing distance is quite important for the aesthetic experience of artworks. This is typically not acknowledged in laboratory research where distances are mostly fixed and even fixed at a very close distance.

Aesthetic Experience in Relation to the Viewing Distances

In the following section, we will focus on the multidimensional construct of aesthetic experience comprising five quantitative variables that participants assessed for each artwork and a qualitative variable indicating whether an Aesthetic Aha insight was experienced. An initial visual inspection of the data for the first experimental block with assigned distances (**Figure 3**) already indicated that the respective assigned distance had an influence on several variables of aesthetic experience.

We statistically tested the impact of assigned distances on aesthetic experience by employing separate series of linear mixed-effects analyses with the independent measure viewing for each of the five variables of the construct of aesthetic experience, that is, (1) 3D impression, (2) emotional value, (3) interestingness, (4) liking, and (5) powerfulness. As base model (Model #0), we defined only random intercepts for participants and artists. Then we successively increased the complexity of the model by first entering distance as fixed slopes – FS (fixed factors) – (Model #1) in order to test the impact of distance on aesthetic experience and then by adding random slopes for participants and artists (Model #2). Visual inspection of residual plots did not reveal any obvious deviations from homoscedasticity or normality. *P*-values were obtained by likelihood-ratio tests of the subsequent models against the base model. The coefficient of determination for each model was calculated via a likelihood-ratio test utilizing the toolbox *MuMIn* (Barton, 2019). See **Table 3** for detailed results.

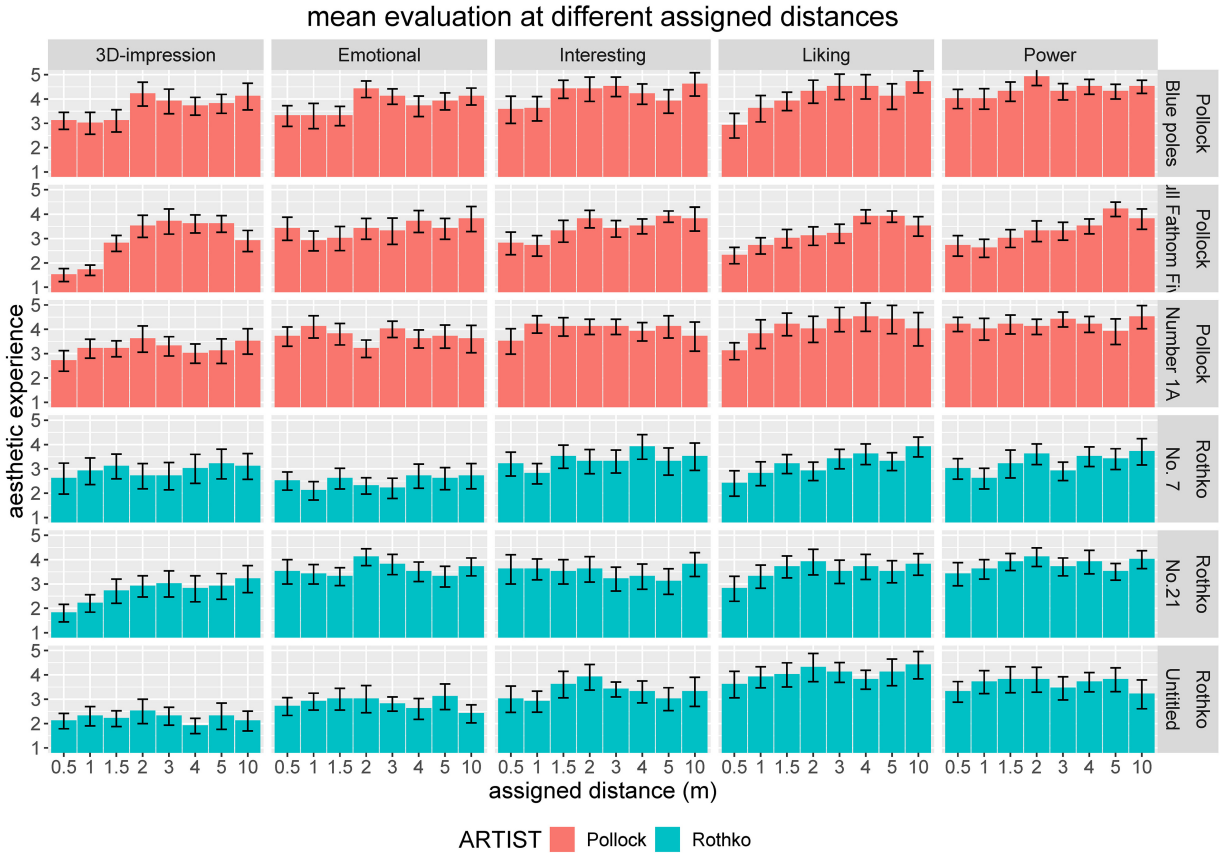

FIGURE 3 | Impact of assigned viewing distance on aesthetic experience comprising five different quantitative variables (3D impression, emotional value, interestingness, liking, and powerfulness) split according to artworks (paintings by Pollock in the top rows and paintings by Rothko in the bottom rows). Error bars indicate standard error of the mean (SEM).

Linear mixed-effects analysis revealed that, with the exception of emotional value, all quantitative variables of aesthetic experience were impacted by assigned viewing distance. Furthermore, this impact was quite constant for both artists, as indicated by a non-significant information increase when adding random slopes for distances-by-artists.

We inspected this uniformity of effect in further detail by focusing on the aesthetic experience variable *liking*, which showed a particularly strong modulatory power of distance – the strongest in fact, as revealed by the linear mixed-model-effect analyses. We revealed a clear increase in liking the farther away the viewpoint of the participants was, with an optimal viewing distance regarding the modal value of approximately 3 to 4 m (**Figure 4**), which is substantially farther away than in the study by Carbon (2017) when observing the natural (on-site) viewing behavior in a Gerhard Richter art show – M = 1.72 m [1.49–2.12 m]. As the Richter paintings were a bit smaller than the stimuli employed in the present study, we applied the formula of empirical viewing distance in relation to the picture size provided by Carbon (2017). This yielded smaller predicted distances than observed ones, for example, 1.71 m for the smallest painting – Rothko's "No.7 Dark Brown, Gray and Orange Brown" with a size of 1.25 m^2, and 1.98 m for the largest painting – Pollock's Blue Poles (Number 11) with a size of 2.58 m^2. It seems that the optimal viewing distance is related not only to the canvas size but also to the subject or the specific artistic style, which differed in both studies.

With the second experimental block, we further elaborated the investigation of optimal viewing distances. Here, we explicitly asked and allowed participants to choose their optimal viewing distance to gain the strongest aesthetic experience of the artworks. We found that participants chose quite large distances to view the artworks optimally. Taking the most frequently chosen viewing distances into account, we revealed a range of [3.0–4.0 m] for Pollock paintings and [5.5–6.0 m] for Rothko paintings (**Figure 5**).

So again, empirical viewing distances in an ecologically valid context were much farther away than typical distances realized in typical experimental laboratory settings.

Self-chosen viewing distances were also accompanied by different aesthetic experiences (**Figure 6**). For Pollock paintings particularly, we observed most of the higher quality aesthetic experiences at farther distances, whereas Rothko paintings were appreciated at medium and sometimes also at closer distances,

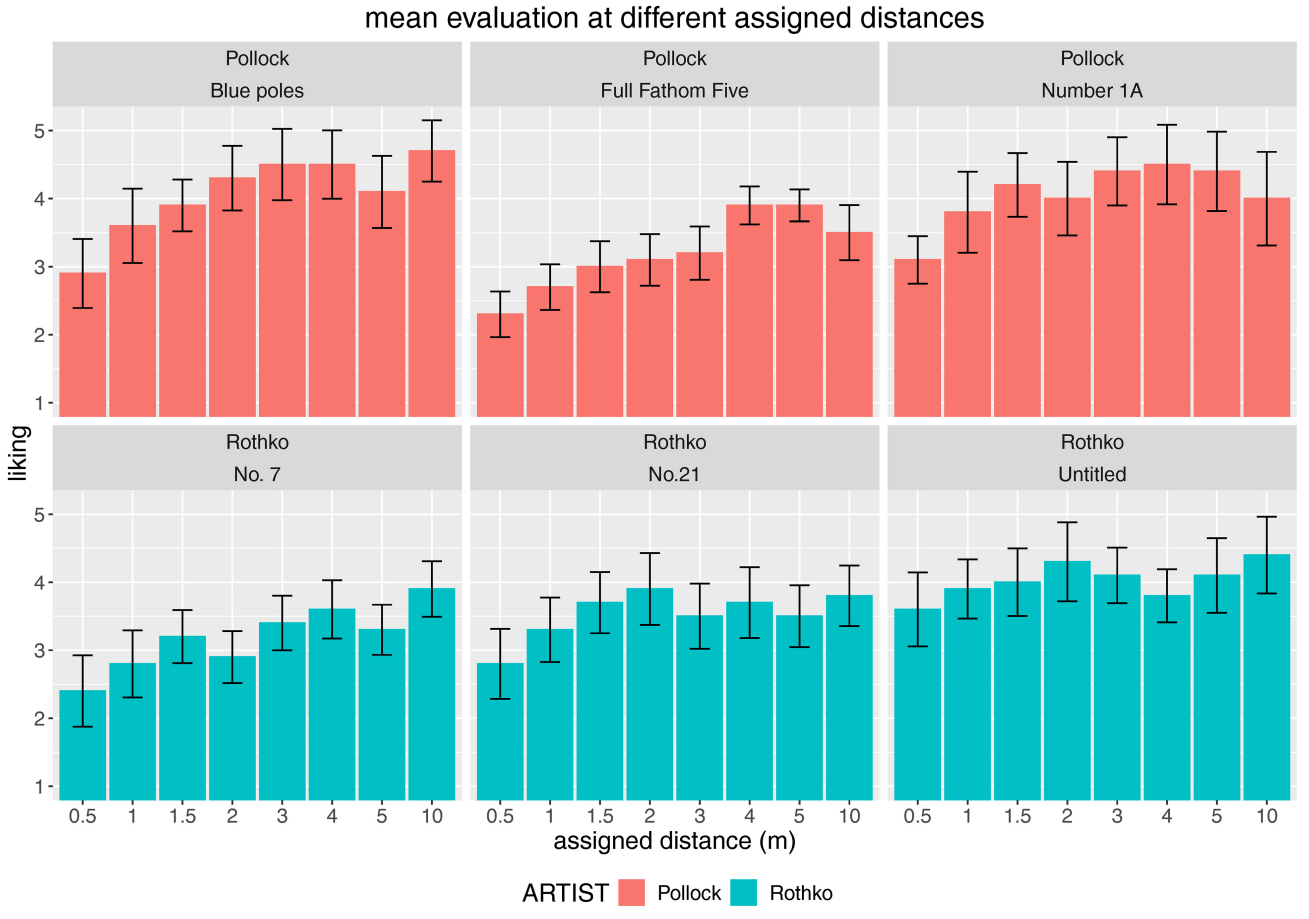

FIGURE 4 | Impact of assigned viewing distance on liking for each employed artwork (paintings by Pollock in the top row and paintings by Rothko in the bottom row). Error bars indicate standard error of the mean (SEM).

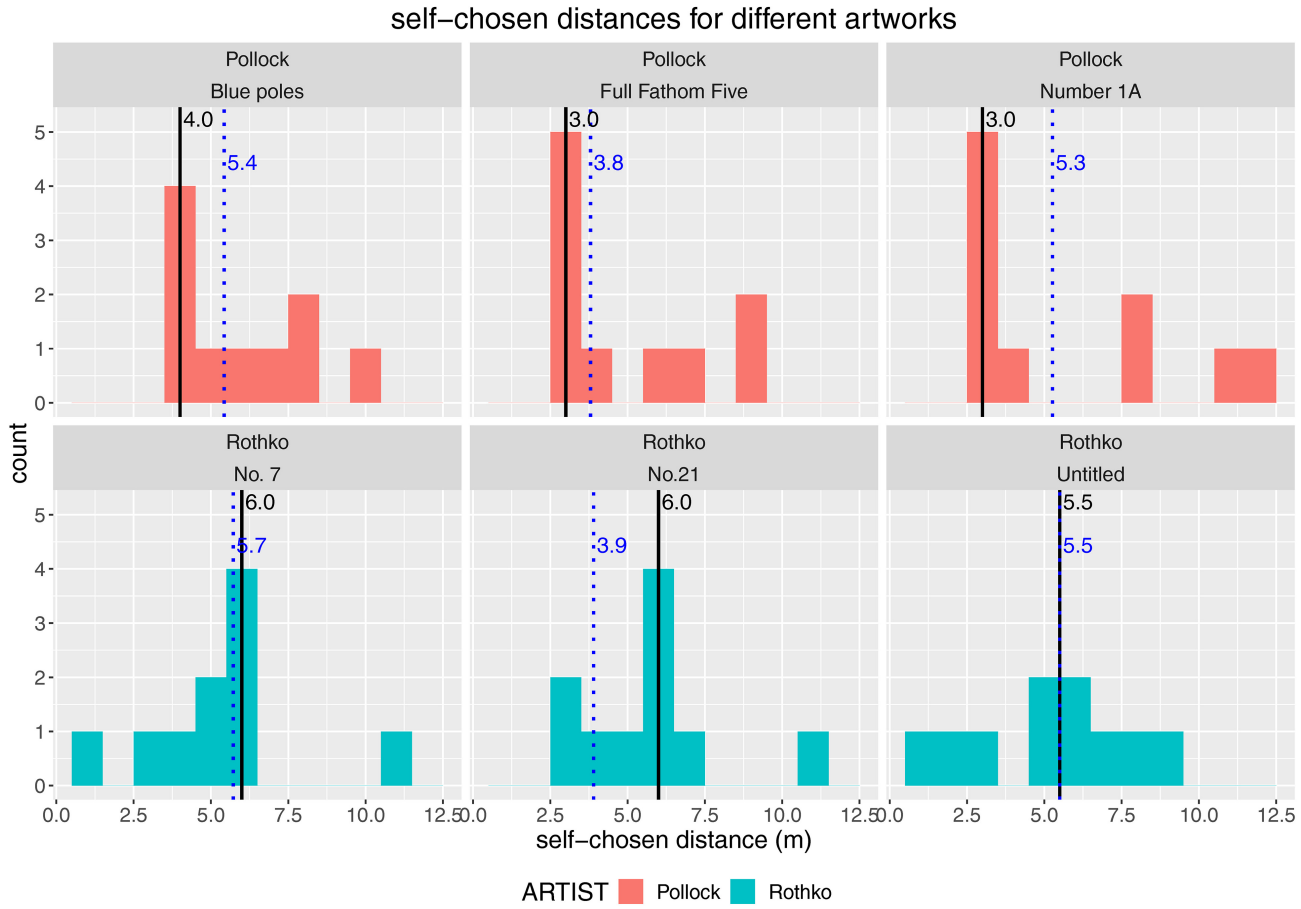

FIGURE 5 | Histograms of self-chosen distances for each employed artwork (paintings by Pollock in the top row and paintings by Rothko in the bottom row). Black solid vertical lines plus black numbers show the modes of the distributions; blue dotted vertical lines plus blue numbers show the medians of the distributions.

which were still much farther away than typically realized in laboratory experiments.

Qualities of an Aesthetic Aha

Based on previous research on the so-called Aesthetic Aha insight in which people report increased pleasure when having such an insight experience, for example, shown for the visual domain (Muth and Carbon, 2013; Muth et al., 2013) but also quite recently for haptics (Muth et al., 2019b), we analyzed the impact of experiencing an Aha on the here-targeted variables of aesthetic experience. Mean data for each of these variables shown in **Figure 7** indicate a positive influence of experiencing an Aha insight on the aesthetic experience of artworks, especially for the paintings of Mark Rothko. For Rothko paintings, we revealed numerical benefits for all variables and significant increases for all variables except *liking* (**Figure 7**). For Pollock paintings, Aesthetic Aha showed only a significant increase for the variable *interesting*. These findings are particularly interesting as the Aesthetic Aha effect was mainly attributed to a benefit concerning pleasure, but was speculated to impact the full range of aesthetic experience as well. In the original study by Muth and Carbon (2013), pleasure was operationalized via the German term "Gefallen" and translated to "liking." However, in English, it seems to be better captured by the term "pleasing"; in the context of haptics, for instance, we asked for "pleasingness" as well as "pleasantness," see Muth et al. (2019b). The results of the present study, at least for the Rothko paintings, would partly support this view, but the Aha insight benefit might also be limited to certain kinds of aesthetic displays.

Predicting Liking Through Other Dimensions of Aesthetic Experience

Finally, we were interested in how liking of an artwork can best be predicted by other dimensions of aesthetic experience. In order to test this, we employed linear mixed-effects analyses with increasingly complex models.

As indicated by **Table 4**, we identified as best fitting a model that took all aesthetic experience variables into account as fixed factors, plus the variables *interestingness* and *powerfulness* as random slopes by artworks as well as participants. For this "Model #2," the fixed factors *interestingness* and

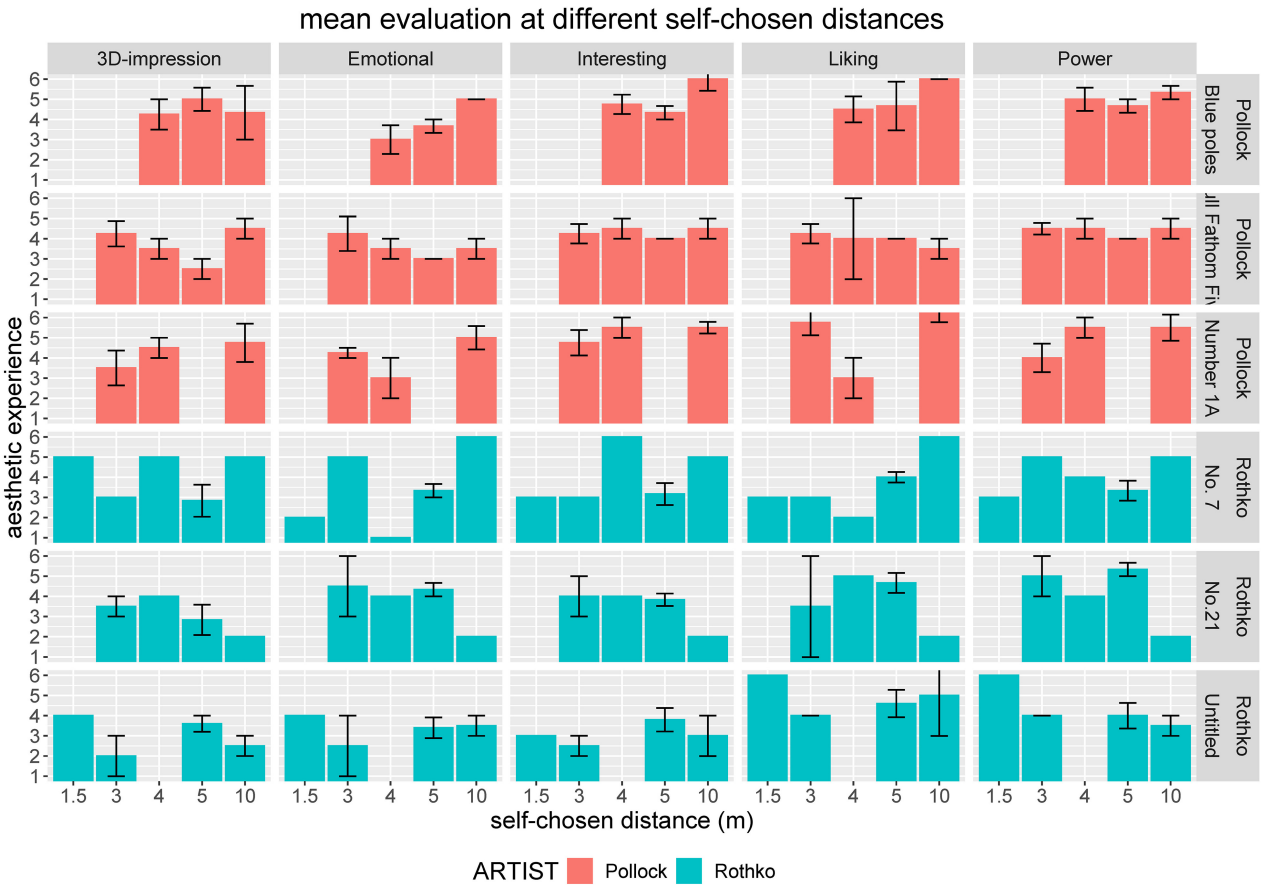

FIGURE 6 | Self-chosen viewing distances relating to aesthetic experience comprising five different quantitative variables (3D impression, emotional value, interestingness, liking, and powerfulness) split according to artworks (paintings by Pollock in the top rows and paintings by Rothko in the bottom rows). Error bars indicate standard error of the mean (SEM).

powerfulness showed moderately large significant effects; both factors positively related to the *liking* of artworks.

GENERAL DISCUSSION

The main aim of the present exploratory study was to add insights about ecologically valid behavior of art perceivers in a museum context. We created an experimental setting that emulates typical properties of such a context by organizing a small art show where people were allowed to view artworks without time constraints at different viewing distances. In a first experimental block, they were assigned to fixed distances, and then in the second experimental block, they were asked to freely choose the distances to optimally view the artworks on their own.

First, we observed an impact of viewing distance on aesthetic experience. Based on the specifics of the inspected painting, we revealed certain distances that were mostly much larger than are typically employed in laboratory-based research on aesthetics where the distance is mainly defined by the optimal viewer-screen distance. Here, with the help of large-scale prints of artworks, people had Aesthetic Aha insights quite often and benefited from self-chosen distances. As soon as they were able to choose their personal viewing distance, this indeed was a kind of optimal one in order to maximize the level of aesthetic experience. Such self-chosen distances were mostly in the range of 3 m up to 6 m, with smaller distances for Pollock than Rothko paintings. But even when participants were assigned fixed distances, they showed a specific pattern of viewing distance relationship with certain aesthetic experiences. Especially *liking* of a painting benefited from farther distances, but also the powerfulness, the 3D impression and the interestingness of paintings were influenced by the position from which the viewer inspected the artworks.

When participants reported an Aesthetic Aha insight, we also detected intensified aesthetic experience, specifically for Rothko paintings. They reported an increased 3D impression and more emotional value; they found the artworks more interesting and characterized them as being more powerful. Interestingly, such Aha insights did not trigger higher levels of liking, a key variable of aesthetic experience which Muth and Carbon (2013) proposed to be impacted by Aha insight moments (see Carbon, 2010). At the moment, we can only speculate as to why neither Rothko nor Pollock paintings were better liked when Aesthetic

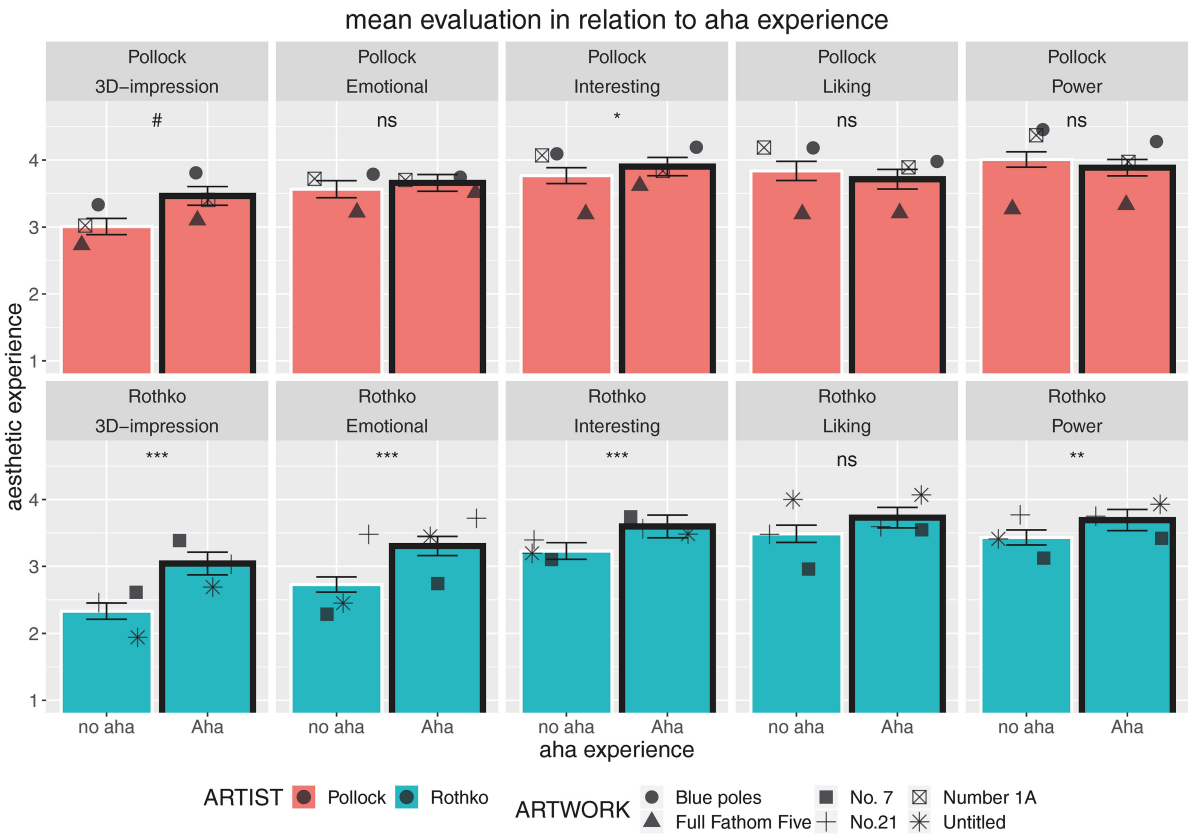

FIGURE 7 | Experimental block on assigned distances: Relationship between having an Aesthetic Aha insight (Muth and Carbon, 2013) and aesthetic experience comprising five different quantitative variables (3D impression, emotional value, interestingness, liking, and powerfulness) split according to artist (paintings by Pollock in the top row and paintings by Rothko in the bottom row). Dots show the mean data for specific paintings. Error bars indicate standard error of the mean (SEM). Differences between "no aha" and "Aha" trials were tested for statistical significance via linear mixed-effects analysis with 2 × 5 single models with the only fixed factor representing an aha absent or present (ns, non significant, #$p < 0.1$, *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$).

Aha happened, but probably the aesthetic experience, which is triggered by such Aha moments is much broader than was initially suggested. Thus, the term "Aesthetic Aha" also seems to be a suitable term for referring to a broad concept of processes being involved in epiphany moments of insight (see Carbon, 2019). Further research has to investigate the impact and reach of Aesthetic Aha effects, and especially the role of interestingness in this respect. Interestingness was strongly impacted by Aesthetic Aha for Rothko as well as Pollock paintings in the current study and is a variable of much interest in recent streams of empirical aesthetic studies (Silvia, 2005a, 2008; Muth et al., 2015a). And indeed, whereas classical studies and theories mainly refer to beauty and liking, more recent ones – especially those investigating contemporary or "challenging art" (Belke et al., 2015) – do focus on interest for the inspection (Silvia, 2005b) or focus on the promise to understand parts of an artwork (Muth et al., 2015a, 2019a; Muth and Carbon, 2016).

We also looked at the classical question of what dimensions of aesthetic experience predict the liking of a painting. Among our targeted variables, we again revealed not only interestingness, but also powerfulness, as promising candidates for predicting how much people will like a painting. Knowledge about the relationship between powerfulness and liking is still very limited, although initial research exists (Pepperell, 2011). Sometimes even different types of powerfulness are discussed, for example, perceptual versus cognitive aspects (Muth et al., 2015a), both being influenced by insights and by ambiguity – and both phenomena playing a crucial role in abstract art as utilized in the present study. Research on interestingness is much more developed in this respect because of some key publications on interest (Silvia, 2005b; Muth et al., 2015a) and interestingness (Silvia, 2005c; Faerber et al., 2010). It is quite clear that, similarly to powerfulness, interest is often not directly connected to liking, and probably even less connected to beauty aspects, especially in modern art where challenge, the promise of insight, and actual insight are much more important. These now more-focused concepts are very closely linked with interest as they are perfect triggers to attend and elaborate an artwork, and interest seems the key concept for such curious behavior (Silvia, 2008). The type of artwork and especially the meaningfulness of an artwork might modulate the relationship between liking and interest. Whereas world-renowned paintings create a natural interest at the same time as being liked, contemporary artworks might be primarily qualified

TABLE 4 | Linear mixed-effects analysis for models aiming to predict *liking* by the four aesthetic experience variables 3D impression, emotional value, interestingness, and powerfulness.

Tested model	df	AIC	logLik	R^2	$p(\chi^2)$
Base *M*odel #0	8	1442	−713	0.589	
Model #1a	13	1433	−704	0.604	0.0021
Model #1b	13	1402	−688	0.628	<0.0001
Model #2	**18**	**1400**	**−682**	**0.637**	**0.0305**
Model #2	**Estimate**	***t***	**df**	***p***	**Cohen *d***
FE 3D impression	0.014	<1	388.5	0.7262, n.s.	–
FE emotional	0.075	1.50	314.5	0.1335, n.s.	–
FE interesting	0.425	4.23	6.4	0.0047	0.3818 "medium"
FE power	0.363	5.34	8.7	0.0005	0.4820 "medium"

Base Model #0 contains only these four variables as fixed factors, plus participants and artworks as random intercepts. Model #1a and Model #1b add random slopes for interestingness and powerfulness by artworks and participants, respectively. Model #2 combines Models #1 and #1b by adding random slopes by artworks and participants. Best-fitting model, while being parsimonious, is indicated by bold face. FS, fixed slopes (fixed factors); df, degrees of freedom; R^2, coefficient of determination, based on the likelihood-ratio test; $p(\chi^2)$, probability of accepting a significant effect despite a non-existent difference regarding the more complex versus the one-step less complex model. For the best-fitting model, statistics about fixed effects are given in detail. Effect sizes (expressed as Cohen d) are qualified according to the suggestions of Cohen (1988).

as being interesting but not primarily liked. An again-different relationship can be observed for more kitschy art, which is often liked but does not trigger too much interest (Ortlieb and Carbon, 2019). The elaboration over time and inspection might also change the flexible relationship between interest and liking, with challenging art being liked only after deep elaboration (see Carbon and Leder, 2005) and less innovative art being devalued after sufficient elaboration (Belke et al., 2015) or after one has "solved" the message of a picture (Muth et al., 2015b). Only the joint effort of many research groups investigating the details and the moderators of such essential relationships among aesthetic concepts, which were and still are the cause of many endless debates in the field of empirical aesthetics, might uncover the real drivers for and the nature of aesthetic experience.

Finally, it is important to stress that effects found in the present study cannot be easily generalized to other artworks (for instance, to more figurative, more popular, more easy-to-process art), other settings, and other parameters. The study, however, illustrates how impactful certain variables – such as viewing distance, elaboration, and even whether viewing distances are prefixed or freely chosen – are with respect to experiencing art and triggering Aesthetic Aha moments. Particularly, the perfect viewing distance allowing for "optimum" aesthetic experience probably depends very much on the specific material inspected: Most large-scale pictures, like the ones used in the present study, ask for much larger viewing distances than some incredibly detailed small-sized pictures (e.g., pictures from the Dutch 16th-century naturalist miniature tradition), which develop their full aesthetic impact only when inspected very closely.

CONCLUSION

If we aim to understand and investigate true art experience as a rich phenomenon of deep elaboration and strong affective and cognitive impact, we first need to trigger such experiences such as art epiphany (Carbon, 2019). We can gain knowledge about the typical factors triggering and supporting such experiences by analyzing the typical settings of art galleries and the behavior visitors show in them by employing observation studies in the field. On the basis of this knowledge, we can implement ecologically valid settings and employ the required measurement strategies recruited from the powerful toolbox of experimental and systematic empirical research. This strategy assists the aim of approaching closer to the real phenomenon of art experience without losing scientific control.

DATA AVAILABILITY STATEMENT

The datasets generated for this study are available on request to the corresponding author.

ETHICS STATEMENT

The study was given ethical approval by the local ethics committee of the University of Bamberg (Bamberg, November 23, 2014, signed by the chairperson of the ethics committee). The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

Idea, planning, procedure, analysis, report, writing, critical reflection, and literature review was done by C-CC.

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Aesthetic Attributes of Museum Environmental Experience: A Pilot Study With Children as Visitors

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The research project is a small pilot study of the restorative aspects of museum experience on children; these include the sense of fascination during the visit. Museum environmental awareness was a latecomer to Museum and Visitor studies but is now highly valued. No longer just the "objects" contained in the museum fascinate but also the environment itself becomes an object of fascination. Some authors provide a clear categorization of feelings experienced by the visitor during a museum experience and suggest a framework with four categories of satisfying experience: objective, cognitive, introspective, and social. In designing our study, we began with the definition of museum experience and added a fifth category of "environmental experience." With this term, we refer to the extent to which the physical environment in and around a museum affects visitors. Indeed, our aim is to analyze the visitor's stream of feelings and opinions during a museum visit (specifically, the MART—Museum of Modern and Contemporary Art of Trento and Rovereto) to find a proper definition of the aesthetic elements characterizing the "environmental preference." To do this, we referenced classical and experimental paradigms of Environmental Psychology applied to a museum context and building aesthetic researches, combining qualitative and quantitative approaches. The case study involved 41 children, 20 male and 21 female, from two primary school classes in Rovereto (Italy); the average age was 8.3 years old.

Keywords: environmental psychology, architecture, design, children, museum learning, natural built environment, restorativeness, aesthetics

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INTRODUCTION

In this paper, we review the development of the ways that the relationship between museums and visitors can be understood. Starting from the definition of the "museum experience," we underline a quite underdeveloped issue in museum studies, that is the relevance of the museum physical environment, also considering the museum as a restorative environment (Packer and Bond, 2010). The museum experience is changing as a result of the recent interest in the emotional nature of museum visiting; some museums are moving away from formal, didactic models of museum learning toward new models that embrace experimental activities. There is a great deal of curiosity about the emotional interactions between visitors and a museum's exhibits. In recent years, educational and environmental psychology have underlined the relevance of the attributes of the learning setting, searching for the correlation between students in a given context (Linnenbrink-Garcia and Pekrun, 2011). Subsequently, we describe a small case study, aimed at extending our

understanding of the ways in which the nature of a museum building can impact young visitors. In particular, we pay attention to the children's visiting experience within the museum, investigating the interpretation of the children's aesthetic experience within the museum environment, during and after museum learning activities.

Museums as we know them today evolved from the so-called "Cabinets of Curiosities" that began appearing in the 1500s. These "cabinets" were typically in the hands of wealthy collectors, and some of the collections formed the base on which a number of important existing museums were created. Over time, publicly accessible collections of objects and other artifacts gained value for their potential role in informing the wider community about culture, history, and science. Initially, the relationship between museums and the community was likely to be one of giving rather than interacting. The museum "improved" the visitor and was a source of authoritative knowledge. In recent decades, there has been a shift in the way the relationship is understood. There has been an increasing recognition of the richness of the ways in which a museum might influence people who interact with it. The museum asserts its public service role and places education at the center of that role. According to the ICOM Statutes, adopted by the 22nd General Assembly in Vienna, Austria, on 24 August, 2007: "A museum is a non-profit, permanent institution in the service of society and its development, open to the public, which acquires, conserves, researches, communicates and exhibits the tangible and intangible heritage of humanity and its environment for the purposes of education, study and enjoyment."

Therefore, education is universally considered one of the main aims of a museum. "Museum Education can be defined as a set of values, concepts, knowledge and practices aimed at ensuring the visitor's development; it is a process of acculturation which relies on pedagogical methods, development, fulfillment, and the acquisition of new knowledge" (Desvallées and Mairesse, 2010, p. 31). It seems that the visiting experience can lead to long-term introspective and cognitive outcomes, especially in terms of social awareness (DeWitt and Storksdieck, 2008). During the museum experience, the visitors are involved in a process of discussion, interpretation, and negotiation of meaning in relation to the cultural heritage embedded in the place; they are part of an "interpretative community," where meaning-making is mediated between individual and collective interpretations (Hooper-Greenhill, 2000). Paris (1997) suggests that social interaction facilitates visitor learning, enhances motivation and negotiation skills, and monitors accomplishment.

This premise is important to understand our research design and the interest we have in evaluating an aesthetic experience during a learning activity. The museum educational purpose affects all the activities that take place inside the museum and justifies the institutional choices of architecture and design. Moreover, these factors determine the interaction, cognitive understanding, and learning achieved in the transmission of museum contents. There are two reasons why our case study involves a sample of children: the first concerns the scarce literature of children visiting experience, although many of the museum's educational and learning activities are dedicated to the schools' target. The bond between museum and visitors is not taken for granted but is strictly related to the involvement with the community in which people live. This link should be encouraged and motivated emotionally during childhood. Bourdieu (1967), in his studies dedicated to the culture audience, tells us that we must create the "affection for cultural heritage" in children early in life because it is only when the presence of culture is registered in everyday life that it is missed (or sought) in adulthood. The educational department of MART is a national model in Italy. For this reason, we found it interesting to investigate the "environmental experience" during some learning activities dedicated to local primary schools.

The same lack of studies has been found regarding the issue of Restorativeness. The theory of Restorativeness has an aesthetic basis, which refers to the concept of fascination (Kaplan, 1987). Although we understand how Restorativeness affects adults, few studies have sought to describe the relationship between children and urban places or how this relationship could help to reexamine the cultural and learning environment. In our research, which focuses on the museum environment during children's learning activities, we investigated the museum through its fascination attributes. In relation to learning settings, researchers highlight that providing children with access to environments that enhance and not merely support restorative processes, and which facilitate or optimize development and performance, is clearly beneficial to children (Bagot et al., 2015; Kelz et al., 2015).

Reasons to Redefine the Aesthetic Episode During the "Museum Experience"

Through this research, we investigate the relationship between the aesthetic episode and the museum experience. In particular, we ask ourselves how and to what extent, during a museum visit, the environment participates in the success of the aesthetic episode. In fact, there is often a process of aesthetic evaluation of museum architecture and design in which the visitor is involved and at the same time not very aware. Often, the focus on museum educational dimension overshadows the context, yet the two are closely related (Mastandrea et al., 2019).

In the last 30 years, the concept of "education" in museums has been progressively expanded by museum professionals and academics to create a theoretical and methodological framework for interpreting learning activities in the museum environment (Allard and Boucher, 1998; Hein, 2002; Leinhardt et al., 2003). Dierking and Falk (1992, 2000) developed a "contextual model of learning"—the personal, sociocultural, and physical contexts, within the flow of time. Csikszentmihalyi and Robinson (1990) stressed the significance of the aesthetic experience, applying their "flow" model to museums. "Flow" is described as an authentic experience that occurs if people are deeply involved in a creative process. The original account of the state of flow has proved remarkably strong, confirmed in studies of art and aesthetic experience and many other recreational activities. Rather than focusing on the person, unrelated to context, "flow" research emphasizes the dynamic system of the person and the context.

Pekarik et al. (1999) studied the expectations that visitors bring to a museum and described the various elements that comprise the subsequent experience. Because of the fluidity and multidimensionality of the phenomenon, they developed the following four-part framework to encompass the concept of "museum experience:"

- Object experiences: in which the individual focuses on the content, the object, or "the real thing;"
- Cognitive experiences: in which the individual gains information or knowledge;
- Introspective experiences: in which the individual turns inward, to personal feelings, memories, and experiences, with a sense of belonging or connectedness;
- Social experiences: in which the individual interacts with family members, friends, and often museum staff.

Yet, context is extremely important. Combs (1999) suggested that learning and recreation are the primary reasons behind a museum visit. The experience of learning in a museum becomes one of discovery overlaid with personal and social elements that are also pleasant and enjoyable. Subsequently, visitor research has adopted this interactionist perspective and focuses not only on the activities carried out by visitors at the museum but also on the ways the museum environment in which the activities take place affect the visitors. This approach considers the observation that architecture and environmental design can affect people's emotional states as well as the way they behave. Recent research with museum visitors has supported the notion that visiting art museums and exhibitions has an emotional impact on individuals exceeding beyond what is triggered by the objects on display. Observing extraordinary objects, moving in an unusual space, being surrounded by people—friends or strangers—who are similarly involved in interpreting what they see, these are all factors contributing to the pleasure of the experience.

We consider that the aesthetic process can also take place inside the "museum context" and because of it, despite the fact that classical theories focus primarily on evaluating the aesthetics of the object. The first psychologist to put forward an empirical approach to aesthetic appreciation was probably Fechner (1876), the creator of the "aesthetics from below" concept that focuses on the way in which an object's perceived structural characteristics are appreciated by the observer. For Fechner, an object's structure contains intrinsically aesthetic qualities such as proportion, symmetry, and complexity, which cause an individual to have a specific reaction and aesthetic preference (Tinio and Leder, 2009). In contrast, a subsequent "aesthetics from the top" model concerns an individual's knowledge, expertise, emotional background, and personality traits, which also have a role in shaping the final experience (Mastandrea, 2014). In the 1970s, Berlyne introduced his psychobiological aesthetic theory based on the concept of "excitement" or arousal as a stimulus for curiosity and exploration. Object attributes such as originality, uncertainty, and ambiguity were considered legitimate elements in shaping the aesthetic experience (Berlyne, 1974). Recently, especially with the development of neuroaesthetics, a greater interest in the emotional component of an aesthetic experience has appeared in relevant literature. Leder et al. (2004), for example, suggested a descriptive model that describes how information is processed during an aesthetic experience on three levels: perceptive, cognitive, and emotional. The boundaries between cognitive and emotional experience become more subtle, and the aesthetic judgment is hardly distinguishable between subjective and objective opinions. Ten years later, Leder and Nadal (2014) reviewed the model highlighting the role of contextual factors on aesthetic experience. According to the authors this includes two aspects: the aesthetic judgment, based on cognitive process and correlated to the interpretation of the object (the artwork), and the aesthetic emotion, based on the emotional path experienced by the preceptor during the entire experience. The two could be confused, overlapped, or diverged in the preceptor's mind.

The aesthetic episode also hides itself behind physiological sensations (Scherer, 2004): we can detect numerous examples of these reactions by observing behaviors and attitudes of visitors. Pekarik (2002) launched a reflection in the Curator Journal on the mental state involved in museum learning: "The mental state involved in emotionally responding to the object can be very different from the mental state involved in reading and thinking. While our desire to effectively facilitate meaning pushes us to emphasize communication through language, many museum experiences are firmly rooted in feelings that are not enhanced by words" (Pekarik, 2002, p. 263). Pekarik's intention was to highlight the emotional response to a museum exhibit, suggesting that the visitor's learning process could be much more about "feeling" than "thinking" or "explaining." Hooper-Greenhill (2007) affirms that while learning in a museum, "mind and body work together;" it is clear that children experience the visit as "a physical experience, which engages their feelings and emotions and allows their minds to open up to new ideas" (p. 165). Roberts (1991, 1992) pays attention to visitors' affective responses to their museum experience, such as sudden comments like "I really enjoyed it!," "I had fun," "It was boring," "That visit really moved me." Affective responses can also be demonstrated in visitors' physical behavior such as the continuous or recurrent observation of an object. Some behaviors indicate an affective engagement by returning to look at an object, showing it to someone else, discussing its value, and comparing opinions with others. Presence and movement in the museum environment can be a clear indicator of the involvement of visitors.

It becomes increasingly difficult to categorize the sensations described by visitors, yet in these, we continually find important indicators of aesthetic experience to encourage future analysis. For example, the sense of inspiration, stature, and spirituality culturally attributed to aesthetic experience (Zeki, 1993, 2002) has a place in the museum experience. Some recent articles have shown that these experiences give the visitor a temporary sense of separation from reality and then a subsequent return to everyday life with renewed awareness: the sensation of being part of "something bigger" (Packer and Bond, 2010). In the light of these testimonies, the correlation between the aesthetic episode and the environment, according to the principles of Restorativeness, appears strong.

Experiencing the Museum Environment: An Increasingly Important Aspect

Although the disciplines of Environmental Psychology and Visitor Studies have discussed the theme of the museum environment and the way in which it affects visitors at considerable length, we are still far from a recognized definition of what constitutes the "museum environment." Among the 21 fundamental concepts of museology listed in the reference tool *Key Concepts of Museology* edited by ICOM's International Committee for Museology (ICOFOM), we find the term "architecture" but not "environment." "Architecture is defined as the art of designing and installing or building a space that will be used to house specific museum functions, more particularly the functions of exhibition and display, preventive and remedial active conservation, study, management, and receiving visitors. Since the invention of the modern museum, from the end of the 18th century and the beginning of the 19th, while old heritage buildings were also being reconverted for museum use, a specific architecture evolved that was linked to the requirements of preserving, researching and communicating collections through permanent or temporary exhibitions" (Desvallées and Mairesse, 2010, p. 24).

From a psychological perspective, it is useful to see the museum institution as an environment that "hosts" the visitor. Put more generally, any physical context becomes an essential part of the perceived experience, and every experience is a part of an individual's interaction with their environment, both human and physical (Dewey, 1934). For this reason, the disciplines of Environmental Psychology and Visitors Studies are trying to expand the debate about the ways in which a visitor's experience is moderated by the architecture and physical design of a museum. For example, Tröndle et al. (2012) showed that the experience of art in museums is closely related to the itinerary of visitors through space. Mastandrea et al. (2009) showed how the research environment (being in a laboratory rather than in a museum) changes the perception of art. Studies in which the museum environment is thought in terms of "customer experience" are more frequent. Doering (1999) discusses visitor needs in relation to a "setting" or "servicescape" that support and enhance visit experiences. "According to Bitner (1992), the servicescape, or service environment, includes ambient conditions such as temperature, lighting and noise; spatial layout and functionality; and signs and symbols such as the quality of furnishings which explicitly and implicitly convey expectations and 'image.' She suggests that these features influence customers' (or visitors') cognitive, emotional and physiological responses to the environment" (Packer, 2008, p. 34; Bitner, 1992).

We assume that the time has come to think of an "environmental experience," in which the individual interacts with the museum spaces, moving around and enjoying the building architecture and the exhibition design in terms of aesthetic impact. Museum design is fundamental for a successful museum experience. A museum visit unfolds through movement in space: the environment determines how visitors explore, engage, contemplate, reflect, and understand exhibitions. The entire educational message depends on the perception of space. According to Nasar (1994), some of the architectural characteristics that are beneficial to the individual are the following:

- Visual quality: a space that is interesting, but not confusing, where its intriguing points are not immediately obvious but are revealed as people move through the space.
- Balance of order and complexity: individuals tend to like spaces that are neat and only moderately complex. A space is complex when there is variety in the spatial elements arranged without many color patterns.
- Naturalness: the implicit or explicit reference to nature, in the architectural structure, in the design choices, and also in the environmental conditions (such as natural light, the presence of water, adequate ventilation).

"The medium is the message" is a phrase coined by McLuhan and Fiore (1967), meaning that the form of a medium embeds itself in any message it wishes to transmit, creating a symbiotic relationship by which the medium influences how the message is perceived. Museums convey to visitors the message of cultural heritage and its values through cultural content (objects) and by facilitating certain cognitive, introspective, and social experiences. However, the museum experience is more than this; it incorporates the influences of the contextual physical environment. Thus, what is learned from exposure to a museum is a process of what the French literature describes as "Mediation Culturelle" (translated into English as Cultural Mediation or Interpretation). In the French literature, the term mediation is frequently used to refer to "a whole range of actions carried out in a museum context in order to build bridges between that which is exhibited (seeing) and the meanings that these objects and sites may carry (knowledge)" (Desvallées and Mairesse, 2010, p. 47).

With the new wave of contemporary museums and exhibition spaces developed by "starchitects" (the so-called "the Bilbao effect"), the relationship between the museum, the visitor, and the structure's architecture and design can no longer be ignored (Rybczynski, 2002; Plaza, 2007). The architecture of the building and the design of the exhibition spaces mediates the messages from the objects contained in the museum (Sirefman, 1999; MacLeod, 2005). The museum architecture itself becomes a medium. "Post urban museum architecture cannot simply be a container; it must have content of its own. As a building in and of itself, the architecture need not compete with the art or artifacts on display; in fact, it can enhance the exhibition experience. These two needs container and architectural presence are not mutually exclusive; a museum can at once be a significant edifice and be sympathetic to its required functions" (Sirefman, 1999, p. 298). For this reason, we can say that the museum environment can be considered a medium itself (Ponzini, 2011, 2014). Increasingly, museums are consciously designed and built with the mediating role in mind.

The Museum as a *Restorative* Experience Is Based on Fascination

In his discussion of attention, James (1892) observed that voluntary attendance to some stimuli took effort, an effort that we experience "...whenever we *resist the attractions* of more potent stimuli and keep our minds occupied with some

object that is naturally unimpressive" (James, 1892, p. 224). This sense of effort has been understood throughout the ongoing study of attention to lead to fatigue. According to Attention Restoration Theory (ART) (Kaplan and Kaplan, 1989), for example, the need to continually focus attention produces mental exhaustion. This state, called "directed attention fatigue," can give rise to irritability, anxiety, anger, frustration, inability to perform cognitive tasks, and increased errors in performance. Nevertheless, attention fatigue can be overcome in so-called "restorative environments" that evoke effortless attention (Berto et al., 2010). An important aspect of research findings linked to ART is that people often experience nature as being restorative. Being in natural settings (or even looking at images of natural settings) can lead to a reduction in mental fatigue. Natural environments arousing "fascination," a condition in which a person can reflect in a state of *effortless attention*, abound. Fascination is the main attribute that an environment requires to be considered restorative, and it plays a crucial role in attention restoration theory (Kaplan, 1995). Fascinating stimuli are attractive, prevent boredom, and, most importantly, enable people to function without directing their attention (Berto, 2005).

Some studies have shown that museums have a high potential for fascination. Packer and Bond (2010) noted a significant overlap between museum attributes and those suggested by Kaplan (1995) as creating a restorative experience. The findings set out in their study indicate that for some people, museums can be as restorative as natural environments, thus providing insights into the factors that contribute to the visitor's well-being. The phenomenon of restoration was further explored by questionnaires, collected after a visit, and from which the authors discovered that most visitors reported having attained a sense of relaxation and renewed ability to deal positively with life (Packer, 2008). It follows that a restorative condition can be extremely helpful for visitors involved in a museum learning process.

The relationships between the level of perceived restorativeness of an environment and its aesthetic evaluation have been documented in some studies. Galindo and Hidalgo (2005) revealed that "harmony," "openness," "brightness," "suitability for leisure," and "meeting place" correlated with perceived restorativeness. Much has been written about the selection of "favorite" places (Korpela and Hartig, 1996; Korpela et al., 2001) and on aesthetic judgments of places (Purcell et al., 2001; Peron et al., 2002). Hidalgo et al. (2006) identified categories for attractive and unattractive urban places. The research involved residents from two European cities who were asked to identify the most visually attractive and unattractive place in their city. The five main categories investigated were cultural–historical places/landscapes, recreational places for leisure and/or walking, places with a view, housing areas, and industrial places. Historic–cultural (48%) and recreational places (33%) were experienced as more aesthetic and restorative. These results have several implications. First, the study suggests that a museum environment could have the potential to be a restorative place due to its "historic–cultural" vocation and role. Second, the potential of a museum as an environment for learning might be enhanced because of the recreational aspect of a visit. Moreover, "Culture" and "Recreation" are two of the main categories of reasons given for visiting a museum in general. Using open-ended questions, Korpela (2002) asked children about their favorite places. The preference was for locations where activities and social interactions were available.

Kaplan et al. (1993) returned to past research and reanalyzed focus group comments about the museum experience, finding evidence of Restorative attributes:

- Fascination: places that require little or no attentional effort,
- Being away: taking a break from the daily routine,
- Extent (Scope and Coherence): a place that is rich and coherent enough to be explored,
- Compatibility: the extent to which an environment supports your inclinations and aims.

Based on an additional study, the researchers expanded the range of restorative outcomes to include feeling refreshed, restored, thoughtful, relaxed, and not feeling tired or worried. Packer and Bond (2010) analyzed the restorative attributes and benefits described by visitors in some important public learning institutions: art galleries, botanical gardens, parks, zoos, aquaria, and historic sites. On the basis of the study, the authors drew up a list of motivations that bring visitors to these cultural and recreational places: "learning and discovery," "passive enjoyment," "restoration," "social interaction," and "self-fulfillment."

Contemporary research has begun to explore the role of restorative environments in the school setting (Bagot et al., 2015; Berto et al., 2015). If some aspects of current educational experience serve to train children in effortful directed attention, while others allow for the exploration that comes from involuntary attention, it is important to know which balance exists in museums. How might a visit to a museum be structured to maximize the cognitive, emotional, and social benefits to a child? The museum environment, through the attributes that trigger "fascination," might induce in children a condition of effortless attention and consequently might also facilitate the learning process.

A PILOT STUDY

This introduction has briefly outlined the progressive expansion of the museum communities' understanding of the various psychological ways a museum might affect a visitor. One of the effects we have described at length is the way an environment can facilitate recovery from the fatigue caused by the effort of focusing attention on events or activities that do not of themselves attract attention. This case study, involving a small group of children engaged in a specially structured school visit at the MART, Museum of Modern and Contemporary Art of Trento and Rovereto, aims to investigate their perception of the museum as a restorative environment and its connection with children's whole museum experience. In the context of discussing the education of children, we have indicated the restorative aspect of the school environment as attracting recent research

attention. We have also put forward the general hypothesis that the architecture and design of a museum might provide restorative elements that affect other aspects of the aesthetic experience relevant to education.

Promote the Architectural Heritage of MART: A Collaborative Museum Learning Project

The study is based on the evaluation of the museum visit as positive, profound, and enriching experience. We started from the assumption that a true museum experience cannot be reproduced in a laboratory. To increase the ecological validity of the founding, it was necessary to implement the study inside a museum as a real school learning program. DeWitt and Storksdieck (2008) demonstrated that cognitive and affective learning can occur as a result of class visits to out-of-school settings, such as the museum experience. They highlight that "learning outcomes are fundamentally influenced by the structure of the field trip, setting novelty, prior knowledge and interest of the students, the social context of the visit, teacher agendas, student experiences during the field trip, and the presence or absence and quality of preparation and follow-up" (p. 182). With MART Education Office approval, we created a special learning program called "EMOZIONI IN MOSTRA!," which was included in their annual program for local schools. This inclusion undoubtedly contributed to promoting the initiative, encouraging enthusiasm and support from all participants: parents, teachers, and students.

Every learning school program includes educational objectives relating to acquiring skills, knowledge, aptitudes, etc. Some of the educational goals shared by our research group, the museum staff, and schoolteachers are inviting the children to take part in a museum experience inside MART and develop an idea of architectural heritage; explaining the role of the architect, the characteristics of architecture and interior design, encouraging the use of the senses to perceive the museum environment; improving children's vocabulary to describe the MART architecture; improving children's aesthetic judgment ability; and encouraging them to give their own graphic interpretation of the museum experience.

When designing the visit, we paid particular attention to the part dedicated to the learning activity (timing, modality, and contents) to facilitate the aesthetic experience. Following the analysis of Shusterman (1997), the case study was organized in order to highlight three main dimensions that confer an aesthetic quality to an experience: an evaluative dimension, that it involves the perception of an object (museum architecture); an affective dimension, about engagement, attraction, and attention (the visit and its learning activities); and a semantic dimension, in which an aesthetic experience became an interpretation via a meaning making process (the postvisit activities and the drawing realization) (Schorch, 2014).

All the activities were designed to allow children to give us their interpretation of the environmental museum experience. From the psychology of art to neuroaesthetics, the concept of interpretation has always been present in aesthetic debate. Arnheim (2002), and the Gestalt school before him, clearly states that artistic objects share with artists and users an interpretation of himself, suggested by the structure and the integrated shape qualities. The interpretation is one, and there is only one way to receive it correctly. Subsequently, Zeki (2004) recognizes the ambiguous interpretation: the fact that it is not necessary to achieve a "correct" or "unanimous" interpretation but recognizing the existence of many and evolving interpretations is a positive fact. Nowadays, interpretation is a recognized cognitive process that is part of the aesthetic experience and its search for meaning. Leder and Nadal (2014) assessed interpretation as an individual dimension while acknowledging the coexistence of a social dimension. In many aspects, art and aesthetics serve social functions, and museum environments itself can fulfill the need of social interpretation (Bourdieu, 1979).

During the educational program, children are accompanied in forming an interpretation of the museum experience individually, as a person, and collectively, as a class group. Within this interpretation, we look for the elements that refer to MART museum environment. "All material elements of an exhibition and the respective framings (building, specific location within a certain type of architecture, style of announcements) define the ways in which an exhibition becomes meaningful for the individual visitors, connecting the intended message with their specific repertoires of associations and connotations, and the pertinent and relevant social facts. Thus meaning and information for an exhibition visitor can only be produced within the complex and necessarily positive interaction of his/her own categories of thinking and experiencing and the forms offered in the exhibition (Umiker-Sebeok, 1994). The visitor will 'see' what is shown, and will see and interpret whatever is there within his/her own background of experiences and pre-knowledge. [. . .] The idea that everything in a museum, all artifacts or object elements in the museum surrounding, exert sign functions is basic to an understanding of the museum as a semiotic communications system (Stránský, 1991)" (Weltzl-Fairchild, 1995, p. 66).

RESEARCH AIMS

During the research process, we focused exclusively on the architecture and design of the building, as an example of architectural construction, conceived and executed according to precise choices of style, meaning, purpose, and audiences. This aspect was considered interesting by the museum institution precisely because it had never been experienced before: this was an opportunity to test the MART's Architectural Heritage potential. What are the factors that influence responses to the MART architecture and design? Galindo and Hidalgo (2005) distinguished attractive places from both aesthetic and restorative points of view. They showed that Nasar's aesthetic attributes characterized the most attractive place in terms of openness, mystery, complexity, order, vegetation, maintenance, style, and perceived use. All the most restorative places presented these aesthetic criteria. Considering these results, we elaborated the following research aims. The first was to investigate the perceived

restorativeness of a visit, by distinguishing among different physical environments inside the museum: the "Dome," the "Bridge," and the "Gallery."

These three different environments were chosen in line with Nasar's (1994) specification of the three attributes that a beneficial environment requires, namely, visual quality, the balance of order and complexity, and naturalness. Visual quality, which refers to a space that is interesting but not confusing, could be the most important attribute of the "Dome" to be considered in our case study. Considering the second attribute, that is the balance of order and complexity, it can be argued that the "Gallery" was the museum space that best represents this attribute, with white walls and natural light, which allow one to be immediately drawn to the artworks on display. Finally, naturalness, the imitation of natural elements, openness, and natural light, was an attribute present in all the three locations. The "Dome" has the sky and the fountain with running water; the "Bridge" recalls the shape of a tree and also contains a real tree; and the "Gallery" has large windows through which you can see the mountains and the forest and also has a wooden igloo.

These three attributes can also relate to restorativeness and its subdimensions. Visual quality, given its definition, can be considered to be connected with scope, fascination, and coherence. The balance of order and complexity recalls the dimension of coherence and, to some extent, fascination. Finally, naturalness is connected with being away and fascination.

These considerations lead to our research hypotheses: the museum architecture and design, given its physical characteristics, should show high level of restorativeness. Moreover, the different physical environments in the museum should differ in the level of the different subdimension of restorativeness. Specifically, the "Dome," with higher level of visual quality, should show higher level of scope than the other two environments and a moderate level of fascination and coherence, and the "Gallery," showing a good balance of order and complexity, should show higher level of coherence and fascination than the other two environments. All three environments, given the high level of naturalness, should be high in fascination and being away.

The second aim was to explore children's "museum environmental experience," more specifically, the way perceived restorativeness and preference reflected in the individual and collective interpretation/representations produced by the children.

The exploration of children's "environmental preference" was conducted through different activities involving a direct self-measure of preference during the visit and a social activity called "the negotiated drawing" after the visit.

The exploration of children's "environmental experience" was conducted through an individual activity called "the collage inside the head." We classified their interpretation/representations of the whole museum experience, considering the four components, plus one: objective, introspective, cognitive, social, and environmental (Pekarik et al., 1999).

Regarding the environmental preference, we expected a correlation between the type of museum spot declared as "preferred" and the number of times this has been represented by children. Concerning the "environmental experience," we assumed that the category has been represented on a par with the other four: objective, cognitive, introspective, and social.

MATERIALS AND METHODS

Participants and Procedure

The research involved 41 children, 20 male and 21 female, from two primary school classes in Rovereto (Italy); mean age was 8.3 years old (SD xxx). The project comprised two phases: the visit (a tour in the museum) and the postvisit activity (a school activity after the museum visit). We want to specify that the group of children was a convenience sampling. We know that convenience sampling is not recommended for research due to the possibility of sampling errors and the lack of representation of the population. In these specific educational circumstances in partnership with the Mart, practical sampling was the only possible option.

Stimuli: MART's Design and Architectural Characteristics

MART was designed by the architect Mario Botta, in collaboration with the engineer Giulio Andreolli. The building is famous for its large glass and steel dome above the central access hall to the museum. Our research focused on three different environments considered representative of MART architecture in terms of its open spaces: "the Dome," "The Bridge," and "the Galley" (**Figures 1A–C**).

The environment and the visit contents were selected starting from two essays about the architecture of Mario Botta. The first book, an "unofficial" essay property of MART's Educational Office, was chosen for its interviews with Mario Botta; the second because it was written by the architect himself (Botta and Andreolli, 1995). Both books include the direct words of the architect of MART and his creative approach. In them, he describes in detail the artistic vision and stylistic choices underlying the museum design.

Below, we describe the contents of the guided tour, extracted from the literature listed:

- *The Dome*. A long and narrow corridor connects the main road and MART main entrance. Mario Botta describes this corridor as an "umbilical cord" because the city of Rovereto encloses the museum as in a womb. In it the museum grows and evolves, disclosing its full potential. The architect uses this image to describe the close relationship between the museum, the city, and its citizens. Building such a long and narrow entrance, the architect wanted to play with contrast, surprising the visitor with the discovery of somewhere unexpected: the large circular square covered by a majestic dome of glass and steel. The dome has a hole at the center, from which it can filter sunlight and rain is filtered. It is difficult to know if you are outdoors or indoors. Mario Botta says that "we are a little inside, but also outdoors." "The covered square may look like an outdoor

FIGURE 1 | The three different physical environments inside the MART museum: the Dome **(A)**, the Bridge **(B)**, and the Gallery **(C)**. Two examples of negotiated drawing, representing the Dome **(D)** and the Gallery **(E)**. Two examples of collage. Panel **(F)** represents the Bridge: "When I think of the museum, I'm afraid to fall down." Panel **(G)** represents some question marks and exclamation points: "When I'm at the museum, I think to exclamation and questions!" **(H,I)** Two examples of negotiated drawing, representing the Bridge during the visit learning activity.

space but is also a transition from the city and the museum." Technically, we are still outside the museum but not quite in the town, ready to enter. "The square: upon entering from the street you immediately feel like you're in a special place, prompting immediate reflections on its nature." What is a museum? What is there inside? What can I do there? From the square, it is possible to access various museum spaces, with a series of doors all along the perimeter: "This beating heart is the hub through which all the various activities are functionally distributed: the museum, the library, the administration, the café, the reserved teaching spaces and the City auditorium."

- *The Bridge.* This is the entrance to the museum: the real protagonist of the space is a staircase that ends with a glass bridge. "From the stairs, you can access the different levels (floors) through the side passageway or through the walkway on the top floor; the passageways give visitors an idea of the size of the vertical section of the building." Via this walkway, the visitor crosses the museum at its highest point. Once on the bridge, the visitor can see the full breadth and height of the building, with the thrilling sense of a void. Mario Botta says: "The emptiness of the two juxtaposed vertical staircases make a vertical spine." The staircases designed by Mario

Botta allude symbolically to vegetable life, a solid, natural, branching structure.

- *The Gallery*. Mario Botta refers to the design choice for these spaces as "Exhibition hall nudity. . . where the architecture takes a step back to let Art and its protagonists talk." The architect thinks of these spaces, generically bright and totally white as a stage: the works are actors playing their part in Art History. Nothing can distract the visitor from the observation of the artwork, not the wall, not the floor or the ceilings. "Inside the exhibition galleries, where the artworks are exhibited, appropriate lighting and neutral architecture prevent a babble of different languages and facilitate the direct contact between the art and the visitors."

The Visit

The visit was scheduled for a weekday morning. In collaboration with the MART Educational Office, we chose a time when the museum was not crowded. In addition, MART's Educational Office ensured no other tours were taking place in the same exhibition spaces during the visit. Thus, our activities were not interrupted or hampered in any way. The children were able to visit the museum in a peaceful and quiet atmosphere. The children moved in a group and were accompanied throughout the visit by an educator, so problems of wayfinding were mitigated.

The children's museum tour was organized as follows to capture the children's attention. At the beginning of the visit, each child received a small brochure with a selection of drawings and quotations from Mario Botta's books. We asked them to imagine they were a group of judges, experts in architecture, invited to the museum to evaluate Mario Botta's architecture and design. The children were guided in an architectural walk through three different museum locations: the Dome, the Bridge, and the Gallery. The total duration of the visit was 60 min. At each location, the activity was carried out in the same way: 7 min of architectural explanation, 3 min of "physical exercise," 5 min to complete an assessment scale, and 5 min to get to the next place. The expression "physical exercise" means brief motor activity to engage the children: walking, running, throwing an object, and sitting down. It is not a novelty that aesthetic experience and aesthetic emotion are linked to movement. Chatterjee and Vartanian's (2014) propose a model of "aesthetic triad" in which "the aesthetic experiences derive from the interaction between sensory-motor neuronal systems, evaluation of emotions and knowledge of meaning" (Leder and Nadal, 2014).

- *Activity 1 in the Dome*. After the architectural and design explanations, the children were invited to spread out around the fountain. On a signal, a hand clap from the educator, they began to walk in all directions, and then, with another clap of the hands, they changed direction. The class was then invited to sit around the fountain and to think about and discuss how they felt about moving in this space: walking in all directions, choosing a destination, changing it, and then gathering together at the center again.
- *Activity 2 on the Bridge.* After the architectural and design explanations, the children walked in pairs and stood along the sides of the bridge against the glass barriers. The pairs were divided into two, and the educator gave the children a small piece of paper, red on one side and white on the other. The children were invited simultaneously to throw it into the void and watch the pieces of paper falling to the ground below. Then, the class was asked to sit and think about how they felt suspended on the bridge and what they understood about the size of that space.
- *Activity 3 in the Gallery*. After the architectural and design explanations, the children were invited to observe Mario Merz's artwork "Chiaro scuro" (1983) and think about the contrast of natural and artificial materials used by the artist. The children were invited to sit on the floor next to the igloo they liked best and were involved in a collective discussion: which of the two igloos seems more comfortable? Which of the two houses seems safer? In which of the two houses do I want to live? How do I feel about this artwork, in this room?

After each activity, the children were invited to reflect individually, without having to provide a response to the group (to avoid the possibility of influencing each other). At the end of every reflective moment, the children did the test.

The Postvisit Activity

The two postvisit activities in which the children were involved took place 2 weeks after the visit. The aim of the two activities was to help the children to formalize and express their interpretation of the "museum environmental experience." Mixed techniques of data collection with children are not new to research on museum learning: "These visual and written statements provide a remarkable record of the pupils' responses to the often wonderfully exciting things they have just experienced in the museum. Their work is spontaneous, fresh and immediate, capturing their joy and enthusiasm before these are overlaid by events" (Hooper-Greenhill, 2007, p. 185).

Denham et al. (2007) describes the main elements of children's emotional competence as a gradual path: among this awareness of emotional experience, discernment of one's own and others' emotional states and emotional literacy are not obvious for the age of 8 years old. In terms of aesthetic judgment and in case of aesthetic emotions, it could be difficult for children to express themselves. We have chosen the drawing tool to analyze the process of evaluating the environmental and aesthetic experience, thus avoiding verbalization: "children's drawings are used to access children's opinions and experiences by focusing on their personal narrations and interpretations" (Einarsdottir et al., 2009, p. 217). We considered drawings as an effective means for children to explore and communicate their content understandings and "environmental preference:" "Focusing on drawing as meaning-making moves away from the discourse of drawing as representation and, instead, focuses on children's intentions, considers the process of drawing, and recognizes children's drawings as purposeful: 'drawing thus becomes a constructive process of thinking in action, rather than a developing ability to make visual reference to objects in the world' (Cox, 2005, p. 123)" (Einarsdottir et al., 2009, p. 218).

- During the first activity—the "negotiated drawing"—the children were asked to explain, describe, and discuss their

point of view and listen to other points of view about the museum experience. For the first activity we chose, the "negotiated drawing" activity (Cox, 1994; Cox et al., 1995), it involves two participants drawing in pairs, on the same blank sheet. In this study, each child used three colors that could not be exchanged between them. In this way, children have to discuss what to draw and how to do the drawing. Specifically, they need to cooperate in completing the figures they wanted to draw, alternating in the use of the colors provided. Before drawing, each couple had to discuss and try to answer the following questions: "Whose places is this? What do I learn in this place? How do I feel in this place?," the place being the museum after the museum experience. At the end of the discussion, each couple was asked to draw: "My visiting experience at the museum."

- During the second activity—the "collage inside the head"—the children were asked to reflect about the same topic but individually. The children were involved in a book reading. Sitting in a circle, the children and the researchers read the book "What are you thinking about?" (Moreau, 2012) from the genre of "silent book," that is books without text. Silent books are produced to encourage spontaneous narration by children. The storytelling becomes a collaborative process based on the graphic illustrations. Every page in "What are you thinking about?" is illustrated with a head, and the reader sees the thoughts inside the character's head. After the book reading that introduced the children to the concept of visualizing thoughts, the children drew the shape of a face on a sheet of paper then, using small pieces of paper of various shapes and colors, made a collage to compose some "thoughts" inside the outline of the head. Researchers used the prompt "When I think of the museum…" and asked them to complete the sentence with their clearest memories of the museum experience.

Measures and Coding

Three different measures were used to analyze each aspect of the research: the first was a quantitative tool, whereas the other two were qualitative. The latter required a coding system designed specifically for research applied to the educational context:

- To understand the restorative attributes perceived by the children during the visit, we used the Perceived Restorativeness Scale—Children (PRS-ch), designed for school children (Berto et al., 2015). The scale was inspired by the Kaplans' theories, based on the ART and the adult version consisting of 17 items describing four restorative factors: being away, fascination, coherence, and scope. A 4-point Likert scale was used (from 0 to 4, where 0 = "completely disagree" and 4 = "completely agree" (Pasini et al., 2014). The children were asked to think about how true each statement was for them and to tick the number corresponding to their judgment. The PRS-ch scale was their way of judging: they gave each sentence (item) a 1 to 4 rating, depending on how much they agreed with the statement about each specific environment, from 0 to 4, where 0 = "completely disagree" and 4 = "completely agree." Preference was assessed as well, considered by us as an insight to the aesthetic preference, using a single item ("I like this place") and a 4-point Likert scale. We called these data the "environmental preference."
- The appreciation of museum architecture and design was evaluated back at school after the visit, using the "negotiated drawings" produced by the children. We have considered the representation of one space rather than another as a choice. The drawings were also used as an indicator of the most relevant memory of the museum environment and compared with the results of the "environmental preference."
- To understand the interpretation of "environmental experience" in the museum, we used the collages. These were classified by researchers into five categories taken from the Museum Experience definition by Pekarik et al. (1999): (1) objective: explicit reference to museum artworks; (2) cognitive: explicit reference to exhibit information; (3) introspective: explicit reference to personal memories, emotions, and reflections; (4) social: explicit reference to classmates, teachers, museum educators, or visitors; and (5) environmental: explicit reference to museum spaces, design, and architecture. By "explicit reference to" we mean clear graphic elements (present in the drawing) and written words (in the title given to the collage). Three independent researchers analyzed the definition of museum experience (Pekarik et al., 1999) and the component categories, identifying the elements in each. They then looked for these elements in the drawings. In the event of judges' disagreement, they discussed the collages until agreement was reached.

The enormous challenge of classifying museum experience was immediately clear to us. There is no one museum experience, pure and simple; it is a multidimensional phenomenon. All the elements characterizing personal visiting experience are closely linked.

Data Analysis

We conducted a repeated measures ANOVA to test whether the perceived restorativeness (total score and component factors) and preference differed in the three environments. To locate the sources of the global differences reflected by the repeated measures ANOVAs, we evaluated the differences between the environments with a series of paired *t*-tests. In cases of statistically significant differences, we computed partial eta squared (η_p^2) for repeated measures ANOVA and Cohen's *d* for *post hoc* analysis (Cohen, 1988; Tabachnick and Fidell, 2013). In agreement with Cohen's criteria (Cohen, 1988), effect sizes were evaluated as negligible ($\eta_p^2 < 0.01$; $d < 0.20$), small ($0.01 \leq \eta_p^2 < 0.06$; $0.20 \leq d < 0.50$), medium ($0.06 \leq \eta_p^2 < 0.14$, $0.50 \leq d < 0.80$), or large ($\eta_p^2 \geq 0.14$, $d \geq 0.80$).

To evaluate museum experience, we considered children's drawings, looking at the environment they decided to represent, and museum experience categorization, using descriptive statistics.

RESULTS

Perceived Restorativeness

Our primary interest was to explore the level of restorativeness perceived by the children during the museum visit. The perceived restorativeness level was quite high for two of the three environments, the Dome and the Gallery, while the third environment, the Bridge, had a slightly lower level (**Table 1**).

To test whether the perceived restorativeness differed in the three environments, a repeated measure ANOVA was run, considering the three different spots as the within subject factor. The results showed a significant effect of the environment [$F(2,78) = 11.053$, $p < 0.001$]. The effect size was large: $\eta_p^2 = 0.22$. The *post hoc* analysis highlighted that the Bridge was the least restorative environment, and the Dome and Gallery were equally restorative ($p_B < 0.001$). Effect size was from medium to large: Cohen's d was 0.694 for the difference between the bridge and the dome and 0.827 for the difference between the bridge and the gallery.

In a second step, we decided to consider the four restorative factors separately for each spot in order to understand which was the most and which the least restorative factor in the children's museum experience. Fascination and coherence seem to be the two most prominent factors; scope was the least prominent factor for all the three environments (**Table 2** and **Figure 2**).

To test whether these differences are statistically significant, a repeated measure ANOVA 3 × 4 was run, with two within factors: the "environment" (with three levels: Dome, Bridge, and Gallery) and the "restorative factor" (with four PRS's dimensions: being away, fascination, coherence, and scope). The main effect of environment was significant: $F(2,78) = 12.23$, $p < 0.001$, with a large effect size ($\eta_p^2 = 0.24$). This result depends on the fact that the Bridge was the less restorative environment (see the previous result).

The main effect of "restorative factor" [$F(3,117) = 48.00$, $p < 0.001$], with a large effect size ($\eta_p^2 = 0.55$), is due to the lower level of scope (2.1), followed by being away (2.6), coherence (3.2), and fascination (3.3).

In addition, the interaction "environment" × "restorative factor" was significant, albeit with a small effect size: $F(6,234) = 3.69$, $p < 0.01$, $\eta_p^2 = 0.09$. Descriptive statistics showed that the Dome had the highest level of restorativeness for all restorative factors except for being away, where the Gallery had a higher evaluation. As shown in **Figure 2**, the PRS measures restorativeness in descending order: for the Dome, followed by the Gallery, and finally the Bridge. This is true for every PRS factor, except for being away (B-A), which is slightly higher in the Gallery. An interaction effect is produced by the Scope that seems to be much higher in the Dome than in the other two spaces.

The Museum Experience: Preference and Categorization

In addition, preference showed difference between the three environments [$F(2,78) = 4.10$, $p = 0.020$, $\eta_p^2 = 0.10$] with the Bridge that obtained a lower score than the Dome [$t(40) = 2.20$, $p = 0.034$, $d = 0.34$] and the Gallery [$t(39) = 2.69$, $p = 0.010$, $d = 0.40$]. **Table 3** shows these results.

The drawings were also classified according to the environment represented by the children: **Table 4** shows the number of drawing for each environment.

The choice of which environment they decided to draw was compared with the preference levels. The results show that children drew the three environments equally, and their choice was evenly distributed over the Dome, Bridge, Gallery, and Museum (the category added for children who represented the museum as a generic place: a building viewed from the outside).

TABLE 1 | Mean level of the Perceived Restorativeness Scale (PRS) in the three museum environments (*N* = 41).

	PRS level	
	Mean	**SD**
Dome	3.03	0.4
Bridge	2.63	0.8
Gallery	2.95	0.8

TABLE 2 | Mean level of each restorative factor in the three museum environments (*N* = 41).

	Fascination	**Being-away**	**Coherence**	**Scope**
Dome	3.46	2.58	3.39	2.54
Bridge	3.01	2.34	3.03	1.73
Gallery	3.31	2.75	3.30	1.98

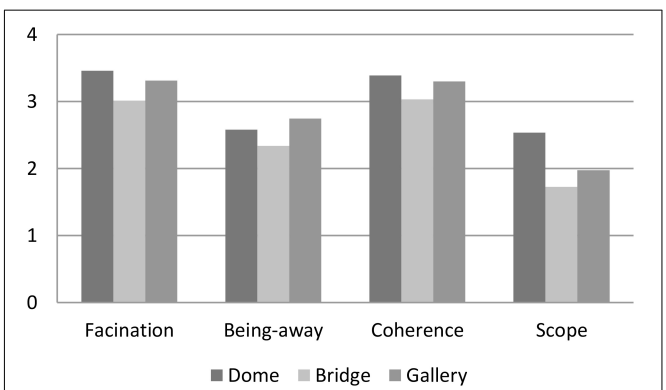

FIGURE 2 | Mean level of the four restorative factors in the three museum environments (*N* = 41).

TABLE 3 | Mean level of environmental preference in the three museum environments.

	Environmental preference	
	Mean	**SD**
Dome	3.65	0.6
Bridge	3.25	1.1
Gallery	3.58	0.9

TABLE 4 | Number of drawings for each environment.

Subject	Number of drawings
Dome	9
Bridge	10
Gallery	12
Museum	10

TABLE 5 | Museum experience categorization.

Introspective	22	13M/9F
Cognitive	6	4M/2F
Objective	9	1M/8F
Environmental	3	1M/2F
Social	0	0M/0F
Other	1	1M/0F

Although the Dome was the least chosen subject, it was experienced as the favorite spot standing on the preference response.

Finally, collages' categorization is shown in **Table 5**. This table shows the distribution of each children's collage, separately for boys and girls.

After categorizing the collages, we created a new category, "Others' experiences," to classify the collage of a child who did not represent anything with implicit or explicit references to the museum visit (a child with behavioral problems produced this collage).

DISCUSSION

The findings indicate that the MART environment possesses aesthetic and restorative attributes. The test results showed that there were elements of the environment that triggered "fascination" in all three environments considered during the visit. The results, however, have not totally confirmed our hypotheses about the three kinds of Nasar's formal aesthetic variables: visual quality, balance of order, and naturalness. This is probably due to the fact that these concepts are very fluid in the MART space.

In particular, the Dome had the highest overall score for three of the four restorativeness factors: fascination, coherence, and scope. This outcome may be due to the design characteristics of the Dome environment: a bright open space that invites exploration. On the other hand, the Bridge appeared to be the least restorative location with the lowest levels for all four restorative factors, probably due to the constraints of the physical space. It is narrow, high above a void, where movement is impossible and is devoid of elements with which one can interact. The highest of the PRS scores for the Bridge was for coherence, which was slightly higher than the score for Fascination. This result is probably due to the statement number 15 in the scale. That is, "in this place, it is easy to see what's around me." Due to its elevated and central position, the Bridge provides an open view of the various exhibition galleries. Scope was the least prominent attribute (equal to being away for the Dome). Scope was assessed by two PRS items: number 6—"In this place I am free to play, run and move," and number 8—"This place is big enough to be explored." This result was not surprising: running and playing are not the kind of actions open to visitors in a museum. The Dome, where children perceived a higher level of freedom to move around the square, was an exception.

We expected that the "Gallery" would show a good balance of order and complexity and, consequently, a higher level of coherence and fascination than the other two environments. Surprisingly, the Gallery scored highest in terms of being away. This result may be due to the fact that the gallery was the only space where the learning activity included the observation of an object—the artwork. Because of this, in the exhibition galleries, children were much more focused on something beyond themselves. The other two environments engaged children with a learning activity much more associated with the perception of their own presence in the museum space.

Turning to the postvisit activities, we found that "the negotiated drawings" represented a concrete, complex, and dynamic visit experience. All of them included elements of visual quality, balance of order and complexity, and naturalness. In particular, the children measured themselves through the representation of the museum environment (and the activity that took place in it) that had most affected them. We could clearly recognize the Dome, the Bridge, and the Gallery for their "formal aesthetic" attributes (**Figures 1D–G**).

Comparing the environmental preferences expressed by the children, we saw that the Dome was the most appreciated environment. This result is not surprising given that the Dome was also perceived as the most restorative place. Despite this, the relatively high number of drawings representing the Bridge indicated that the Bridge had a marked an impact on the children. However, as seen from the PRS scores, it was not a restorative element that seemed to cause the impact.

Obviously, a place can be appreciated without being restorative by virtue of other characteristics. To explore this issue, we analyzed the negotiated drawings in order to understand what kinds of feelings children experienced during the Bridge activity. Although the bridge was scary and gave some children a sense of vertigo, the activity was great fun for the children. The drawings show details of all the elements involved in the Bridge experience: the structure, the staircase, and classmates (**Figures 1H,I**).

The feelings were clearly impressed in their memory and consequently came out in their drawings. Therefore, it can be assumed that the Bridge experience provoked strong emotional and contrasting feelings, not of a restorative nature but nonetheless positive. Russell (2003) suggests that the key to understanding people's response to the environment is through emotion. He describes the concept of "environmental affect," comprising two main components: pleasure and arousal, subsequently described as "core affect" (Russell, 2003). Affective reactions to a place can be described by a model of emotion (Russell, 1988) based on contrast: pleasant/unpleasant and stimulating/sleepy. Affective qualities, described by an adjective, are based on a combination of these two dimensions: "exciting" is the combination of stimulation and pleasure (Roe, 2008). An additional element is whether or not one feels a sense of control

of what might happen in an environment. Mehrabian and Russell (1974) included this element in their Pleasure, Arousal, and Dominance (PAD) model. The introduction of the "dominance" dimension reflects the extent to which a person feels in control or at risk in a particular environment. It is likely that one aspect of the Bridge experience included a sense of the possible lack of control.

Indeed, the Bridge is not a restorative environment; it was not comfortable or relaxing, but it was exciting (Berlyne, 1974). On the basis of appraisal theories of emotion, some authors suggest that negative emotions can bring of aesthetic feelings (Silvia, 2009, 2010, 2012).

Regarding the collage, despite the fact that we involved children in a specific test activity about MART architecture, Environmental only attracted three children's collage. Among the Environmental collages, only one mentioned a specific museum spot: "I think of the fountain in the square," referring to a large fountain in the middle of the MART area under the Dome.

We chose Objective experience for the collages that represented an artwork and mentioned it in the title: nine children, one boy and eight girls. Interestingly, this is the result with the largest gender gap between boys and girls. Of these nine children, six mentioned the artwork by name: "In the museum I think of the Rotating Head," "In the museum I think of…the Strength of the curve." The other three described and represented the object clearly, so they were evidently impressed by the object, even without the specific name. In the category Cognitive experience, we placed the collages that mentioned the learning process as the most satisfactory experience: to gain new information, acquire notions of art, expand personal knowledge, and reflect on inputs. Some children felt particularly engaged in the learning process, producing enthusiastic titles: "In the museum, I think about exclamations and questions!," "In the museum I learn to learn," "I learn to be happy in the museum!"). All collages that specifically named emotions during the visit were placed in the Introspective category: "I feel very happy in the museum! I think of all the colors and fun stuff!," "In the museum I'm bored…," "I think in the museum that I was afraid."

During the collage activity, most children produced representations of an introspective visit (21 collages). The environmental element disappeared almost completely (three collages), and the social element was not represented at all. This type of result suggests that, given a very similar prompt ("My experience at the museum"/"When I think of the museum…") but changing the method of expressing recollections of experience (individual or social), the museum representation changes.

CONCLUSION

Our argument in this paper has been that as the understanding of the psychological relationships between people and museums has evolved, the effects of the physical "envelope that holds the objects" have come into focus more clearly. Not only the buildings but also the surrounding landscape has been shown to shape our experience of visiting a museum.

Through this museum learning experience—involving children and their parents, teachers, and a museum learning team, researchers were also able to explore some unanswered research questions in museum studies. We followed a psychological approach, applying the theoretical framework of Educational and Environmental Psychology and exploring some topics for the first time in a museum context. Field observations in an ecological research environment were analyzed combining the quantitative and qualitative perspective.

Our aim included developing an understanding of how the museum environment, when consciously exploited, can have a positive impact on children and their learning process. Our empirical work has begun to explore the links between museum design and restorativeness experienced by visitors. MART as a museum can be consider a "restorative environment," an escape, a refuge, a break from the routine of daily life (Kaplan, 1995; Packer and Bond, 2010). Through a high level of fascination, the museum gave the opportunity to children to perform learning tasks in a condition of effortless attention. The result was remarkably interesting because it supports the restorativeness theory of learning environments designed for children (Berto et al., 2015).

Finally, our research confirms the relationship between restorativeness and museums (Packer and Bond, 2010), noting a significant overlap between museum attributes and those suggested by Kaplan (1995) for a restorative experience. The findings indicate that for most children, museums provide insights into the factors that contribute to well-being. Our research supports the idea of museums as places that contribute to a visitor's aesthetic experience with a sense of relaxation, peace and calm, or thoughtfulness, but not only that.

Of the three environmental settings investigated, the Dome was the place with most restorative attributes. Classified as an outdoor environment, its natural characteristics may have contributed to this success. However, the Gallery also provided opportunities for regenerative experience, too, with the highest score for being away. Presumably, the presence of artworks helped children to live the sensation of escape and refuge, away from the routine of daily life. Focusing in particular on the restorative benefits perceived by children during the visit, we were surprised by the result for the Bridge, experienced by children as both terrifying and exciting. Due to this unexpected result, we reassessed the museum as a place able, among other things, to provoke strong aesthetic emotions and arousal. Further qualitative investigations can be made on drawings and collages made by children: categorizing the elements represented within can help to deepen the link between aesthetics and environmental preference (Lackney, 2000). Although our research asked children to reflect by drawing on the museum environment during the visit, we discovered that this Environmental experience was not particularly significant in young visitors' memories.

The research has some limitations. It was challenging to reconcile different disciplines: the Philosophy of Culture, Museum Education, Environmental Psychology, and Educational Psychology. The need to adopt an interdisciplinary approach

was dictated by the wish to take Museum Studies further by integrating quantitative theory and methods from psychology.

Moreover, mainly due to the lack of time and financial resources, the research was carried out quickly as pilot project. It would be interesting to extend this research topic in the future with a larger sample of visitors and over a longer period of time, including a control group. Although the research staff gave children their full attention and care, many children needed a more relaxed atmosphere and more time to visit the museum and its exhibits. A "control group" would have been very useful, but it was not possible to include the activity for local schools, which had already scheduled extracurricular activities for the current year.

Finally, the study was carried out in one museum alone, and it is certainly possible that the satisfying experiences and restorative elements identified in this particular museum are lacking in others. These results are valid and restricted to the MART—Museo d'arte moderna e contemporanea di Trento e Rovereto. Such a small study cannot make too many generalizations and is essentially preliminary research opening up new paths of enquiry for detailed examination. From the perspective of ecological validity, it would be desirable to use a sample of museums and be able to generalize findings across the wide spectrum of institutions that are categorized as being a "museum." Nevertheless, the findings should encourage further research into the important and beneficial psychological effects that can be derived from visiting a museum.

DATA AVAILABILITY STATEMENT

The datasets generated for this study are available on request to the corresponding author.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Ethical Board of the Department of Human Sciences, University of Verona. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

CA drafted the manuscript and wrote the sections of the literature review, the case study, and results. EM analyzed the data set. RH contributed in writing the theoretical framing, the discussion, and to the manuscript refinement. MP contributed in conceiving the rationale of the article as a whole, especially the Materials and Methods, and was involved in all sections of the manuscript. All authors contributed to the article and approved the submitted version.

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