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A comparison of art engagement in museums and through digital media

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As cultural consumption increasingly moves to a digital space, it is crucial to understand the evolving landscape of art consumption both in and outside of a physical museum context. The current study delves into this contrast, seeking to understand how art is perceived and appreciated in museums and on a digital medium (like a computer screen). Across two experiments at the Barnes Foundation and Penn Museum in Philadelphia, Pennsylvania, we explored how the aesthetic engagement of paintings and artifacts is influenced by the physical context in which an artwork is encountered and by the characteristics of the viewer. Our findings suggest that the cognitive and emotional impacts of artworks on viewers, as well as the viewers' overall aesthetic experiences are comparable across physical museum spaces and digital platforms. However, participants reported gaining more understanding from art viewed in museums, compared to participants who viewed art in the lab. Art experience and openness to experience influenced aesthetic impacts and ratings differently in the museum and in the lab. Overall, routes to broader valuations of liking were more similar than different between the museum and lab contexts, whereas patterns of impacts that might lead to new knowledge or understanding gained differed between museum and lab contexts. As digital technologies are increasingly integrated into diverse processes in museums such as collections management, curation, exhibitions, and education and learning, our research highlights how museums can leverage digital expansion to achieve their missions as centers of learning and education.

Keywords Museum, Art, Aesthetics, Neuroaesthetics, Context

Museums are dynamic and reflective institutions, evolving in parallel to the society in which they exist[1]. They hold a crucial place in the contemporary world as venues for challenging, affirming, and exploring individual, social and cultural identity, questioning concepts and narratives of the past and the present[2]. Approximately 104 thousand museums exist worldwide, with popular museums like the Louvre in Paris hosting over 7.5 million visitors each year[3]. Yet, as the world takes an increasingly digital form, the art world finds itself at the intersection of tradition and technology, with art migrating from a physical to a digital space[4].

The online presence of museums intensified during the COVID-19 pandemic with virtual environments playing a critical role in digital museum transformation[5]. Museums have integrated digital strategies into their curatorial and exhibition practices, going beyond merely digitizing collections, maintaining websites, and managing social media. Digital curation allows museums to dramatically increase their reach, and make art collections more accessible without time, money, or location barriers[4]. As cultural consumption increasingly moves to a digital space, it is crucial to understand the evolving landscape of art consumption both in and outside of a physical museum context. The current study delves into these contrasts, seeking to understand how art is perceived and appreciated in museums and on a digital medium (like a computer screen). We focus not only on aesthetic preference, but also the cognitive and affective impacts that arise from viewing artworks in different contexts.

The fields of empirical and neuro- aesthetics have seen a burgeoning interest in studies focusing on understanding the aesthetic experience, and implications for social, human, and neurobiological sciences[6,7]. Research in the field has established that context plays an important role in the top-down modulation of aesthetic

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experiences, changing how we perceive and evaluate artworks[8,9]. Findings from our lab as well as others suggest that people's aesthetic experiences are shaped by physical context (e.g., whether they view artworks online or in a museum; Estrada Gonzalez et al., 2020), perceived cultural context—e.g., whether the artwork depicts content from one's own culture[10–12], and/or the semantic context associated with the artwork—e.g., text-based contextual information about the artwork[11]. Eye-tracking studies have shown that background information influences how gaze is directed to areas of conceptual significance within the artwork[13,14]. With increasing awareness of the role of context in aesthetic judgments, researchers now frame art appreciation as a complex interplay between the viewer, the art object, and the conditions under which it is experienced[7,15].

The importance of context underscores the need for ecologically valid studies in natural settings in empirical aesthetics. Researchers argue that studies exploring aesthetic experiences in controlled laboratory settings are detached from the sensory and physical experience that one might experience in museums, increasing the gap between empirical aesthetic science and prototypical aesthetic experiences[16–20]. Previous work suggests that artworks in museums are rated as more pleasant, and evoke longer viewing times, whereas those viewed on computer screens are rated as less interesting, memorable, and arousing[21,22]. In contrast, viewing art via digital media enhances an active engagement with art, fosters art education, allows the viewer to view art without the barriers of time, money, and location[3]. One prominent example is the Google Art Project (GAP) that allows the user to virtually walk-through digitized museum spaces and zoom into images to study brushstrokes. This feature provides an opportunity to explore artworks more closely than may be possible in a museum. Thus, as exposure to digital media becomes more common, it becomes important to understand the difference between in-museum and digital experiences of art.

An extensive review by Pelowski et al.[7] on museum studies outlined three main factors that influence aesthetic experiences in laboratory settings as well as museums: (1) features of the artwork, which include both stimulus features such as size, texture, symmetry, etc., as well as knowledge cues such as perceived authenticity; (2) characteristics of the viewer, which include art experience, age, as well as group size and differences; and (3) characteristics of the presentation context, which include lighting, informational labels, viewing time, and other physical and cultural aspects of a museum. While many studies have assessed paintings, fewer have considered artifacts, which encompass a wider range of materials and sizes, and are usually three-dimensional. Further, characteristics of the audience such as age, education, art experience, and openness to experience all influence aesthetic judgments in online or laboratory settings[10,23–26].

In the current study, we explored how different artworks (paintings or artifacts), and characteristics of the viewer (age, education, art experience, openness to experience) influence aesthetic experience in different physical contexts (in the lab or in the museum) across two experiments. In Experiment 1, participants viewed paintings at the Barnes Foundation, either at the museum, or on a computer screen in the laboratory. In Experiment 2, participants viewed artifacts at the Penn Museum, either at the museum, or on a computer screen in the laboratory. The Barnes Foundation, founded by Albert C. Barnes, houses some of the world's most important impressionist, post-impressionist, and modern paintings including works by Renoir, Matisse, and Picasso (barnesfoundation.org). Artworks are displayed unlike a typical museum at the Barnes – no texts or labels are displayed on the walls. The Penn Museum at the University of Pennsylvania is home to extraordinary artifacts and archaeological finds from across the world, and bridges archaeology with anthropology (penn.museum).

Along with standard aesthetic preference ratings such as liking and beauty, we also included cognitive-affective 'impact-on-viewer' terms (how does this artwork make you think/feel?) derived from a taxonomy capturing the potential range of cognitive and affective effects artworks can have on viewers[27]. These terms were grouped into 11 impact dimensions: *angry*, *calm*, *compassionate*, *enlightened*, *edified*, *enraptured*, *inspired*, *interested*, *pleasure*, and *upset*. In line with the proposition of aesthetic cognitivism that art promotes knowledge and understanding[28], our study also investigated the influence of physical context on the acquisition of new knowledge and understanding from art. One week after evaluating the impact of artworks, participants completed a memory task to determine whether context influences the number of artworks recalled from the first study stage.

Finally, we explored different routes to broader valuations such as liking, as well as the likelihood of gaining new knowledge or understanding from the paintings and artifacts. Likert scale ratings used for measuring aesthetic preference usually ask participants to rate how much they like a painting on a scale from 1 to 5. However, while participants may assign the same rating to a painting in different settings, the reasons for liking it in the museum context may differ from those in a laboratory context. For instance, liking in a museum context may be predicted by more epistemic-transformational impacts such as feeling enlightened or inspired whereas liking in a laboratory may be determined more by how interested individuals are in the artwork. Similarly, following the premise of aesthetic cognitivism that understanding might stem from aesthetic impacts, we explored whether certain impacts contributed more towards new understanding than some others in the museum and the lab. Thus, we explored different routes to liking and understanding, i.e., whether our aesthetic impact terms predict liking or the likelihood of gaining new knowledge and understanding differently for museum and laboratory contexts.

Hypotheses and predictions

We test the (pre-registered) hypothesis that aesthetic engagement is influenced by the physical context in which a piece of art is encountered (whether in a museum, or on screen in the laboratory). Specifically, we predict:

1. Ratings on the aesthetic variables of beauty and liking will be higher in the museum than in the laboratory.

2. Different impacts (as measured by our aesthetic impact dimensions) in participants who view the art in the museum compared to those who view it in the laboratory (we remain agnostic about the direction of these impacts).
3. Artworks will be better remembered when viewed in the museum compared to when viewed in the laboratory.
4. Understanding will be higher in the museum context than in the laboratory context.

As exploratory (not pre-registered) analyses, we also consider how audience characteristics such as age, education, openness to experience, and art experience influence the role of physical context. Based on prior work, we anticipate that art experience and openness to experience will predict aesthetic ratings, but we do not have any directional predictions for how they might predict the aesthetic experience differently for the museum and laboratory contexts.

Method

Open science statement

We report how the sample size was determined, all data exclusions, and all measures used in the study[29]. Data pre-processing, statistical analyses, and data visualizations were performed using R (R Studio). Data analyses were preregistered on the Open Science Framework (Experiment 1, Barnes Foundation: https://osf.io/6ytmh; Experiment 2 followed the same analysis pipeline as Experiment 1).

For all experiments, mixed effects model analyses were executed using the *lme4* package (v.1.1–28) in RStudio (v2023.12.1 + 402). Post-hoc tests were executed using the emmeans package (v.1.7.2). We used an alpha of 0.05 to make inferences and controlled for multiple comparisons using Tukey-HSD in post-hoc tests.

Code availability

Following open science initiatives, all raw data and code are available online for other researchers to pursue alternative questions of interest (https://osf.io/6ytmh).

Stimuli selection

For Experiment 1, eight artworks were selected from Galleries 1 to 13 at the Barnes Foundation, with all artworks chosen from the first-floor galleries for accessibility and convenience. The selected works represented various artistic styles and periods, providing a broad spectrum for participant evaluations. The artworks included:

1. Bathing Group by Pierre Auguste Renoir (1916) from Gallery 1,
2. Still Life by Paul Cézanne (1892–94) from Gallery 5,
3. Giving Thanks by Horace Pippin (1942) from Gallery 7,
4. The Temptation of St. Anthony by Hieronymous Bosch (mid-16th century) from Gallery 8,
5. Sophocles and Euripides by Giorgio de Chirico (1925) from Gallery 11,
6. Two Women by Joan Miró (1937) from Gallery 12,
7. Cuban Hospitality by Jules Pascin (1915) from Gallery 13,
8. Landscape of Gourdon by Chaim Soutine (1920–21) from Gallery 6.

The artwork from Gallery 6 (*Landscape of Gourdon*) had to be excluded from the analysis, as it was removed from the museum for restoration work midway through the data collection process.

For Experiment 2, eight artifacts were selected from the Penn Museum's African, Native American, and Mesoamerican collections. These objects represent a range of cultural traditions and artistic techniques, originating from diverse historical periods and geographic regions. The selected objects are identified by their catalog numbers for reference:

1. A Silver "Gondar" Cross with socket from Ethiopia, Coptic culture, 1950–1982 CE (catalog no. 87-13-26).
2. A Human figure from Angola, Vili culture, late 19th–early 20th century CE (catalog no. 30-46-2).
3. A Mesa Verde Black-on-White Ware bowl from the Anasazi culture, Arizona, 1200–1300 CE (catalog no. 22976).
4. A Jingle dress from the Otoe-Missouria Tribe of Oklahoma, 2013 CE (catalog no. 2013-15-1 A).
5. A Simplified anthropomorphic figure on a plaque from Panama, Coclé culture, 8th century (catalog no. 40-13-11).
6. A Diablo (Devil) mask from Guatemala, 1960s (catalog no. 93-13-15).
7. A Carved elephant tusk from Nigeria, Benin Kingdom, 19th century CE (catalog no. AF2032).
8. A Plaque with figures from Nigeria, Benin Kingdom, 16th century CE (catalog no. AF2066).

Sample size justification

For both experiments, we recruited as many participants as possible in an eight-week data collection period, with approximately half of the participants doing the experiment in the museum, and the other half completing the experiment on a digital screen in our testing laboratory. The Barnes Foundation study (Experiment 1) was conducted first, followed by the Penn Museum study (Experiment 2).

Participants

Participants were recruited using SONA at the University of Pennsylvania, and via posters and word-of-mouth from the broader Penn community. Participants were paid $20 for their participation ($15 for the main experiment, and $5 for the follow-up survey, see Tasks and Procedure). A total of 88 participants completed

Experiment 1, with 40 participants (10 men, 27 women, 3 non-binary; $Mean_{age}$ = 25.30, SD_{age} = 4.53) in the Barnes Foundation (museum condition) and 48 participants (12 men, 34 women, 1 non-binary, $Mean_{age}$ = 27.44, SD_{age} = 8.92) in the lab (lab condition). A total of 106 participants completed Experiment 2, with 56 participants (24 men, 31 women and 1 unspecified; $Mean_{age}$ = 19.9, SD_{age} = 1.2) in the Penn Museum (museum condition) and 50 participants (12 men, 36 women, 1 non-binary and 1 unspecified; $Mean_{age}$ = 23.5, SD_{age} = 6) in the lab condition. Participants provided written informed consent, and all study procedures were approved by the University of Pennsylvania IRB (Ethics Approval Number: 806447). All research was conducted in accordance with the Declaration of Helsinki.

Tasks and procedure

For Experiment 1, we employed a between-group design. One group of participants did the study at the Barnes Foundation in Philadelphia, Pennsylvania. The other group of participants did the study in the lab at the University of Pennsylvania. The museum participants were invited to the Barnes Foundation. They were given a link to a Qualtrics survey on their phones. The survey included detailed directions to the eight artworks they were asked to rate (see Stimuli Generation). Participants were asked to move from one gallery to another (starting from the main gallery, Gallery 1). Approximately half of the participants proceeded from Gallery 1 to Gallery 13, whereas the remaining half proceeded from Gallery 13 to Gallery 1 to mitigate any order effects.

Once they were in front of the artwork, participants rated each artwork on how beautiful they found it, how much they liked it, and how familiar they were with the artwork. Following this, they rated it on 11 aesthetic impact dimensions i.e., whether the artwork made them feel angry, calm, compassionate, challenging, edified, enraptured, enlightened, interesting, inspired, pleasure, and upset. Each impact is representative of a group of words that is related to that impact[27]. For example, for the impact term 'angry,' terms within the sub-group include angry/enraged, frightened, revolted, abrasive, offended, and subversive—for a list of impacts and related terms in each group, see Christensen et al.,[27] and the Supplementary Material.

For each of the 11 impacts, all terms within each impact group were presented to the participants. Participants were asked to pick the two terms that were most relevant to them in the context of the artwork they were viewing. They then rated these two terms on a likert scale from 1(low) to 5(high). For example, if participants feel 'angry' and 'frightened' by an artwork, they only rate on these two terms (and not on abrasive, offended, etc.). They were also given the option to select "none of these apply." After participants finished rating on all 11 impacts, they were then asked whether they gained new knowledge or understanding from the painting (yes, no, maybe). They then proceeded to the next artwork and repeated the same process for the 8 chosen artworks. Participants were allowed to view other artworks in the museum galleries after rating the selected artwork in each gallery. The order in which the ratings were presented was randomized for each participant.

After rating all the artworks, participants answered demographic questions, and questions to measure their art experience (Art Experience Questionnaire; AEQ)[30]. Finally, they were asked to go back to the artwork that had the most impact on them (from the 8 selected artworks) and answer three free-text questions in as much detail as possible (unrelated to the aims of the current study) − 1) describe the painting in as much detail as possible; 2) write in as much detail as possible what you think or feel when viewing the painting; 3) what new knowledge or understanding (if any) did you gain from the painting?

Participants in the lab condition followed the same procedure as above except that they viewed the artworks on a computer screen (but also did the ratings on their phone). Instead of moving from one gallery to another, participants used arrow keys to navigate from one slide to the other on the computer screen (using Microsoft PowerPoint). Instead of galleries, we directed participants to different 'groups' of slides that included other paintings from the same galleries from the museum (the PowerPoint presentation used in the current study is available on the OSF). Participants were not able to manually zoom in to the artworks, but they could bring themselves closer to the screen, or move further away from the screen if they wanted to. All images were high-definition images, and adhered to the proportions of the original artworks in the museum.

For both participants in the lab and in the museum, a follow-up survey was conducted one week from the date on which they visited the museum or lab. In the follow-up survey, participants answered questions to measure their openness with experience, and did a memory task—for items used to measure openness to experience, see Darda and Chatterjee[24]. First, they were asked to describe from memory the eight selected artworks they viewed in the museum or on the computer screen in the lab. Next, they saw 16 artworks, eight of which were the artworks they saw one week before, and the other eight were artworks from the same artists who made the artworks they saw previously. Participants were asked to select all the artworks they remembered seeing at the museum or in the lab (all stimuli available on the OSF).

For Experiment 2, the procedure was the same, except with the following changes: (1) the museum participants completed the study at the Penn Museum in Philadelphia, Pennsylvania; (2) in the lab condition, the PowerPoint presentation (or in some cases a pdf file on Preview) included only the eight target artifacts, and no other artifacts from the museum; and (3) some participants in Experiment 2 did the study for course credits.

Data analysis

We set out to test whether the aesthetic experience in the museum is different to the aesthetic experience in the lab. For each impact term, the average of the two terms in the impact group relevant to the participant was used as the rating score for that impact per participant. For each participant, accuracy was calculated based on the number of artworks out of the total of eight artworks that the participant remembered correctly.

Out of the 88 participants, 70 participants did the follow-up survey in Experiment 1. Eighty-four participants out of 106 participants did the follow-up survey in Experiment 2. Therefore, scores on the openness to experience questionnaire were missing for 18 participants in Experiment 1 and 22 participants in Experiment 2. To account for missing data, we used multiple imputation by predictive mean matching using the {mice} package in R.

This approach uses the distribution of the observed data to estimate possible values for the missing data points, which helps to obtain approximately unbiased estimates[31,32]. This approach allowed us to use the data from all participants for our analyses. While we had not pre-registered this analysis, results were similar with and without imputation of the openness to experience data. Therefore, we use data from all participants in the analyses.

As pre-registered, for each experiment, for each of our dependent variables (ratings of liking, beauty, familiarity, and 11 impact terms), we ran linear mixed effects models with context (museum, lab) as the fixed effect and by-subject and by-item random effects. The categorical variable of context was coded as 0.5 for the museum condition and −0.5 for the lab condition. However, to control for effects of demographic variables, art experience, and openness to experience (OE), we further added age, education, total AEQ score, and total OE score as fixed effects to the model. All continuous variables were centered to the mean by subtracting the mean from every value of the variable. As the results from the comprehensive model that accounted for demographic and personality factors were similar to the simpler model that did not include these factors, we decided to report the comprehensive model in the main paper.

While both experiments were pre-registered separately, we combined the two datasets for higher power, and to statistically compare differences between when participants viewed paintings at the Barnes Foundation (Experiment 1) and when participants viewed artifacts at the Penn Museum (Experiment 2). By integrating the datasets, we can leverage complementary insights that each experiment provides, as well as understand differences in stimuli and museum contexts across the two experiments. We report the separate models for each experiment in the supplementary material, and the combined analyses in the main paper for completeness. Therefore, we included context (museum, lab) as well as object (painting, artifact) and their interaction as fixed effects in the model. All continuous variables were centered to the mean.

The final model used was:

$$Model\_main <- Rating \sim 1 + context * object + age + education + AEQ\ score + OE\ score + 1|sid + 1|item$$

To address whether art experience as measured by the AEQ modulated the effect of context and object (not preregistered), we added the interaction between art experience, object, and context (with art experience as a continuous variable and context and object as categorical variables) as a fixed effect to the model.

$$Model\_art\_experience <- Rating \sim 1 + art\ experience * context * object + age + education + OE\ score + 1|sid + 1|item$$

To address the effects of openness to experience (not preregistered), we further ran an exploratory model with the interaction between context, object, and OE score (with OE score as a continuous variable and context and object as categorical variables) as a fixed effect.

$$Model\_openness\_experience <- Rating \sim 1 + openness\ to\ experience\ experience * context * object + age + education + AEQ\ score + 1|sid + 1|item$$

As exploratory (preregistered) analyses, to address whether participants gained understanding from the paintings, we ran a generalized linear mixed effects model with understanding as a binomial dependent variable (1 = gained new knowledge or understanding, 0 = did not gain new knowledge or understanding). The final model that converged was:

$$Model\_understanding <- understanding \sim 1 + context + object + age + education + AEQ\ score + OE\ score + 1/sid$$

As preregistered, to assess accuracy differences in the museum and lab contexts, we ran the following linear model that converged for both *quantitative* accuracy and *qualitative* accuracy. Quantitative accuracy was calculated as number of artworks remembered (out of 16 artworks presented) divided by total number of artworks (eight artworks seen in the museum or in the lab context) multiplied by hundred. Qualitative accuracy referred to the number of artworks remembered when asked to recall and describe the artworks seen previously (an accurate description of the artwork constituted as a correct response, accuracy was calculated as number of artworks remembered divided by total number of artworks (8) multiplied by 100). For qualitative accuracy, two authors went through each described response independently for each participant. An accurate description of the artwork constituted as a correct response – no description was ambiguous, and the authors were in complete agreement on which constituted a correct response and which not.

$$Model\_acc <- Accuracy \sim 1 + context + object + age + education + art\ experience + openness\ to\ experience$$

Results

Liking, beauty, and familiarity

For the main model, art experience positively predicted beauty and familiarity ratings (ps < 0.05), education negatively predicted liking, beauty, and familiarity ratings (all ps < 0.05), openness to experience positively predicted ratings of beauty ($p = .037$), and object predicted ratings of liking, beauty, and familiarity such that artifacts at the Penn Museum were rated overall higher than paintings at the Barnes Foundation (ps < 0.05; see Table 1; Fig. 1). No other main effects or interactions were statistically significant (see Supplementary tables S1-S3). Figure 1 shows a trend for higher ratings in the museum than the lab, especially for artifacts at the Penn Museum, but this finding does not pass our threshold for statistical significance.

For the art experience model, the two-way interaction between context and art experience predicted ratings of beauty ($p = .043$). For the rest of the main effects and interactions, see Supplementary Tables 4–6. Post hoc tests revealed that art experience positively predicted beauty in the lab condition ($p = .001$) but not in the museum condition ($p = .212$; see Fig. 2; see Supplementary Tables S4-S6).

For the openness to experience model, the two-way interaction between context and openness to experience predicted ratings of beauty and liking (ps < 0.05). Post hoc tests revealed that openness to experience positively

Predictors	Liking				Beauty			
	Estimates	CI	Statistic	*p*	Estimates	CI	Statistic	*p*
(Intercept)	3.00	2.91–3.09	65.72	**< 0.001**	3.01	2.92–3.09	71.59	**< 0.001**
Art experience	0.08	-0.02–0.17	1.64	0.101	0.12	0.03–0.20	2.62	**0.009**
Age	0.02	-0.08–0.12	0.42	0.677	0.01	-0.08–0.10	0.22	0.826
Context	0.15	-0.03–0.34	1.61	0.107	0.05	-0.12–0.22	0.54	0.587
Context x Object	0.23	-0.14–0.59	1.23	0.221	0.30	-0.04–0.63	1.74	0.081
Education	-0.07	-0.17–0.03	-1.30	0.194	-0.10	-0.20 – -0.01	-2.09	**0.037**
Object	0.30	0.12–0.47	3.23	**0.001**	0.49	0.32–0.65	5.78	**< 0.001**
Openness to experience	0.15	0.06–0.24	3.14	**0.002**	0.17	0.08–0.25	3.83	**< 0.001**
σ^2	1.30				1.34			
τ_{00}	0.22_{sid}				0.15_{sid}			
ICC	0.15				0.10			
N	199_{sid}				199_{sid}			
Observations	1443				1446			
Marginal R^2 / Conditional R^2	0.051 / 0.189				0.081 / 0.176			

Table 1. Statistical estimates for beauty and liking ratings for the model with the interaction between object and context included as a fixed effect.

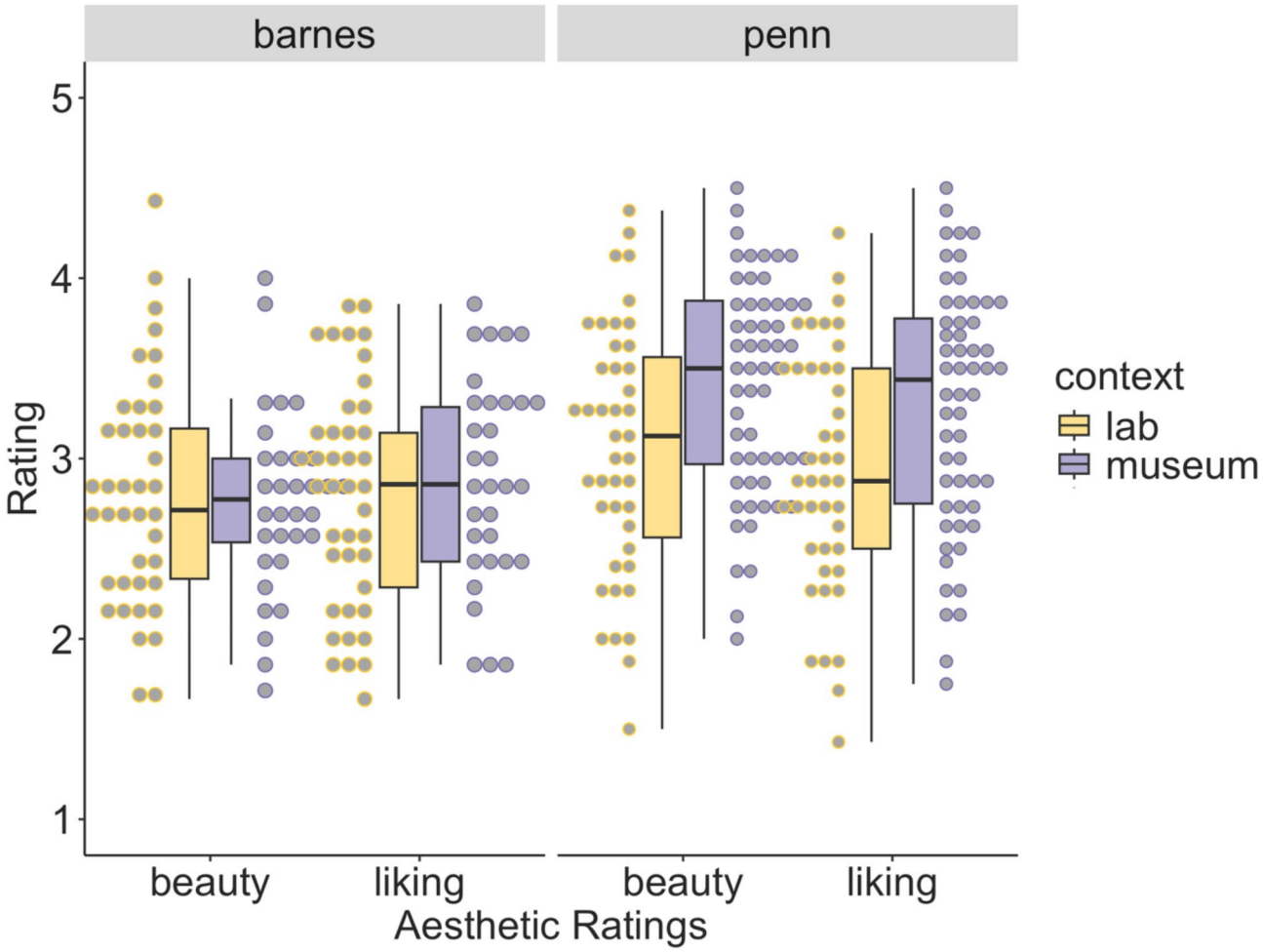

Fig. 1. The impact of context (museum, lab) for paintings at the Barnes Foundation, and artifacts at the Penn Museum. Liking and beauty ratings are higher for artifacts at the Penn Museum than the Barnes Foundation.

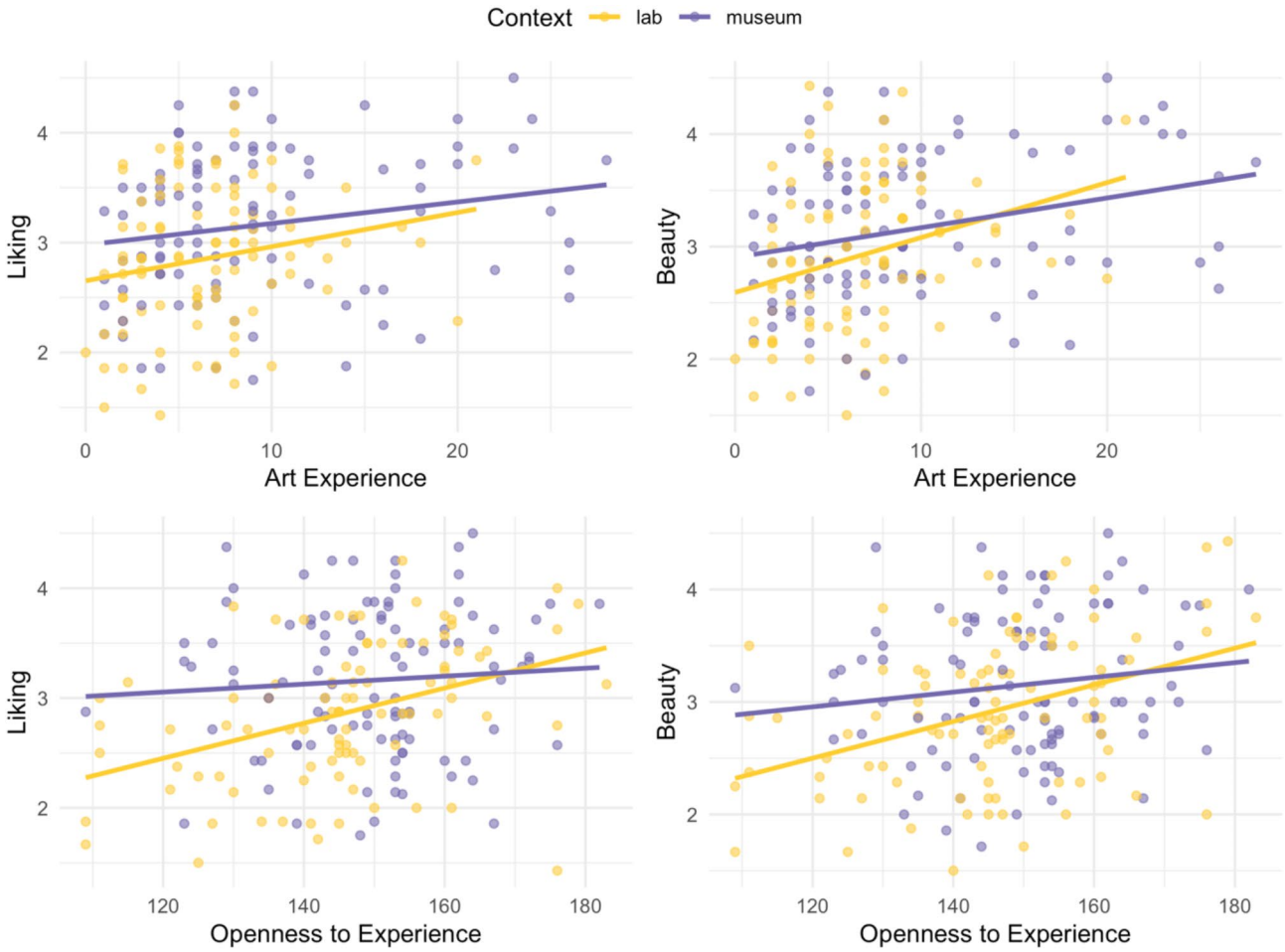

Fig. 2. The impact of art experience and openness to experience on liking and beauty in the museum and lab contexts for paintings at the Barnes Foundation and artifacts at the Penn Museum. Art experience positively predicted beauty ratings in the lab, but not in the museum. Openness to experience positively predicted liking and beauty in the lab but not in the museum.

predicted ratings of liking and beauty in the lab condition (ps < 0.05) but not in the museum condition (ps > 0.05; see Fig. 2; see Supplementary Tables S7-S9).

Aesthetic impacts

For the main models, art experience positively predicted ratings of how enlightened and inspired participants felt when viewing paintings or artifacts (ps < 0.05). Age positively predicted ratings of edified, enlightened, and inspired participants felt (ps < 0.05), and education negatively predicted ratings of calm, enraptured, enlightened, inspired, and pleasure (ps < 0.05). Openness to experience positively predicted ratings of challenged, interested, inspired, and pleasure (ps < 0.05). The main effect of object predicted ratings of how calm and upset participants felt, with higher ratings for paintings than for objects (ps < 0.05; see Fig. 3). No other main effects or interactions were statistically significant (see Supplementary Tables S1-S3).

For the art experience model, no interactions including art experience were statistically significant (see Supplementary Tables 4–6). For the openness to experience model, the three-way interaction between openness to experience, context, and object predicted ratings of how edified ($p = .032$) participants felt, but no differences in contrasts were found when correcting for multiple comparisons. No other interactions involving openness to experience were statistically significant (see Supplementary Tables S7-9).

Understanding

For the understanding model, context ($p < .001$) and object ($p < .001$) predicted understanding ratings such that the likelihood of gaining new knowledge or understanding was higher in the museum condition than the lab condition, and higher for artifacts at the Penn Museum than paintings at the Barnes Foundation. Art experience positively predicted understanding ($p = .012$). No other main effects were statistically significant (see Table 2).

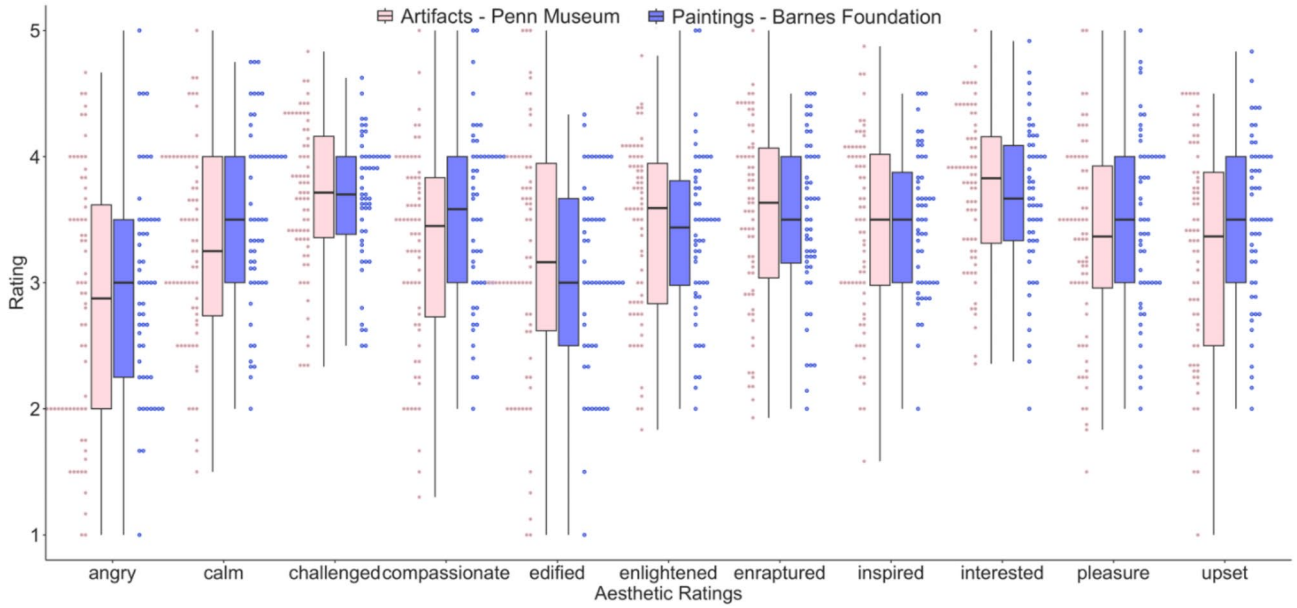

Fig. 3. Aesthetic impact ratings for paintings at the Barnes Museum and artifacts at the Penn Foundation.

	Understanding			
Predictors	**Log-Odds**	**CI**	**Statistic**	***p***
(Intercept)	-0.25	-0.64–0.13	-1.29	0.197
Context	2.06	1.23–2.90	4.87	**< 0.001**
Object	1.85	1.05–2.65	4.55	**< 0.001**
Age	-0.13	-0.53–0.26	-0.65	0.514
Education	-0.34	-0.78–0.10	-1.52	0.129
Art experience	0.53	0.12–0.94	2.52	**0.012**
Openness to experience	0.07	-0.33–0.47	0.35	0.724
Random effects				
σ^2	3.29			
$\tau_{00\ sid}$	4.85			
ICC	0.60			
N_{sid}	197			
Observations	1064			
Marginal R^2 / Conditional R^2	0.268 / 0.704			

Table 2. Statistical estimates for the linear mixed effects model for whether participants gained new knowledge or Understanding from the paintings/artifacts.

Accuracy

For the accuracy models, for both qualitative and quantitative accuracy, the main effect of object predicted accuracy such that participants were able to accurately recall the artifacts they saw at the Penn Museum better than paintings viewed at the Barnes Foundation (ps < 0.001). No other main effects or interactions were found to be statistically significant (see Supplementary Table 10). Figure 4 shows recall accuracy for both paintings and artifacts in the museum and lab. Although eye-balling the data suggests a trend for higher accuracy in the museum than the lab, this difference was not significant at our statistical threshold.

Different routes to valuation

As exploratory analyses, we further explored different routes to liking[24,33]. When people 'like' an artwork, they might like it to the same extent, but their reasons for liking it may be different. For example, in the informationally-enriched museum context, people might like the artworks because of their epistemic qualities (how edified, enlightened or inspired the artworks make them think or feel). However, in the lab context, when looking at artworks on a computer screen, people might like artworks because of their immersive qualities (such as how interested or enraptured they are by the artworks) as the lab context gives them the liberty to look at the art more closely without the interference of other people.

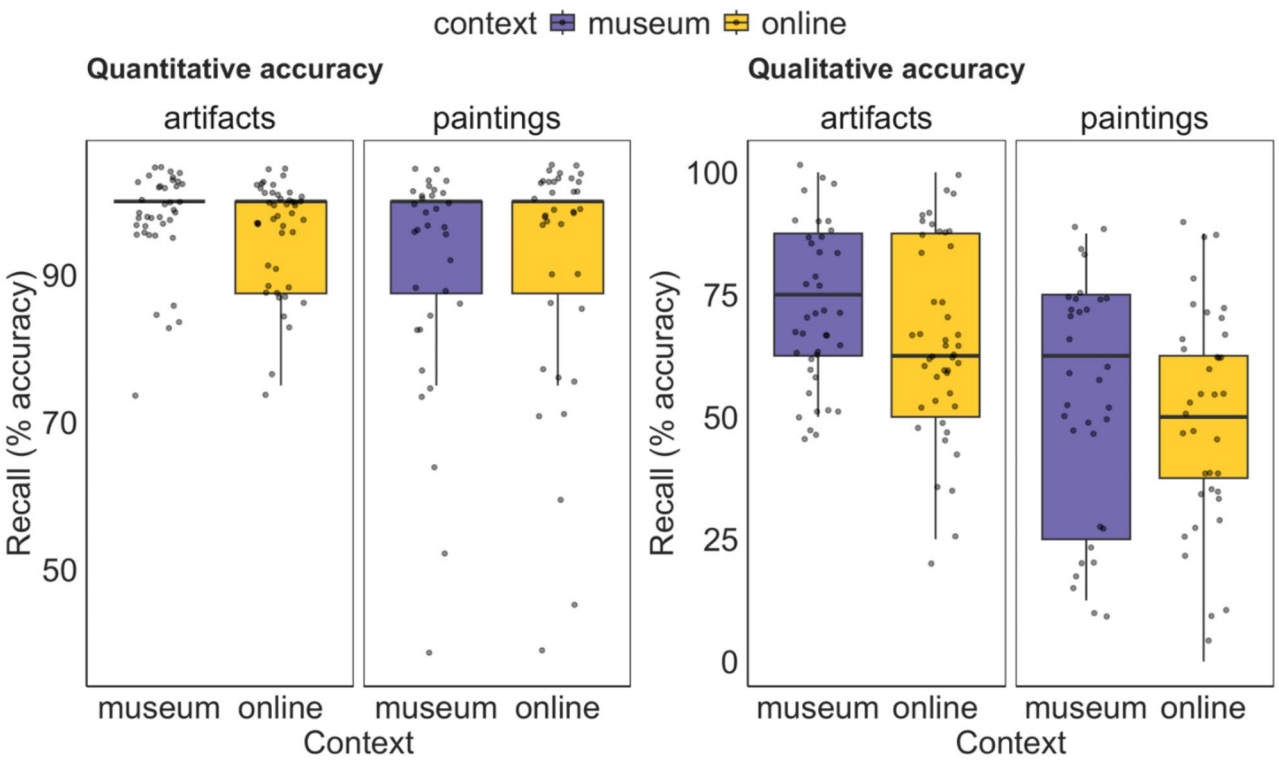

Fig. 4. Recall accuracy for museum and lab contexts.

To identify such different routes to liking, we constructed two linear models (one for the museum context and one for the lab context) with the aesthetic impacts as predictors and liking as the outcome variable. For the museum context, how interested ($p = .004$) participants felt on viewing the artworks positively predicted liking (see Supplementary Table 11, Fig. 5), and how challenged ($p = .038$) participants felt on viewing the artworks negatively predicted liking. How compassionate ($p = .015$) and upset participants felt negatively predicted liking ratings in the lab context ($p = .026$).

For understanding, in the museum context, how edified ($p = .003$), enlightened ($p < .001$) and interested ($p = .002$) participants felt positively predicted the likelihood of reporting new knowledge or understanding gained from the artworks, whereas how inspired ($p = .020$), how much pleasure ($p = .004$) and how upset ($p = .022$) participants felt negatively predicted the likelihood of reporting new knowledge or understanding gained from the artworks. For the lab context, no aesthetic impact was found to be a statistically significant predictor (see Supplementary Table 12). Figure 5 shows different routes to liking and understanding for the museum and lab contexts.

Discussion

In the current study, we explored how the aesthetic engagement of paintings and artifacts is influenced by the physical context in which an artwork is encountered and by the characteristics of the viewer. Across two experiments, our results suggest that participants reported gaining more understanding from art viewed in museums, compared to participants who viewed art in the lab. Differences were not found for aesthetic judgments and aesthetic impacts across these contexts. Aesthetic engagement of artifacts and paintings also differed, and art experience and openness to experience influenced aesthetic impacts and ratings differently in the museum and in the lab. No differences were found in recall after one week in the lab and museum contexts. Overall, routes to broader valuations of liking were more similar than different between the museum and lab contexts, whereas patterns of impacts that might lead to new knowledge or understanding gained differed between museum and lab contexts.

Aesthetic experience in the museum and the lab

Participants reported gaining more understanding from paintings and artifacts they viewed at the museum than participants who viewed them in the laboratory. Previous work suggests that a complex interplay of factors influences our aesthetic experiences, especially in a museum[7,17,19,21,22,34]. For instance, texture is a factor that differentiates between artworks in a museum and in a laboratory setting. A painting or artifact's three-dimensional quality is lost when it is presented on screen, leading to a loss of visual and haptic information[35]. In addition, perceived authenticity of artworks as well as perceived effort of the artist can impact the artwork's judgment[36,37]. Similarly, the size of artworks may influence their aesthetic experience, as art in the museums may often be larger than art viewed on the screen[38]. However, although participants were likelier to gain new

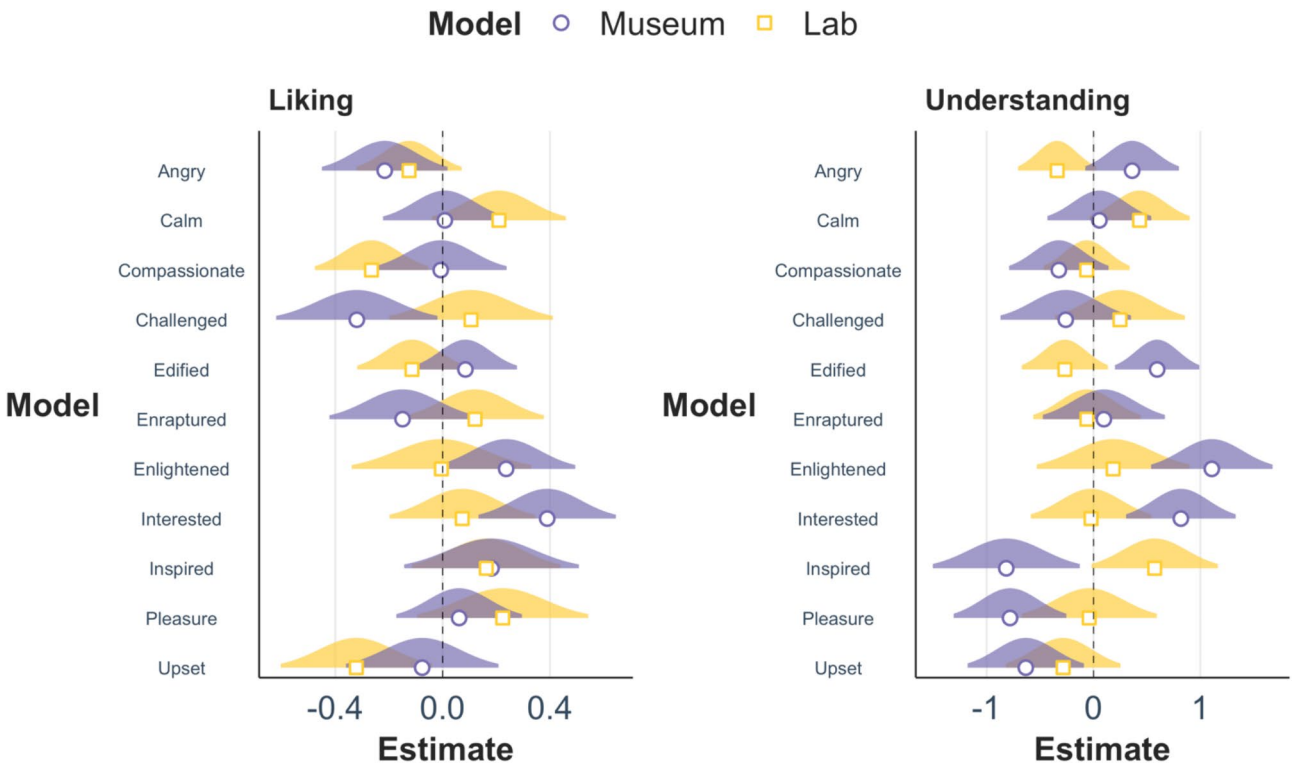

Fig. 5. Different routes to valuations of liking and understanding for museum (in purple) and lab (in yellow) contexts.

knowledge or understanding in museum contexts, we did not find differences in aesthetic preferences, impacts, and memorability (ability to recall artworks after one week's time) in the current study. This observation contrasts with previous findings, suggesting that even though perceived understanding gained from artworks was higher in museum contexts, affective and cognitive impacts are integral to the aesthetic experience, irrespective of the physical context in which art is encountered.

In a museum, the physical environment in and around the museum affects its visitors[39], including the arrangement of art, the paths that visitors follow, and the way objects are displayed[40,41]. While these factors are a part of the museum experience, they may also serve as distractors while engaging with art. In the laboratory, however, the art viewing process, though constrained, involves removing distracting or confounding variables as much as possible to isolate the art viewing experience. Contexts and motivations for viewing art are also different between lab settings and online or through digital media in home environments. In a lab, the setting is controlled and the experience standardized, often driven by study requirements, which can limit personal engagement. At home, viewers may engage with art online in a more casual environment. At-home engagement is typically self-directed and spontaneous, allowing for personal motivations and contextual factors (e.g., multitasking, emotional comfort) to shape the experience. This may affect not only their emotional and cognitive responses but also their interaction with and perception of the artwork. The use of different digital media in different settings may explain the discrepancy in our study and previous work and highlights the need for future research to explore at-home engagement with digital museum objects.

As digital interactions with art become more prevalent and potentially reduce context-dependent distractions, it is possible that the digital experience of viewing art has been elevated to the same level as viewing art in its original museum setting. This shift may also reflect a deeper transformation in how we perceive and value art. Historically, the concept of public art exhibitions emerged only after the French Revolution when palaces opened to the public. This exposure led to a growing reverence for these artworks, elevating them to a status of high cultural esteem. Today, we might be witnessing a further evolution where the traditional reverence for physical artworks and museum settings is challenged, shifting towards a new paradigm that is still forming. In this respect, our findings may be associated with the relatively young age of our sample and its greater exposure to art viewed digitally compared to older generations. Future directions may explore in-museum and in-lab experiences with older participants, and/or participants less accustomed to viewing art online.

Aesthetic experience of artifacts and paintings

We interpret differences that we found between paintings and artifacts with caution. Since we only examined impacts of seven paintings and eight artifacts, we would be remiss in making general claims about essential differences in the experience of paintings and artifacts. Nonetheless, paintings evoked stronger feelings of how calm and upset participants felt, while liking, beauty, and familiarity were higher for artifacts. Artifacts used in the current study were three-dimensional and encompassed a range of materials and sizes. They were also more

representative of everyday objects than paintings. Artifacts can activate tension between the "everyday object" character of artworks and their status as "art" which is worthy of being displayed in museums. This could be one explanation for why viewers liked artifacts more and found them more beautiful than paintings[35,42]. In a similar vein, art with special materials such as a rich glaze or gold leaves can also enhance the aesthetic experience[35]. An alternative explanation is that the Barnes Foundation displays its artworks unlike a typical museum. At the Barnes, artworks are arranged in ensembles that emphasize symmetry; without texts or labels displayed on the walls of the galleries. At the Penn Museum, however, artworks are accompanied with labels and information that allow the viewer to situate the artwork in its social-historical context. Work from our lab as well as others have emphasized the role of such semantic text-based contextual information – information about the artist, content of the artwork, or its technique enhances aesthetic engagement[24]. Thus, viewing artifacts in the informationally rich museum environment may contribute to higher liking, beauty, and reported understanding. The unique visual presentation format of the Barnes Foundation, and the inter-object thematic and visual relationships it highlights, may require guidance for the naïve viewer to appreciate. Future research could explore whether paintings evoke more affect-based responses (positive: pleasure, calm, compassionate, and negative: upset, angry, challenged), whereas artifacts evoke more epistemic-transformational impacts from viewers (enlightened, inspired) that lead to higher ratings of liking and beauty, and/or how these impacts are modulated by curatorial context.

Audience characteristics

We included age, education, art experience, and openness to experience as variables in our models to ensure any differences between the museum and lab contexts persisted above and beyond these variables. Previous research has suggested that audience characteristics can differ between museum and lab contexts. For example, museum-goers may often be older, more educated, with higher art and openness to experience, whereas lab participants are typically psychology students who are younger, less educated, and with lower art experience[7]. We found that overall, art experience and openness to experience mostly influenced aesthetic judgments and impact more so in the lab context than in museums. We controlled for overall age, education, art experience, and openness to experience, which suggests that the modulatory effect of art experience and openness to experience goes above and beyond any differences between the participants who viewed art in the museums and those who viewed art in the lab, at least to some extent.

One potential explanation for this finding can be that in a museum, extraneous contextual information may play a role in enhancing the experience of the viewer, more so when the viewer has lower art experience. Previous work from our lab has shown that text-based contextual information impacts those with lower art experience more than those with higher art experience[24]. Thus, the extraneous variables in a museum setting may impact those lower in art experience more, leading to higher aesthetic ratings, which may be comparable to viewers with higher art experience. In the absence of as much contextual information in the lab setting, art experience becomes a stronger predictor of aesthetic judgements. We are cautious about interpreting these exploratory results as our study was not statistically powered to detect these interactions. Yet, our results call into question how audience characteristics may impact the aesthetic experience differently in different contexts and question the generalizability of findings from lab contexts to real-life settings, underscoring the importance for more ecologically valid studies in naturalistic settings[20].

Routes to broader valuations of liking and understanding

Studies in the field have primarily used liking, beauty, or interest ratings to index art judgments, ignoring many affective and cognitive responses. Broader valuations of liking can be comprised of different factors[12,33]. For instance, different factors may contribute to liking in the museum and lab contexts. Our results suggest that aesthetic impact terms that tap into cognitive and affective evaluations predicted ratings of liking similarly for museum and lab contexts.

Similarly, how edified, enlightened, and interested participants felt predicted the likelihood of reporting new knowledge gained in the museum context, but not in the lab, whereas how inspired, how much pleasure, and how upset participants felt predicted the likelihood of *not* gaining new knowledge or understanding in the museum. Aesthetic cognitivism refers to the position that art can promote new knowledge or understanding[43] and that this understanding may arise from emotionally impactful engagements[27]. Our findings suggest that specific contexts (such as viewing art in the museum) and cognitive-emotional impacts may be more relevant to gaining new knowledge or understanding from artworks - participants were more likely to gain new understanding from artworks in the museum (but not in the lab) which were rated higher on how enlightened or edified the artwork made them feel. For example, words related to 'enlightened' in the taxonomy we used include 'informed', 'illuminated', 'revelatory', 'insight' etc. – all of which might be more relevant for gaining new understanding. We did not include low-level features or descriptive features in these models—i.e., how an artwork looks[27]. Future work with more statistical power can explore how different routes to valuations of liking and understanding are influenced by bottom-up and top-down factors in museum and lab contexts.

Limitations and implications

While our study provides significant insights into the impact of artworks on viewers in different contexts, we acknowledge some limitations that may impact the generalizability of our findings. Our relatively low sample size and limited number of stimuli (7 paintings and 8 artifacts) may not be representative of the broader population of individuals and artworks. Further, the relatively young age of our sample may bias our results, especially when comparing between museum and digital contexts. For better generalizability and applicability of our findings, future research should aim to have higher statistical power, larger and more diverse samples and artworks. Even so, our findings suggest that the cognitive and emotional impacts of artworks on viewers, as well as the viewers'

overall aesthetic experiences are comparable across physical museum spaces and digital platforms. This suggests that studies conducted in the laboratory settings might have more ecological validity that what researchers have previously discussed. Yet, differences are nuanced and continue to underscore the importance of studying and understanding aesthetics in contexts where they are typically encountered. Further, differences in the aesthetic engagement of artifacts and paintings highlight how different types of art might evoke different aesthetic judgments and experiences. Empirical aesthetics has focused primarily on paintings as objects of interest, with limited studies looking at how artifacts are experienced by viewers.

Many people visit museums every year, and most of them learn from these visits by engaging with artifacts in different ways, and using different senses[44]. The concept of a museum as merely a collection or an indicator of wealth for rulers or a space restricted only to a select few is evolving into an entity that promotes education and the preservation of cultural heritage, transforming the museum into an agent with social responsibility[45]. In COVID-19 times, museums underwent drastic changes, reinventing themselves and going online to remain alive and accessible[46,47]. Digital transformation brought about by advances in technology coupled with the demand for digital content and experiences accelerated by the pandemic is an ongoing challenge for museums, especially when considering their roles as centres of learning and cultural custodianship.

Digitization of artworks undoubtedly increases their accessibility, allowing global audiences to engage with artifacts and artworks irrespective of geographical and physical barriers. Such a digital shift is especially resonant with a population that is accustomed to digital interactions. Yet, museum spaces seem to provide unique learning and educational opportunities that digital spaces are yet to fully replicate and are especially useful for people with less art experience. As digital technologies are increasingly integrated into diverse processes in museums such as collections management, curation, exhibitions, and education and learning, our research highlights how museums can leverage digital expansion to achieve their missions as centers of learning and education.

Data availability

Following open science initiatives, all raw data are available online for other researchers to pursue alternative questions of interest (https://osf.io/6ytmh).

Received: 26 December 2024; Accepted: 7 March 2025
Published online: 15 March 2025

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Acknowledgements

We thank the Barnes Foundation and Penn Museum for their support with data collection, and anonymous reviewers for their comments on the manuscript.

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Conceptualisation, Methodology: KMD, APC, ERC, AC. Data Collection, Investigation: KMD, VEG, IB, AK, ZN, ERC. Stimuli: WP. Formal Analysis, Data Visualisation: KMD, VEG. Writing – original draft: KMD. Writing – review and editing: KMD, VEG, APC, IB, ERC, WP, AC. Supervision: AC.

Funding information

This research has been funded by the Templeton Religion Trust.

Declarations

Competing interests

The authors declare no competing interests.

Additional information

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1038/s41598-025-93630-0.

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