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Authors for correspondence:
Ionela Bara
e-mail: iobara@ethz.ch
Emily S. Cross
e-mail: ecross@ethz.ch

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Art knowledge training shapes understanding, inspires creativity and stimulates thinking

Ionela Bara[1,2], Richard Ramsey[3] and Emily S. Cross[1,2]

[1]School of Psychology and Neuroscience, University of Glasgow, College of Medical Veterinary and Life Sciences, Glasgow, Scotland, UK
[2]Social Brain Sciences Lab, Department of Humanities Social and Political Sciences, ETH Zurich, Zurich, ZH, Switzerland
[3]Neural Control of Movement Lab, Department of Health Sciences and Technology, ETH Zurich, Zurich, ZH, Switzerland

IB, 0000-0001-8442-5089; RR, 0000-0002-0329-2112; ESC, 0000-0002-1671-5698

According to aesthetic cognitivism theory, art represents a source of knowledge that promotes understanding, creativity and thinking. However, it remains unclear exactly which features of art knowledge shape understanding and thinking. Our pre-registered study examined whether different types of art knowledge training (full audio-visual, brief visual or passive control) impact judgements of understanding, creative inspiration, thought stimulation and intellectual challenge and whether these effects generalize to new contexts. Using a training intervention paradigm and a multilevel Bayesian modelling approach, we found that participants (N ~ 50/training group) assigned higher ratings of understanding, creative inspiration and thought stimulation judgements to trained rather than to untrained artworks, as a function of art training type. Particularly, full audio-visual art training, which included visual and auditory descriptions, led to higher ratings than no training. The effects of training generalized to unseen artworks produced by the same artist but not to artworks by different artists. Compared to the passive control group, these effects were more robust for the full audio-visual than brief visual art training group. These findings highlight how art knowledge training can promote art understanding, creative inspiration and thought stimulation and generalizes to new settings that involve a similar artistic style.

1. Introduction

Understanding art by having the feeling of grasping the artist's message requires some level of art knowledge, which is usually acquired through formal educational training or informal activities, such as visiting museums or attending live events with performing artists [1–5]. While the role of arts in communicating ideas and evoking emotions is widely acknowledged [6–9], the empirical demonstration of how art knowledge shapes understanding, stimulates thinking and creative inspiration, as well as how these effects generalize to novel contexts, remain poorly understood. Given the important role played by the arts in acquiring knowledge and facilitating learning and understanding of human culture, the current study aims to shed light about the transformative power of knowledge acquired through art training. By doing so, we provide novel insight into how the accumulation of art knowledge can impact learning, promotes understanding, inspires creative ideas, stimulates thinking and generalizes to novel settings.

The assumption that art is a source of knowledge that promotes understanding of the world and stimulates cognitive abilities, such as creativity, imagination and thinking, represents the main tenets of the aesthetic cognitivism theory [7,10–12]. Aesthetic cognitivism theory suggests that beyond the typical hedonic values associated with art and aesthetic experience, such as aesthetic appreciation, liking or beauty, art carries cognitive values that facilitate learning, thinking and the engagement of imagination and creativity [7,10,13]. Recent work by Christensen *et al*. [13] examined the semantic associations of different concepts with art. They found that the most common cognitive impact terms linked with art were 'inspired', 'thoughtful' or 'challenged', suggesting that art is related to thinking and cognitive abilities. However, the extent to which art knowledge training might indeed *facilitate* knowledge, understanding, creativity and stimulate thinking more broadly remains unanswered. Determining the extent to which this is indeed the case is important to address now, because it would help rebalance the discussion about the role of arts for individuals and society from a purely hedonic and pleasurable status to a more holistic view that includes intellectual and cognitive value.

Research in the domain of empirical aesthetics indicates that descriptive titles and contextual information about artworks, such as curatorial descriptors, contribute to greater understanding and aesthetic appreciation than the experience of beholding artworks with no titles [14–17]. For example, Millis [15] examined the impact of different titles of artworks on aesthetic experience and found that elaborate titles resulted in higher ratings of artwork understanding, interest and enjoyment than no titles or random titles. This suggests that titles provide important semantic information about artworks that can promote understanding, stimulate curiosity and enhance aesthetic pleasure in viewers.

Furthermore, semantic information about artworks, such as curatorial descriptors, has been linked to a greater understanding and aesthetic appreciation of artworks than simple titles alone or no information [18,19]. In this sense, Szubielska and colleagues [19] investigated the effect of naturalistic gallery context and art knowledge on aesthetic experience. They found that providing knowledge about artworks in the form of short curatorial descriptions rather than titles led to increased ratings of understanding, aesthetic appreciation and aesthetic emotions, suggesting that successful art understanding and aesthetic experience are facilitated by acquiring art knowledge.

While the level of art knowledge is important, the sensory modalities used to deliver art-related information (e.g. visual, audio or textual written information) also play a critical role in guiding learning, understanding and aesthetic experience [20–22]. Research from museum practices suggests that in general, visitors enjoy using both audiovisual guided tours and visual-textual information presented with each artwork. However, audiovisual guided tours tend to lead to enhanced knowledge and engagement in understanding the information presented, compared to short written descriptions [23]. Similarly, a study by Szubielska *et al*. [21] investigated the role of sensory modality in the delivery of information about artworks on understanding, preference and affective judgements. They found that synchronous looking and listening to curatorial descriptions of artworks resulted in greater understanding and increased aesthetic evaluations than solely reading or listening to the material, further reinforcing the notion that combining visual and auditory modalities in delivering art knowledge positively shapes aesthetic processing.

Traditionally, the role of information presentation modality in short-term memory research has favoured a better short-term serial recall of auditory information than visual sequences [24–26]. However, the newer embodied approaches to memory have emphasized an interplay between sensory-perceptual-motor factors when evaluating the sensory modality contribution to short-term memory [27]. Similarly, modality-based learning style accounts have proposed that sensory modality

effects are task-dependent, indicating that learning improves when new material is provided via the most suitable sensory modality for the task of interest [28]. Moreover, from art media film research, Chion [29] argued that the sound in audiovisual films is more than a simple accompaniment to images. Instead, films that include soundtracks can engage both sensory modalities to produce a transformative aesthetic experience. Together, these ideas suggest that learning is facilitated by multimodal (e.g. visual and auditory) presentation of information.

Speaking further to the impact of training on aesthetic processing, recent experimental work from our lab investigated the extent to which an art knowledge training intervention impacts subsequent aesthetic judgements of artworks [30]. The results show that using an art knowledge training intervention of approximately 22 minutes involving both visual and auditory modalities enhanced participants' subsequent ratings of understanding, aesthetic preference, affective and artistic skill judgements for trained but not untrained artworks. Importantly, the effects of art training generalized to unseen artworks produced by the same, but not a different artist, suggesting that audiovisual art knowledge training promotes the generalization of aesthetic judgements to novel contexts.

However, it remains unexplored which precise features of art knowledge training, such as training dose (e.g. 22:08 minutes versus 8:45 minutes) and training modality (audiovisual versus visual-only), are most important for art understanding and meaning making, and that can subsequently inspire creative ideas, stimulate thinking and generalize to novel contexts. Addressing this important question can illuminate the type of knowledge needed to shape learning and guide the generalization of art knowledge to novel settings. Therefore, the overarching aim of the current study is to investigate the extent to which understanding, creative inspiration, thought stimulation and intellectual challenge judgements are impacted by distinct types of art knowledge training, and the extent to which each kind of training generalizes to new contexts. To that end, we used a structured training approach that varied the art training modality, depth of information and dose. Participants engaged in either full audiovisual training, brief visual training or a passive control, with doses set at either 22:08 minutes or 8:45 minutes. By combining training modalities, depth and doses, this study seeks to enhance our understanding of how varying training modalities and doses shape participants' judgments of artworks.

Using a training intervention paradigm and a multilevel Bayesian modelling approach, we predicted:

(1) higher ratings of understanding, creativity, thought stimulation and intellectual challenge judgements for trained artworks than for untrained artworks as a function of art training type. Particularly, full audiovisual art knowledge training involving visual and auditory descriptions of artworks would lead to higher ratings for trained (i.e. those they learn about during the art training) rather than untrained artworks (i.e. those that are novel, and shown only in the post-training conditions).
(2) the impact of art training on understanding, creativity, thought stimulation and intellectual challenge judgements of artworks would generalize to unseen art. Specifically, we predicted that:
    (a) less stylistic similarity between artworks discussed during the art training and unseen artworks would lead to a reduced impact on judgements.
    (b) a brief visual art training video involving only schematic visual descriptions of artworks and passive control would lead to reduced generalization effects. Therefore, we expected the largest effect for the full audiovisual art training, followed by brief visual art training and lastly the passive control.

2. Methods

2.1. Ethics statement

All experimental procedures were approved by the University of Glasgow, College of Medical, Veterinary and Life Sciences (Ethics number: 200220002). All participants provided written informed consent before taking part and were reimbursed for their participation (£6).

2.2. Pre-registration and open science statement

Across this study, the research questions, hypotheses, planned analyses, sample sizes and exclusion criteria were pre-registered before data collection started. The pre-registration can be accessed at

https://aspredicted.org/CGT_F2R. In addition, consistent with recent metascience proposals [31], the raw data, stimuli and analysis code are available online on the Open Science Framework (https://osf.io/7vez9/). By doing so, we encourage others to pursue tests of alternative hypotheses, as well as more exploratory analyses and meta-analyses.

2.3. Participants

The sample size was determined by the maximum number of participants that could be feasibly recruited given the available resources and the demands of conducting between-groups experimental designs. This approach is consistent with Lakens [32], who has argued that research sample sizes are often constrained by practical considerations, such as resource availability. Accordingly, we pre-registered a target of 150 usable participant datasets (i.e. approx. 50 participants in each of the three groups: full audiovisual art training, brief visual art training and passive control). All participants were recruited through the University of Glasgow's Psychological Research Panel. One hundred and fifty volunteers took part in this online study. Participants were randomly assigned to one of the three experimental groups. Fifty participants (29 females, 18 males, 3 unspecified, Mean_{age} = 22.34, s.d._{age} = 4.31, age range = 18 to 46) were recruited for the full audiovisual art training group. Fifty participants (29 females, 21 males, Mean_{age} = 22.18, s.d._{age} = 3.31, age range = 18 to 32) were recruited for the brief visual art training group. Fifty participants (29 females, 19 males, 2 unspecified, Mean_{age} = 24.78, s.d._{age} = 5.88, age range = 18 to 45) were recruited for the passive control group.

According to our pre-registered exclusion criteria, participants were excluded if they answered correctly ≤3 questions out of 7 questions on our post-art knowledge follow-up questionnaire, which assessed the extent to which participants were paying attention during the art training lessons. After exclusions, the final sample for the full audiovisual art training group included 46 participants (26 females, 16 males, 2 unspecified, Mean_{age} = 22.34, s.d._{age} = 4.31, age range = 18 to 46). The final sample for the brief visual art training group consisted of 49 participants (28 females, 21 males, Mean_{age} = 22.18, s.d._{age} = 3.31, age range = 18 to 32) and the passive control group remained as reported above. The results for the post-art training follow-up questions for all experimental groups are reported in the electronic supplementary material, figures S1 and S2. All participants had normal or corrected-to-normal vision and were screened for visual art expertise. The results for the visual art expertise results can be found in the electronic supplementary material, figures S3 and S4.

2.4. Stimuli, design, tasks and procedure

2.4.1. Art stimuli

The art images used in the current study were taken from our previous lab work [30]. There were 20 Realist artworks by various artists, 40 Impressionist artworks by Joaquín Sorolla y Bastida (1863–1923), 20 Post-Impressionist artworks by Paul Gauguin (1848–1903) and 20 Impressionist artworks by William Merritt-Chase (1849–1916). Out of 40 artworks by Sorolla, 20 artworks were used in both the pre- and post-training, whereas 20 artworks were only used in the post-art training. Half of the art images depicted human bodies and half depicted landscapes. The Impressionist and Post-Impressionist stimuli were obtained from the freely available online visual arts encyclopaedia, WikiArt (https://www.wikiart.org/). Each image was normalized to be 785 × 774 pixels in size. Copyright permitting, all the art stimuli that we used are also available on our open science framework page (https://osf.io/7vez9/overview). Sample images from each image category can be seen in figure 1.

2.4.2. Full audio-visual art training video

This consisted of an art knowledge training lesson about Sorolla's pictorial art. The in-depth or full audiovisual art training was a video of 22:08 minutes involving the presentation of visual and auditory information. It provided an art history lesson about 20 paintings by Sorolla in a fixed order, the first 10 paintings described human bodies and 10 described landscapes. The full audiovisual art training video was created considering the typical competencies and learning objectives of a guided art museum tour, such as explaining, analysing, storytelling and contextualizing artworks. The aim was to facilitate a rich learning experience that would broaden participants' awareness of Sorolla's art and would strengthen their ability to think critically and express interpretations based on what they see [33–35].

Figure 1. Sample art images used across all experimental groups in a pre- and post-art training manipulation. The pre-art training involved the presentation of 20 Realist stimuli and 20 Impressionist stimuli by Sorolla (panel A). The post-art training included the art stimuli from the pre-training (20 Realist stimuli and 20 Impressionist stimuli by Sorolla, as well as 20 new art stimuli by Sorolla, 20 new Post-Impressionist art stimuli by Gauguin and 20 art stimuli by Impressionist artist Merritt-Chase (panel B).

The full audiovisual art training was the same as in Bara *et al*. [30] and is available on our Open Science Framework page (https://osf.io/7vez9/overview).

The full audiovisual art training was based on previous research from art history and empirical aesthetics. According to art history research, we used an iconographic analysis to facilitate understanding of the meaning that an artwork had at the time it was created [36–38]. In this sense, we described the artwork's subject (pre-iconographic stage), categorized the artwork's content in line with cultural conventions at the time (iconographic stage) and provided broader interpretations considering the general historic context (iconological stage). We also discussed aspects of formal and stylistic analysis of the visual properties of the artworks, such as composition, viewpoint, pictorial space, form, line, colour and light to understand the shared general features of Impressionist artistic style.

In addition, based on art history research, we used elements of formal analysis that aimed to explore the visual elements of artworks and to analyse the contribution of such elements to the overall impression of an artwork [39–42]. Moreover, the stylistic analysis enabled us to demonstrate that artworks have common visual features among artists working during the same historical time [38,39,43,44], and therefore helped to classify the artworks as belonging to Impressionist artistic style. We also used biographical interpretation to emphasize how stories about Sorolla's personal life can reveal and enrich the meaning of the artworks themselves [42,45]. Finally, we used elements of critical theory to inform about how societal and political structures have influenced Sorolla's art and Impressionism, in general, as an artistic period [38,41,42,45].

2.4.3. Brief visual art training video

This was created from the full audiovisual art training video and consisted of a short art knowledge lesson about the same 20 paintings by Sorolla as the full audiovisual art training lesson. However, the brief visual art training video was 08:45 minutes long and involved only visual information in the

form of images and short text descriptors. All 20 paintings were accompanied by short text descriptors that aimed to summarize and capture one or two main ideas about each artwork. These included descriptions of the artwork's topic, elements of formal and stylistic analysis, and interpretations of the general historic context at the time the artwork was created. The number of words across all text descriptors was within the range of 20–27 words. All the graphical elements, such as the presentation style, fonts, colours and size of the paintings, were matched to be as similar as possible to the full audiovisual art training graphics. As in the full audiovisual art training, the order of paintings was fixed, the first 10 paintings depicted human bodies and the next 10 paintings depicted landscapes.

During the brief visual art training lesson, each painting was presented twice: first, presented as a preview at the full scale in the middle of the screen for 5 seconds, followed by a second presentation for 17 seconds at a smaller scale on the left side of the screen and accompanied on the right side of the screen by one or two text sentences briefly describing each painting. The viewing time was based on previous research by Brieber *et al*. [46] showing that a presentation time of 5 and 17 seconds was associated with greater appreciation ratings than a duration of 30 seconds, suggesting that approximately 17 seconds enables aesthetic judgements. The brief visual art knowledge training is available on our Open Science Framework page (https://osf.io/7vez9/overview). The artworks analysed during the full audiovisual art training and brief visual art training were also assessed by participants during the pre-art training and post-art training sessions across different meaning-understanding judgements.

We chose to create two types of art knowledge training (full audiovisual and brief visual) based on Sorolla's art because, on one hand, Sorolla's art is representational, and we intended for art training that requires moderate effort from participants to process the information. Previous work has indicated that representational art is more easily processed and preferred more than abstract art [47–51]. On the other hand, we aimed for an art style that is usually preferred by art-naïve participants. In this sense, prior evidence has demonstrated that art styles, such as Realism or Impressionism, are highly liked by laypeople [52–57]. Finally, we aimed to offer a new learning opportunity by presenting an artist whose name or pictorial art is mostly unknown today to the UK general public. Although Sorolla was one of the most celebrated artists worldwide during his lifetime, his popularity diminished after the 1920s. The first Sorolla exhibition in the UK in over a century, organized by the National Gallery, was held in 2019 ([58]; The National Gallery, 2019), highlighting that for more than one hundred years, Sorolla was absent from the British museological circuit. On these grounds, as well as our participant art expertise screening questions, we expected Sorolla and his artwork to be unknown to our art-naïve participants, as we found in our previous work [30].

2.4.4. Passive control

We further employed a passive control group in which participants received no art training. This experimental manipulation served two primary purposes: first, it established a baseline for measuring the effects of active training, enabling a clearer assessment of the specific impact of art training on participants' judgments. Second, this approach strengthened the rigour and validity of our research findings, allowing us to more confidently attribute any observed improvements in the experimental group to the training intervention itself.

2.4.5. Design

This study used a mixed within- and between-participant design, which included pre-art training, art knowledge training (either full audiovisual art training, brief visual art training or no training) and post-art training (figure 2). All participants completed pre-art training and post-art training sessions, which included understanding, creative inspiration, thought stimulation and intellectual challenge judgements of artworks in a within-participant design (2 × session: pre and post). A further within-participant design contained seven conditions: pre-Realism, pre-Sorolla, post-Realism, post-Sorolla, post-Sorolla New, post-Gauguin and post-Merritt-Chase. Participants were also randomly assigned to one of two types of art training in a between-participant manipulation (3 × training type: full audiovisual art training video 22:08 minutes, brief visual art training video 08:45 minutes or passive control). The dependent variables were understanding, creative inspiration, thought stimulation and intellectual challenge. All dependent variables (understanding, creative inspiration, thought stimulation and intellectual challenge) were assessed using 5-point Likert-type scales (1 = not at all, 5 = extremely), as described in detail in the 'Procedure' section.

2.4.6. Tasks and procedure

The current study comprised three main components presented in the same order to all participants: pre-art training, art knowledge training and post-training. Both the pre- and post-art training consisted of rating tasks, whereas the training involved either full audiovisual art training, brief visual art training or passive control. The experimental tasks were produced in PsyToolkit [59,60]. The completion of the experiment was restricted to laptop and desktop users only; tablets and mobile phones were not permitted. Participants were instructed to complete the whole experiment in one sitting. The experimental procedure is illustrated in figure 2.

Pre-art training involved participants rating 40 paintings (20 Realist art stimuli and 20 Impressionist art stimuli by Sorolla) on four variables: (i) understanding assessed the extent to which participants understood the painting's meaning ('do you understand the meaning of this painting?'); (ii) creative inspiration evaluated the extent to which the painting inspired imaginative or creative thought ('does understanding the meaning of this painting inspire you creatively?'); (iii) thought stimulation assessed the extent to which the artwork prompted new ideas or associations ('does understanding the meaning of this painting stimulate your thoughts?'); (iv) intellectual challenge assessed the extent to which the artwork stimulated deeper analytical and reflective thinking ('does understanding the meaning of this painting challenge you intellectually?'). Therefore, pre-art training involved a total of 160 ratings. All ratings were assessed on a 5-point Likert scale (1–5; not at all–extremely). The paintings remained on the screen until participants made a rating response. The order of the paintings and the rating questions was randomized across all participants. To avoid confusion, before the pre-art training, each aesthetic judgement was defined and each rating scale point was explained by using examples. A graphical illustration of a typical experimental trial is provided in figure 3.

The art training session consisted of either a full audiovisual art knowledge lesson, a brief visual art knowledge lesson or no art training at all (passive control). Before art knowledge training (full or brief) started, participants were informed about the following: (i) the art video's length (22:08 minutes for full audiovisual art training and 08:45 minutes for brief visual art training); (ii) to carefully watch the art video as they would have to complete art knowledge follow-up questions; (iii) to watch the art video in its entirety in order to continue the post-training phase. After both types of art knowledge training, participants were asked to complete seven multiple-choice questions (MCQs) to assess the level of art knowledge acquired during the training lesson. All seven MCQs were previously tested and validated by Bara *et al*. [30].

The post-art training session involved participants rating 100 paintings. Out of 100 paintings, 20 were the same Realist paintings from the pre-art training session, and 20 were the same Sorolla paintings from the pre-art training and art training sessions. Also, there were 20 new paintings by Sorolla that shared similar style features with Sorolla's paintings from pre-art training. In addition, there were 20 new paintings by Gauguin and 20 new paintings by Merritt-Chase. All 100 paintings were rated on the same four variables as in the pre-art training: understanding, creative inspiration, thought stimulation, intellectual challenge. As in pre-art training, all ratings were assessed on a 5-point Likert scale (1–5; not at all–extremely), and all the paintings remained on the screen until participants made a rating response. Similarly, the order of the paintings and the rating questions was randomized across all participants. Therefore, participants completed a total of 400 ratings during the post-test.

2.5. Data analyses

We preregistered a Bayesian estimation approach to multilevel regression modelling [61]. A key advantage of the Bayesian estimation approach is its ability to account for uncertainty in inferences. Unlike the frequentist method, which relies on point estimates and confidence intervals, the Bayesian approach emphasizes the complete posterior distribution [61]. This approach captures the full range of plausible values, offering a more comprehensive view of uncertainty. Accordingly, we evaluated our hypotheses by reporting and discussing the posterior distribution of our key parameters of interest within the most complex model. The most complex model had the maximum number of varying parameters that the design permitted [62]. Furthermore, in our analysis, we used the posterior (density) distribution of key parameters derived from the most complex model and discussed the point of highest density as well as the lower and upper bounds of the 95% quantile intervals. These intervals served as the basis for making inferential judgments about our pre-registered hypotheses. That being said, we are not using null hypothesis significance testing; we will not be reporting *p*-values, and we will not be making statements about statistical significance.

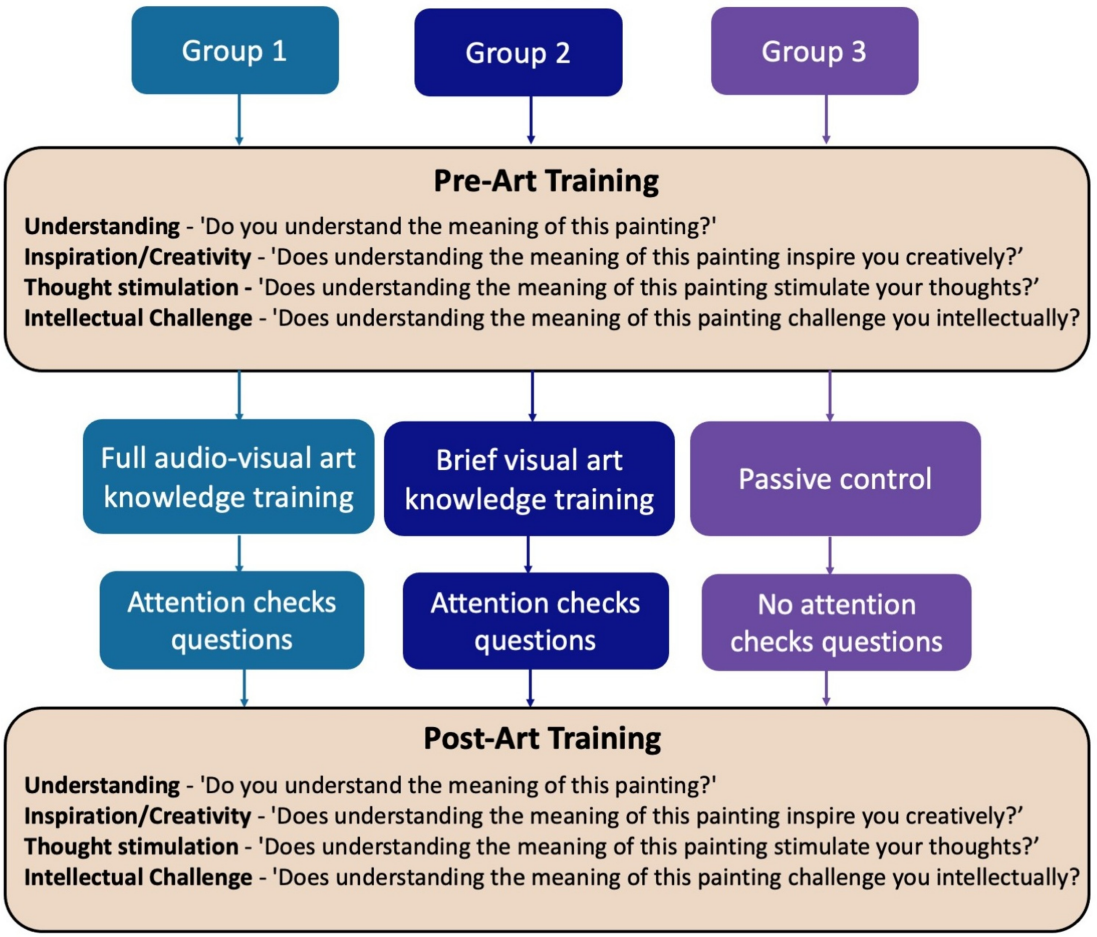

Figure 2. A visual description of the order of the tasks. Both pre-art training and post-art training consisted of ratings on understanding, creative inspiration, thought stimulation and intellectual challenge.

More specifically, we used a recent translation of McElreath's [61] general principles into a different set of tools [63] which use the Bayesian modelling package 'brms' to build multilevel models [64]. Moreover, our data wrangling approach follows the 'tidyverse' principles [65], and we generated plots using the associated data plotting package 'ggplot2', as well as the 'tidybayes' package [66]. Importantly, 'brms' employs the same syntax as the widely used 'lme4' package for estimating mixed-effects models in the frequentist framework [67]. All of these analytical approaches were performed in the R programming language [68].

Given that our dependent variables are ordered categories (a 1–5 rating scale), we used ordinal regression models. We ran two different types of ordinal regression models—one for each question of interest. The first multivariate model included all four DVs and addressed the extent to which different judgements of artworks were impacted by different types of art knowledge training (full audiovisual art, brief visual art training or passive control). The second multivariate model included all four DVs and addressed the extent to which the impact of different types of art training (full audiovisual art, brief visual art training or passive control) on judgements of artworks generalizes to previously unseen artworks.

To build the models incrementally in complexity, we followed the same multivariate modelling strategy as in our previous work [30,69]. For the first research question—pre- versus post-art training effects as a function of different types of art training—we calculated 13 multivariate models, which we built progressively in complexity. All the models' descriptions are reported in the supplementary material (Data Analysis). The model bpp5.3 was the full model, comprising the maximum number of parameters that the design allowed. The formula for the full model (bpp5.3) is specified as follows:

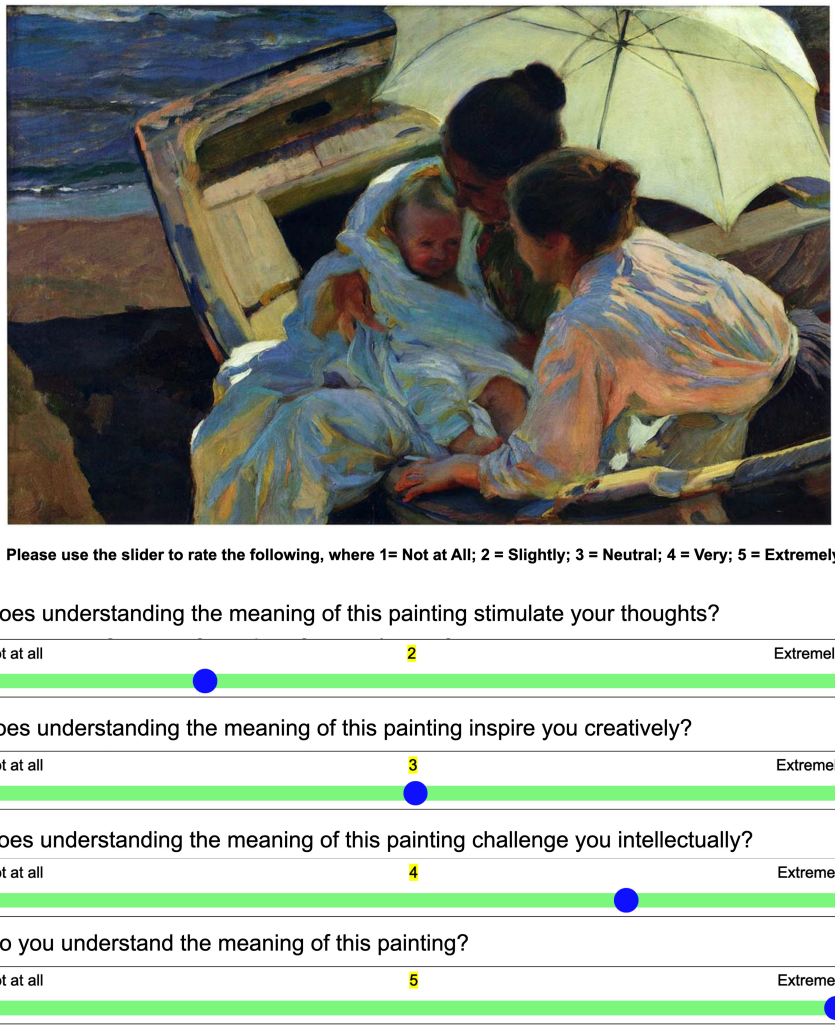

Figure 3. Example of experimental trial during pre- and post-art training.

brms formula = bf(mvbind (understanding, creativity, thinking, challenge) | thres (4, gr = item)
~1 + training * image_type * training_type +
(1 |p| item)+
(1 + training * image_type |a| participant)),

where training = pre- versus post-art training; image_type = Realism versus Sorolla; training_type = full audiovisual art training (22:08 minutes), brief visual art training (8:45 minutes); item = stimuli.

Factors associated with training and image type were coded according to a deviation coding style, where factors sum to zero and the intercept can then be interpreted as the grand mean and the main effects can be interpreted similarly to a conventional ANOVA. As such, both training and image type were coded as −0.5 (pre/Realism) and 0.5 (post/Sorolla). In contrast, Training_type ('full audiovisual' and 'brief visual' art training) was coded by reference to the passive control condition.

For the second research question, we estimated generalization effects. We calculated nine models, which were built incrementally in complexity. Model bg3.3 was the full model. The formula for the full model (model bg3.3) is specified as follows:

brms formula = bf(mvbind (understanding, creativity, thinking, challenge) | thres (4, gr = item)
~1 + condition * training_type +
(1 |p| item)+
(1 + condition |a| participant)),

where condition = pre_Sorolla, post_Sorolla, post_Sorolla_new, post_Merritt_Chase, post_Gauguin; training_type = full audiovisual art training (22:08 minutes), brief visual art training (8:45 minutes); item = stimuli. The factor 'condition' was coded by reference to pre-Sorolla.

Regarding the priors, we used a similar strategy as in our previous work [30,69]. We set priors using a weakly informative approach [70]. The priors used are provided in electronic supplementary material, table S1. Weakly informative priors place a constrained distribution on expected results rather than leaving all results to be equally likely (i.e. uniform). Weakly informative priors are also distinct from specific informative priors, which are more precisely specified because we currently do not have sufficient knowledge to place more specific constraints on what we expect to find. Considering the relatively small effects in the field of psychology in general, we placed priors for the thresholds (or intercepts) at zero with a normal distribution of 1. The fixed effects or predictors, as well as the standard deviations, were centred around zero with a normal distribution of 0.5. Also, by using weakly informative priors, we allow for the possibility of large effects, should they exist in the data [70–73].

In evaluating our key hypotheses, we had a few parameters of special interest as follows.

(1) Since we had three different groups of participants, we expected an interaction term showing that the training effect is larger for Sorolla than Realist paintings, and also larger for the full audiovisual art training and brief visual art training rather than passive control.

(2a) Given that the art stimuli by Sorolla were explained during the full audiovisual and brief visual art training and rated again during the post-training (post_Sorolla – same artist as the art training), we expected the post_Sorolla condition to have the largest effect, followed by post_Sorolla_new (unseen art stimuli by Sorolla, same artist as the art training), post_Merritt_Chase (unseen art stimuli by Merritt-Chase, similar stylistically to Sorolla) and then post_Gauguin (unseen art stimuli by Gauguin, dissimilar stylistically to Sorolla). Therefore, we expected the lowest effect for the post-Gauguin condition given its minimal stylistic resemblance to Sorolla and Impressionist style. Conversely, we expected the largest effect for the post-Sorolla condition as it featured the same artist and artworks used in the art training, followed by post-Sorolla new (same artist as the art training but new artworks) and post Merritt-Chase (different artist from the art training but within the same artistic style).

(2b) Since we used three art training groups, we expected an interaction showing that the condition effect is largest for post_Sorolla in the full audiovisual art or in-depth art training, followed by post_Sorolla in brief visual art training and smallest in the passive control.

If 95% quantile estimates for parameters of interest show substantial overlap with zero, it would suggest training has had minimal to no impact on judgements.

3. Results

The models' chains were carefully monitored, and the convergence diagnostics did not raise any concerns. The chains can be seen in the electronic supplementary material, figure S9.

Pre- and Post-Training Effects. Rating summary data for all four dependent variables (understanding, creative inspiration, thought stimulation, challenge) across pre- and post-training conditions, different image types (Realism and Sorolla) and as a function of different art training types (none = passive control; brief visual art training: 08:54 minutes; full audiovisual art training: 22:08 minutes) are shown in figure 4.

Parameter estimates for the most complex multivariate model (model 13 - bpp5.3) are shown in figure 5 and electronic supplementary material, table S2. While we visualize parameters from the full model, we only discuss the main pre-registered parameters of interest that address our key hypotheses, namely the three-way interaction effects (see the highlighted panels in figure 5). For the understanding DV, the 95% quantile intervals of the posterior distribution for both three-way interactions between training, image type, full audiovisual art training (Panel B) and brief visual training (Panel A) illustrated a clear positive response, with the lower bound of the quantile intervals not including zero. Here, a positive value response means that the post-training rather than pre-training effect was larger for Sorolla than for Realism paintings and larger for full audiovisual art training (Panel B) and brief visual art training (Panel A) compared to passive control.

Regarding the remaining DVs, the 95% quantile intervals of the posterior distribution overlapped with zero for our key interaction terms, suggesting a reduced effect of training on judgements of artworks. However, for creative inspiration and thought stimulation DVs, the 66% quantile intervals did not overlap with zero for the three-way interactions that include the full audiovisual art training term (Panel B). Similarly, the 66% quantile interval of the posterior distribution showed a positive

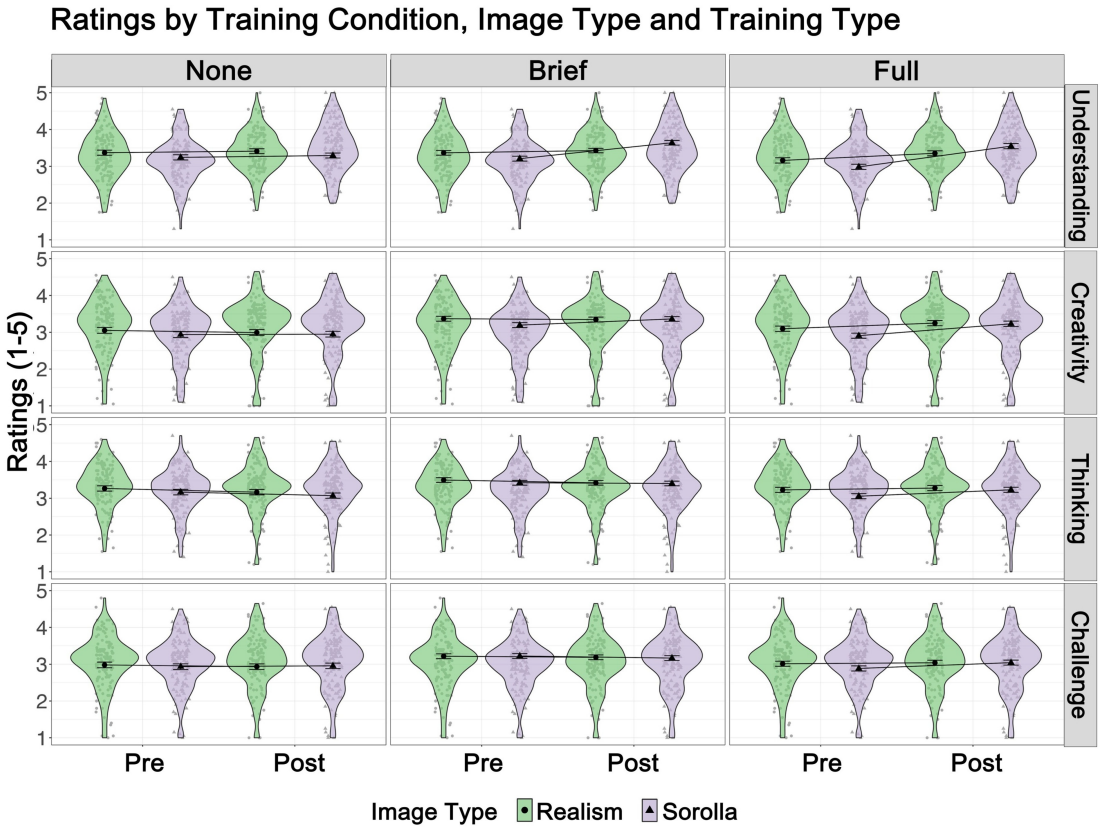

Figure 4. Ratings across training (pre- versus post-), image type (Realism versus Sorolla) and training type (none = passive control, brief visual, full audiovisual) on all four DVs. The columns show the art training types, whereas the rows show the ratings for understanding, creative inspiration, thinking (thought stimulation) and intellectual challenge. The ratings are reported on a 5-point Likert scale (1 = not at all to 5 = extremely). Error bars represent 95% confidence intervals. The black markers (circles and triangles) and interval estimates represent the group mean average, whereas the grey markers represent the individual participants.

response for the three-way interactions that include the brief visual art training term (Panel A) for creative inspiration DV. These results are in line with our hypothesis, but weaker than the effects reported for the 'understanding' DV, which means they should be interpreted more cautiously. In other words, we show clear support for our hypothesis regarding the 'understanding' DV, but more suggestive support for our hypothesis when considering the other DVs.

Generalization effects. Rating summary data for all four dependent variables (understanding, creativity, thinking, challenge) across all four art training types and generalization conditions are shown below (figure 6).

Parameter estimates for the most complex model (model 9: bg3.3) across all four dependent variables are shown in figure 7 and electronic supplementary material, table S3. While we visualize parameters from the full model, we only discuss the main pre-registered parameters of interest that address our key hypotheses (please see the highlighted panels in figure 7). We consider the two-way interactions in the model (Panels A, B, C and D). The lower bound of the 95% quantile intervals of the posterior distribution for the interaction between post_Sorolla and full audiovisual art training on understanding, creative inspiration and thought stimulation DVs showed a positive response (Panel A, second row). Here, a positive value response means that the condition effect was larger for post-Sorolla than pre-Sorolla and larger for full audiovisual art training than passive control.

In comparison, for the interaction between post_Sorolla and brief visual art training, the lower bound of the 95% quantile interval of posterior distribution showed a positive response only for understanding DV (Panel A, first row). Next, we consider interactions between the post_Sorolla_new condition and full audiovisual art training (Panel B, second row). The lower bound of the 95% quantile interval of the posterior distribution showed a positive effect for creative inspiration, thought stimulation and intellectual challenge DVs and just overlapped zero for the understanding DV. For the post_Gauguin (Panel C) and post_Merritt_Chase conditions (Panel D), interactions with art training showed no robust generalization effects.

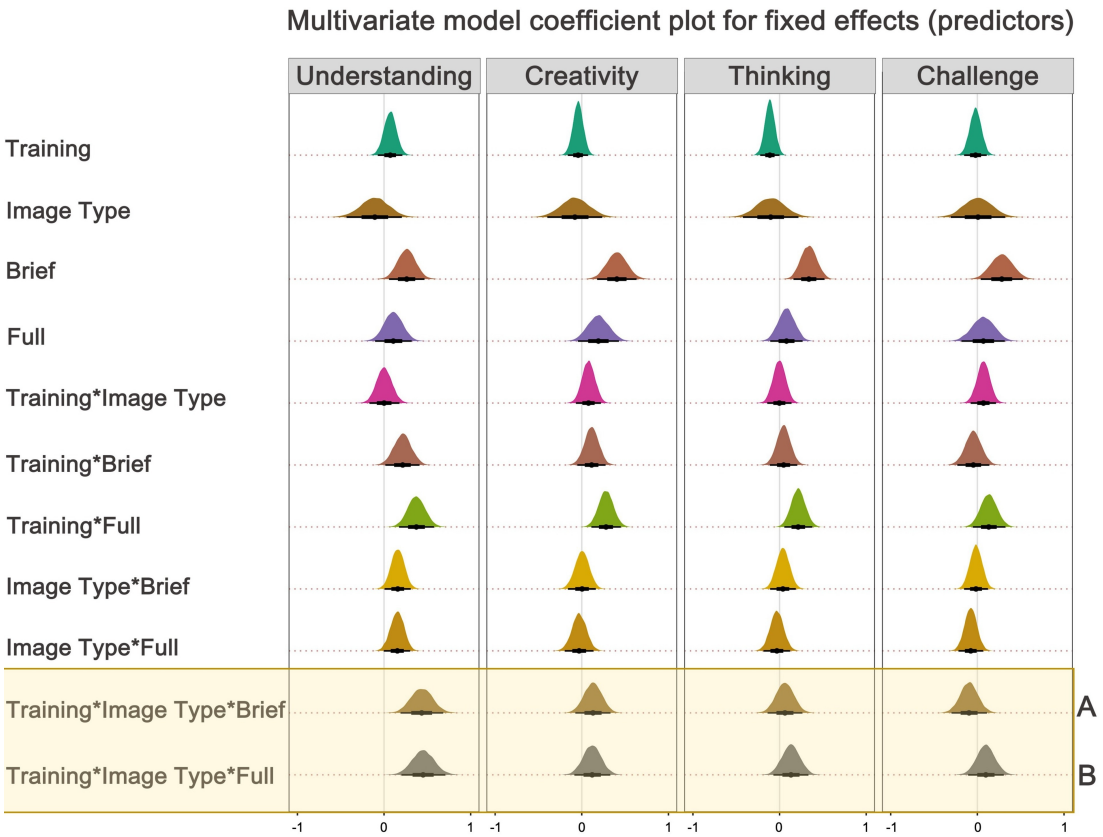

Figure 5. Multivariate parameter estimates for the full model (Model 13) across all four dependent variables: understanding, creative inspiration, thinking (thought stimulation) and intellectual challenge. The highlighted panels show the main parameters of interest. Panel A = three way interaction between training, image type and training type (brief visual art training). Panel B = three way interaction between training, image type and training type (full audiovisual art training). training = pre versus post; image_type = image category (Realism versus Sorolla); brief = brief visual art knowledge training 8:45 minutes; full = in-depth audiovisual art knowledge training 22:08 minutes. Point estimate = median; Error bars represent 66% quantile intervals (thick black lines) and 95% quantile intervals (thin black lines).

Overall, the generalization analysis results indicate that the meaning-understanding judgements of artworks were clear and convincing for post-Sorolla during full audiovisual art training rather than pre-Sorolla and passive control. A similar trend was observed for post-Sorolla during brief visual art training, but only for understanding. In addition, the effects of full audiovisual art training on judgements of artworks generalized to novel and unseen artworks by the same artists (Sorolla new) but not to artworks by new artists (Merritt-Chase and Gauguin).

4. Discussion

The current pre-registered study is among the first to empirically examine the aesthetic cognitivism theory by looking into how acquiring art knowledge can promote art understanding, creative inspiration and thought stimulation. In line with our hypotheses, we found that full audiovisual and brief visual art knowledge trainings, rather than passive control, led to greater meaning-understanding judgements for trained rather than untrained artworks. We also found weaker evidence for a similar impact of art training on creative inspiration and thought stimulation judgments. In addition, the judgements of artworks generalized to previously unseen artworks made by the same artists (Sorolla), but not to different artists. Overall, our findings suggest that audiovisual art knowledge training shapes subsequent judgements of meaning and creativity, which generalize to new artworks as a function of the artwork's similarity to the training material. We address some important implications of our findings in the following sections.

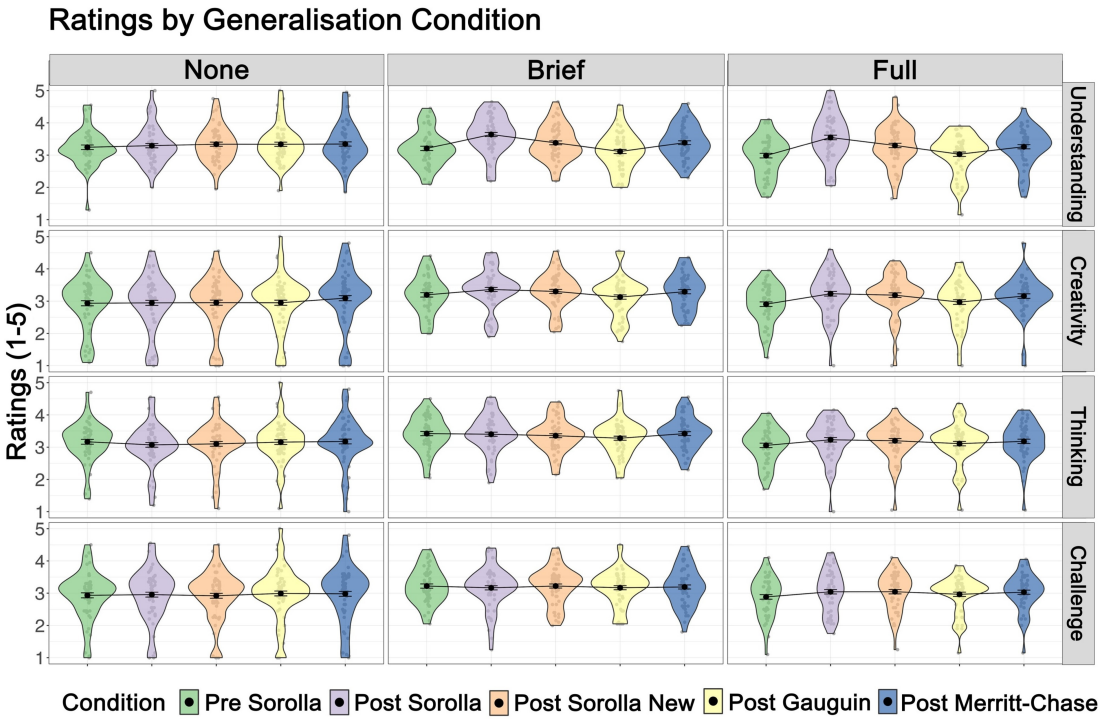

Figure 6. Ratings across dose type and generalization conditions (pre-Sorolla compared to post-Sorolla, post-Sorolla new, post-Gauguin and post-Merritt-Chase) on all four DVs (understanding, creative inspiration, thinking (thought stimulation) and intellectual challenge). The columns show the art training types (none = passive control, brief visual art training, full audiovisual art training). The rows show the ratings for understanding, creative inspiration, thinking (thought stimulation) and intellectual challenge. The ratings are reported on a 5-point Likert scale (1 = not at all to 5 = extremely). Error bars represent 95% confidence intervals. The black and interval estimates represent the group mean average, whereas the grey markers represent the individual participants.

4.1. Implications for learning and generalizability effects

Our findings show that primarily the full audiovisual (or in-depth) art training facilitated the generalization effects of judgements of understanding, creative inspiration, thought stimulation and intellectual challenge to unseen artworks produced by the same artist. These generalization effects could be explained with respect to *near* versus *far* transfer of trained skill or knowledge. Near transfer refers to an improved skill in a similar trained skill, whereas far transfer refers to an enhanced skill that is different from the trained skill [74–76]. Accordingly, learning about Sorolla's Impressionist art through approximately 22-minute audiovisual training and brief visual art training rather than passive control supported the transfer of art knowledge to novel, unseen artworks produced by Sorolla. These results also replicate previous research findings from our laboratory [30] showing that art knowledge training encourages near transfer (similar artistic styles) rather than far transfer of knowledge (transfer to dissimilar artistic styles).

4.2. Implications for aesthetic cognitivism: theory and research

Our study demonstrates that the information acquired mainly through an audiovisual training format and a brief visual art training rather than passive control provided participants with sufficient art knowledge to encourage an increase in self-reported understanding, creative inspiration and thought stimulation. Therefore, consistent with the aesthetic cognitivism framework [7,10–12] and with recent empirical research [13], we show that art knowledge can promote cognitive values that aid meaning-understanding and stimulate thinking. As previously highlighted by Douglas [77], thinking is facilitated by acquired knowledge and drives creative ideas, suggesting that beyond hedonic pleasure, art knowledge fosters cognitive attributes, such as understanding and creativity.

Furthermore, our study provides valuable information about the type of knowledge that shapes understanding, creative inspiration and thought stimulation. Our full audiovisual art training followed typical principles of art history museum guided tours [33,78], involving a comprehensive description

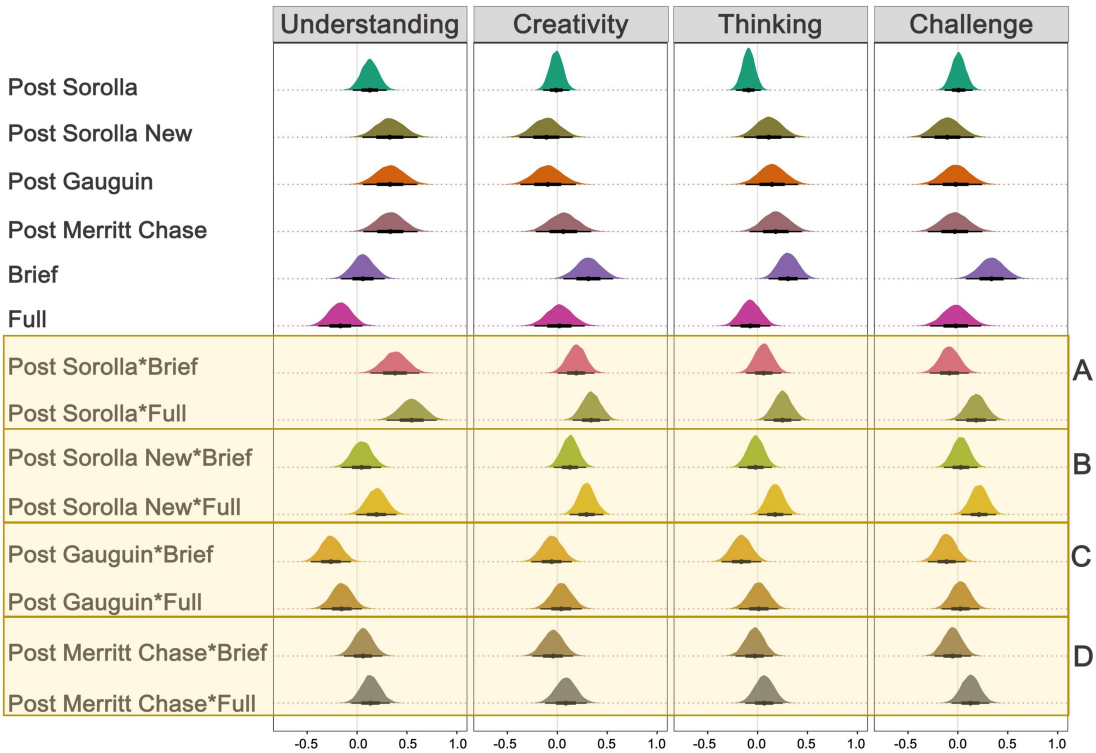

Figure 7. Multivariate parameter estimates for the full model (Model 9) across all four dependent variables: understanding, creative inspiration, thinking (thought stimulation) and intellectual challenge. The highlighted panels show the main parameters of interest. Panels A, B, C and D show two way interaction between post_sorolla condition and training type (panel A), post_sorolla_new and training type (panel B), post_gauguin and training type (panel C) and post_merritt_chase and training type (panel D). post_Sorolla = artworks by Sorolla presented during post-training; post_Sorolla_new = previously unseen artworks by Sorolla presented during post-training; post_Gauguin = previously unseen artworks by Gauguin presented during post-training; post_Merritt_Chase = previously unseen artworks by Merritt-Chase presented during post-training; brief = brief visual art knowledge training 8:45 minutes; full = in-depth audiovisual art knowledge training 22:08 minutes. Point estimate = median; Error bars represent 66% quantile intervals (thick black lines) and 95% quantile intervals (thin black lines).

and interpretation of Sorolla's paintings. Specifically, our training narrative placed the artworks in their historical, cultural and social context, identified and discussed artistic style elements, and interpreted their meaning. From a semantic perspective, our full audiovisual art training was characterized by rich semantic knowledge, capable of guiding art meaning-making and understanding [79]. Given these semantic qualities, it could be argued that our training intervention encouraged an associational type of knowledge emerging from associations between the featured artworks and their analogous art history concepts.

Another implication of our findings is that the arts not only inspire creativity, but as Ishiguro & Okada [80] have argued, promote enjoyment. Furthermore, there is evidence to show that art viewing stimulates creative ideas that support later art production [81]. For example, research has shown that both art viewing and art-related discussions contribute to art understanding, which in turn encourages creative ideas in art-making [82]. This suggests that dialogue about art can ignite the spark of creative inspiration. Overall, these ideas suggest that engaging with art stimulates creativity, supporting the aesthetic cognitivism framework, which highlights art's cognitive value in inspiring new ideas, deepening understanding and fostering creative thought [10].

Similarly, a recent study by Welke *et al*. [83] found that being emotionally moved by artworks can foster inspiration in a creative writing task, suggesting that creative inspiration can also stem from affective engagement with artworks. While we did not measure emotional responses given our cognitive focus, such measures might have revealed whether affective engagement operates alongside the cognitive mechanisms we documented. It is therefore important to situate our findings within the broader theoretical landscape of art reception. Our results complement core literature on emotional responses and aesthetic pleasure in art [84,85], suggesting that cognitive engagement may work in

concert with affective responses. The findings of Welke *et al*. [83], showing that emotional responses can foster creative inspiration, further support this integrated perspective. Future research could extend this approach by systematically examining how cognitive and affective dimensions jointly contribute to creative ideas and meaning-making.

As previously argued, inspiration is a motivational state that encourages the creation and curation of innovative ideas or products [86–88]. While the source of inspiration could be affective (e.g. being emotionally moved) or cognitive (e.g. understanding and thinking), overall, it guides individuals toward creative ideas and actualization of ideas into products or objects [87,89]. Taken together, these ideas suggest that beyond art appreciation, art knowledge benefits creative cognition by promoting inspiration, association of ideas, stimulating thinking and art production.

4.3. Implications for different art training modalities and training duration

Our pre-registered analyses do not directly compare full audiovisual art training with brief visual art training. However, visual inspection of numerical trends suggests that understanding the meaning of the artworks, creative inspiration and thought stimulation were more strongly associated with full audiovisual art training (approx. 22 minutes) than brief visual-only art knowledge training (approx. 9 minutes). The judgements were also more likely to generalize to new contexts when participants undertook the full audiovisual art knowledge training than the brief visual art knowledge training. This suggests that information modality and training duration play important roles in understanding, creative inspiration and thought stimulation. From an information modality perspective, our results are in line with [21] who found that viewing paintings while listening to rather than reading the curatorial descriptors enhanced aesthetic preference, understanding and affective evaluations. Further evidence for successful engagement with multimodal information comes from the music domain. A study by Czepiel *et al*. [90] demonstrated that aesthetic experience of music performance was more strongly associated with audiovisual information rather than auditory information only, suggesting that presentation modality can shape aesthetic appreciation and related cognitive processes.

Regarding the art training duration, the current findings replicate our previous research [30] showing that an approximately 22-minute rather than approximately 9-minute lesson about Sorolla's art provided sufficient level of art knowledge to shape art understanding, creative inspiration and thought stimulation. The duration of the training session is an important aspect that has implications for educational contexts. Indeed, past research has shown that across different learning contents and learner characteristics, a lesson of approximately 30–45 minutes is suitable for retention of the trained material [91], suggesting that learning depends on session duration.

4.4. Implications for the mere exposure effects and familiarity

Our experimental manipulation included a passive control group who did not complete any aspects of the art knowledge training. Although not methodologically common in empirical aesthetics, the passive control group provided an important baseline to compare the effects of the full audiovisual art knowledge training and brief visual art knowledge training. It also offered valuable insights into the repeated exposure and familiarity phenomena. According to the mere exposure effect, familiar or repeated stimuli are typically more liked than unfamiliar ones [92,93]. One of the main explanatory arguments for repeated exposure effects is the processing fluency theory [94,95]. According to that, repeated exposure and low-level stimuli characteristics (e.g. symmetry, complexity, luminance) are thought to increase the ease of processing stimuli-related information, which then enhances likeability or preference [54,96,97].

While we did not set out to investigate the effects of repeated exposure to different artworks on understanding, thought stimulation and creative inspiration, by using a control group where participants viewed the same artworks twice, we observed no reliable change in participants' self-reported judgements. Specifically, we found no evidence for the mere exposure effect, which would predict higher ratings after repeated viewing simply due to the repeated (mere) exposure to the artworks in question. Our results suggest that understanding and thought stimulation judgements might require different information processing systems that support meaningful associations between the acquired knowledge than likeability and preference judgements. Since repeated exposure and fluency processing have been studied in relation to the stimuli characteristics and likeability ratings, it could be that the assessments of understanding, creative inspiration and thought stimulation require top-down

cognitive processing and are therefore less sensitive to repeated exposure effects. Although our results suggest some boundaries to repeated exposure effects, future studies should explore this relationship in greater depth.

4.5. Limitations and constraints on generality

As noted by Simons *et al*. [98], it is valuable to discuss constraints on generality of our findings. We show that art knowledge training shapes judgements of understanding, creative inspiration and thought stimulation by using self-reported measures. While such measures capture perceived rather than objective change, future studies could combine self-report with implicit or behavioural measures (e.g. comprehension or creative production) to examine how perceived and actual understanding, creative inspiration and thought stimulation interact. Also, the size of training effects varied across the different DVs, with some effects estimated more robustly than others. For example, the basic training effect from pre- to post-training was clearer for understanding than the other DVs. Future research that confirmed these findings with more sensitive measures or larger sample sizes would be valuable before more confident inferences can be drawn.

Although our study design cannot disentangle whether specific elements of the art training (e.g. historical, visual characteristics) might have played a different role in participants' judgements, we acknowledge this as a valuable avenue for future research. In addition, while we have been cautious in drawing definitive conclusions based solely on the modality, dose and depth of art training, we strongly advocate for future research to explore additional factors, such as the specificity of art training content, the environment in which the training occurs and participant engagement strategies. In addition, it is important to note that the present study used materials (e.g. the full audiovisual art training) developed in our lab, which may have contributed to the replication of earlier findings on near-transfer effects. Future research should examine this effect using different training materials.

At the same time, we recognize the limits of online-based studies and the necessary caution when interpreting our findings in real-world settings. Future research could investigate the effectiveness of art knowledge training on meaning-understanding judgements by comparing research conducted in controlled laboratory settings to more naturalistic settings, such as art galleries. We also note that expectancy effects cannot be entirely ruled out. Future studies could address this further through blinded instructions and complementary behavioural or implicit measures. Finally, our study assessed judgements of understanding, creative inspiration and thought stimulation through the lenses of training interventions focused on the visual arts. Future studies might extend the aesthetic cognitivism framework to other art forms, such as dance, music or theatre.

4.6. Applied implications—art museums and art education

Our work has potential implications for art museums, art galleries and arts education. The current findings provide empirical evidence that approximately 22-minute audiovisual art history lesson can effectively facilitate art engagement, such as art understanding, creative inspiration and thought stimulation. Art curators and educators might use these insights when devising art-guided tours. While the concept of art museums as spaces for teaching, learning and knowledge has been emphasized by numerous scholars [99,100], the psychological principles underlying successful art lessons to foster cognitive values such as associational thinking and encourage creative inspiration remain little explored.

Furthermore, our study has larger implications for art education policies and alongside other scholars [101,102], our research emphasizes that art education can foster deeper understanding, thought stimulation and creative inspiration. This is a pressing topic, especially as art education is frequently affected by budget cuts and undervalued compared to STEM [103,104]. Our study provides an important empirical step in recognizing the value of art knowledge as a vehicle for understanding and thought stimulation that promotes a broader and more interconnected view of the world.

5. Conclusion

Our research demonstrates that different art knowledge training modalities, depths of information and doses—specifically, full audiovisual, brief visual and passive control—shape participants' judgments of

artworks regarding understanding, creative inspiration, thought stimulation and intellectual challenge. Participants who took part in the full audiovisual training condition reported higher levels of understanding and creative inspiration in their evaluations of trained artworks compared to those who received brief visual training or no training at all. These findings offer valuable insights into how different training approaches affect artwork judgments, suggesting important considerations for developing effective art education strategies that foster meaningful learning experiences.

Ethics. All the experimental procedures in this study were granted ethical approval by the University of Glasgow, College of Medical, Veterinary and Life Sciences (Ethics number: 200220002). All participants provided informed consent before completing the experiment. This experiment did not include fieldwork, and no other permissions were required.

Data accessibility. All the data, stimuli and analysis scripts for each experiment are available online via the Open Science Framework [105].

Supplementary material is available online [106].

Declaration of AI use. We have not used AI-assisted technologies in creating this article.

Authors' contributions. I.B.: conceptualization, data curation, formal analysis, investigation, methodology, project administration, validation, visualization, writing—original draft, writing—review and editing; R.R.: conceptualization, data curation, formal analysis, methodology, validation, visualization, writing—review and editing; E.S.C.: conceptualization, funding acquisition, methodology, project administration, resources, supervision, validation, writing—review and editing.

All authors gave final approval for publication and agreed to be held accountable for the work performed therein.

Conflict of interest declaration. We declare we have no competing interests.

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