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## Bodily feelings and aesthetic experience of art

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### ABSTRACT

Humans all around the world are drawn to creating and consuming art due to its capability to evoke emotions, but the mechanisms underlying art-evoked feelings remain poorly characterised. Here we show how embodiment contributes to emotions evoked by a large database of visual art pieces ( $n = 336$ ). In four experiments, we mapped the subjective feeling space of art-evoked emotions ( $n = 244$ ), quantified “bodily fingerprints” of these emotions ( $n = 615$ ), and recorded the subjects’ interest annotations ( $n = 306$ ) and eye movements ( $n = 21$ ) while viewing the art. We show that art evokes a wide spectrum of feelings, and that the bodily fingerprints triggered by art are central to these feelings, especially in artworks where human figures are salient. Altogether these results support the model that bodily sensations are central to the aesthetic experience.

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### KEYWORDS


Emotion; embodiment; art; aesthetics

Emotion is central to art. Humans all around the world are drawn to creating and consuming art due to its capability to evoke emotions (Chatterjee & Vartanian, 2014; Zentner et al., 2008), and human emotions are also a central subject of numerous artworks ranging from *The Scream* by Edvard Munch to *The Kiss* by Gustav Klimt. Emotions coordinate physiological and behavioural activation patterns to promote survival and govern decision-making across contexts ranging from mate selection (Johnston, 2006) to feeding (Spence et al., 2016) and environmental preferences (Kaplan, 1987). They are modulatory systems interacting with both physiological control circuits, and higher-order cognitive networks supporting decision-making (Nummenmaa & Saarimäki, 2017). Categorical models of emotions propose that evolution has carved a set of basic emotions that support specialised survival functions (Cordaro et al., 2018; Ekman, 1992; Panksepp, 1982). These emotions are characterised by discrete neural and physiological substrates, distinctive subjective feelings, expressions, and neural basis (Nummenmaa & Saarimäki, 2017; Panksepp & Watt, 2011).

Yet, humans may experience powerful emotions in the absence of survival challenges, notably when encountering art. Art is an ancient phenomenon and already homo erectus created primitive ornamentations to their tools (Joordens et al., 2014). Emotions evoked by art presumably constitute one key factor drawing us to making and consuming art (Chatterjee & Vartanian, 2014; Zentner et al., 2008). However, there is no consensus on whether emotions associated with art and aesthetic experiences are governed by the same systems supporting emotions during survival-salient episodes (Putkinen et al., 2021) and whether aesthetic experience is qualitatively similar to other everyday experiences (Marković, 2012). Consequently, the origins of art-evoked emotions are under intensive debate (Armstrong & Detweiler-Bedell, 2008; Leder et al., 2004; Menninghaus et al., 2019; Skov & Nadal, 2020).

An intriguing yet untested hypothesis is that art-evoked emotions stem from the subjectively felt bodily changes resulting from viewing art. Human bodies are central to visual art, both as the object of

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the artwork and as triggers of bodily sensations (described as, for example, “touching”, “moving”; Kallio-Tavin et al., 2021). Human faces receive most attention in both photographs and paintings, indicating the importance of human form in the composition of visual arts (Nummenmaa et al., 2012; Pihko et al., 2011). Somatosensation and interoception play critical roles in emotion (Craig, 2002; Damasio & Carvalho, 2013) and emotions are often considered as embodied processes due to the importance of central representation of the body’s physiological state in emotional experience. Distinct emotions are associated with discernible “bodily fingerprints” that are organised in a categorical and culturally universal manner (Nummenmaa et al., 2014; Volynets et al., 2020). Somatosensory and interoceptive experiences are also important determinants of subjective emotional feelings (Nummenmaa et al., 2018) and accordingly, the aesthetic evaluation of art is also associated with activation of the insular cortex (Cupchik et al., 2009) involved in interoceptive processing. It is thus possible that aesthetic experiences evoked by art could be connected to subjective bodily feelings while encountering art (Schino et al., 2021). This is particularly likely for artworks containing humans, as seeing others’ actions may trigger sensorimotor mirroring that promotes understanding the socioemotional contents of the depicted scene.

Although low-dimensional ratings of emotions (liking and arousal) can be used for describing emotions emerging while viewing art (Leder et al., 2012), recent work suggests that such conceptualisation of aesthetic experiences is too narrow (Cowen et al., 2020; Cowen & Keltner, 2017; Mohammad & Kiritchenko, 2018). The aesthetics-related emotions associated with art and their role in the subjective preferences for specific pieces of art remain poorly characterised. This question is particularly relevant given the mixed and ambiguous emotions evoked by art: Although people generally dislike events and objects that cause negative emotions, various forms of art that evoke negative emotions, such as sadness, may also be strongly liked (Menninghaus et al., 2017; Putkinen et al., 2021).

Here we investigated embodied emotions evoked by art and their relation to the presence of human figures in the art pieces (Figure 1). We mapped the subjective feeling space of art-evoked emotions and quantified the bodily fingerprints of these emotions. Because emotions are key determinants of subjective preferences, we also tested which feelings are

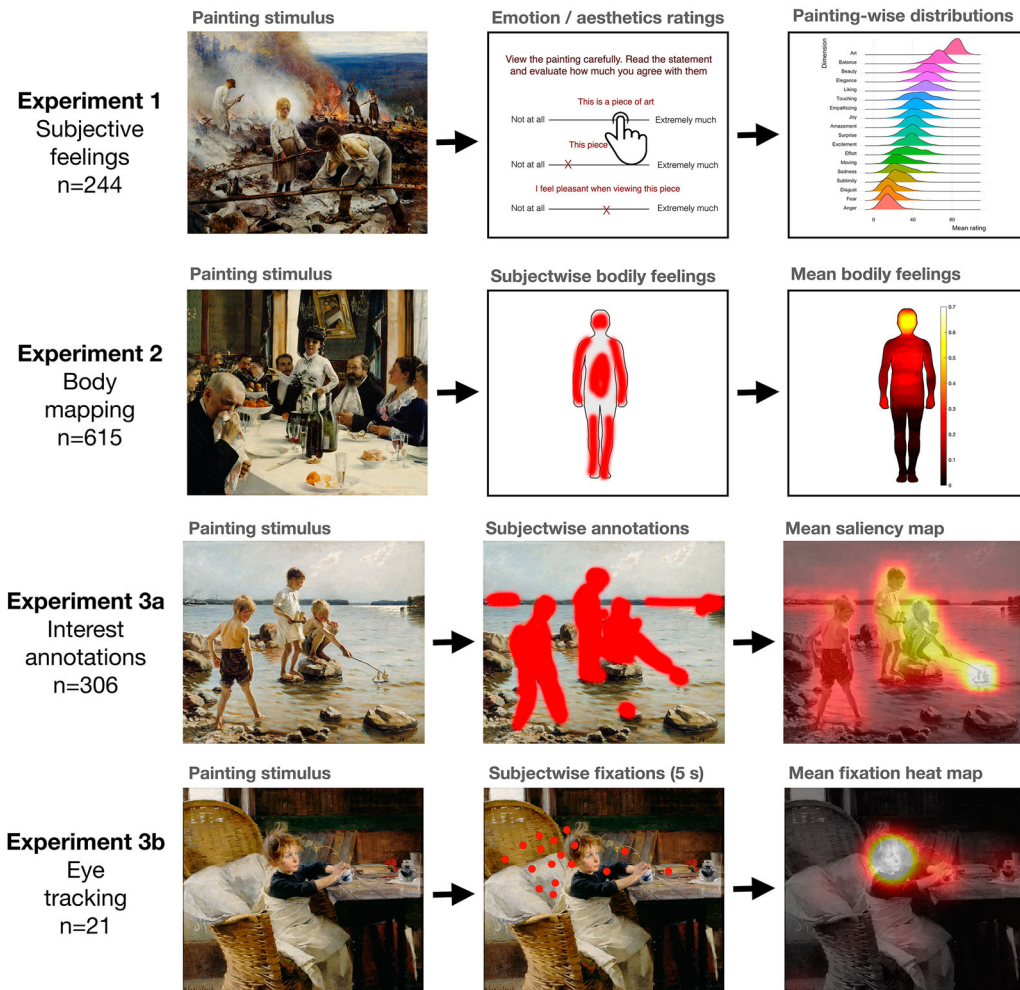
indicative of preferences for art pieces as well as the appreciation of an image as an artwork. We recorded the subjects’ interest annotations and eye movements to assess whether the presence of humans in the artworks were associated with emotions and bodily feelings. The stimuli were a large set ( $n=332$ ) of visual art pieces spanning multiple genres and epochs. The total number of stimuli and subjects in each experiment are summarised in Table 1. Power calculations for bodily sensation mapping experiments have not been developed, sample size was based on the original studies on bodily maps of emotions (Nummenmaa et al., 2014). Statistical analyses were conducted using Matlab R2020b and R statistical software.

## Experiment 1: subjective feelings while viewing visual art

### Materials and methods

The stimuli were digital photographs of 336 paintings and drawings spanning multiple genres and periods. Most of the stimuli were retrieved from the WikiArt Emotions database (See IDs in Supplementary Text 1) and were chosen based on their capacity to evoke emotions in the viewers (Mohammad & Kiritchenko, 2018). These artworks were complemented with 20 internationally famous paintings and 20 famous Finnish paintings presumably not widely known outside Finland (see Supplementary text 2); this was done to make sure the stimulus contained also well-known and well-liked as well as unfamiliar artworks. The stimuli were divided into four broad categories per their content: **Portraits** ( $n=89$ ) where single or small groups of individuals portrayed in posed settings, **people** ( $n=145$ ) where multiple human figures were represented in various activities, **landscapes and objects** ( $n=33$ ) where the nature, environment or objects were the main content and **abstract** ( $n=70$ ) works which portrayed no recognisable objects or where the level of abstraction in presenting them was high. This categorisation should be considered as heuristic content analysis rather than as a fine-grained designation of the art genres; we did not aim at matching the number of paintings in each category.

The experiment was run using Onni online platform developed for measuring bodily sensation maps as well as completing simple questionnaires and preference ratings (Heikkilä et al., 2020). A total of 244 subjects (208 females, 36 males; mean age 40.5 years, SD 18.28 years) volunteered for the study. The experiment



**Figure 1.** Overview of the study design for Experiments 1–3. Sample paintings from top to bottom: *Kaski* (Eero Järnfeldt), *Morsiamen laulu* (Gunnar Berndtson), *Leikkiviä poikia rannalla* (Albert Edelfelt), *Toipilas* (Helene Schjerfbeck).

contained all the paintings presented in a random order on computer / tablet screen. All images were rescaled to fill approximately 70% of the screen on their longer axis and presented in a random order. In this and all

**Table 1.** Summary of the number of stimuli and subjects used in each experiment. Note that stimuli in Experiment 1 and 2 were the same, and a subset of those was used in Experiments 3a–b.

	n (stimuli)	n (subjects)	n (stimuli per subject)
Experiment 1: Subjective feelings	336	244	22 (mean)
Experiment 2: Bodily sensations	336	615	24
Experiment 3a: Interest annotations	60	306	30
Experiment 3b: Eye tracking	60	21	60

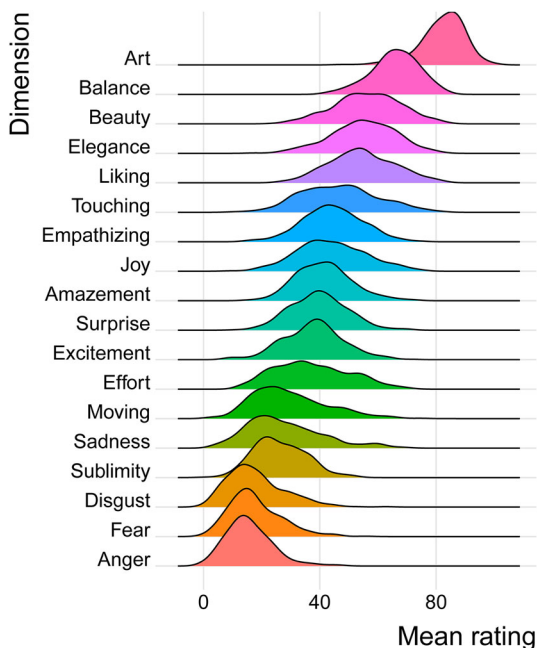
subsequent experiments the subjects were told that the study pertains emotions, visual images, and art. We evaluated the aesthetic experience from multiple viewpoints. First, to verify that the subjects actually considered the works as art, they were asked to evaluate the art-like qualities (do you consider this art) of each image. Second, because our main focus was on emotions, we obtained evaluations for basic (happiness, sadness, surprise, fear, anger, disgust) and non-basic (sublimity, amazement, excitement) emotions. Third, because empathetic responses are known to mediate aesthetic experience (Ardizzi et al., 2021), we measured empathy-related aesthetic experiences (balance, touching, capability to evoke empathy). Because art is sometimes difficult to understand and such effort may decrease the likability of the works (Reber et al., 2004),

we also acquired reports the difficulty/effort needed to understand the work. Finally, as emotions are key determinants of preferences, we also asked subjects to rate the images for preference (liking) and beauty. See Table S-1 file for full list of ratings.

All ratings were given using visual analogue scale coded from 0 (not at all) to 100 (extremely much) and located below the stimuli. The subjects were told to evaluate as many paintings as they wanted (with all the dimensions), this approach was taken to maximise the number of ratings per painting without making the task overly laborious. An average of 22 responses (range: 1–332) for all the rated dimensions per painting were obtained. We analyzed the data by averaging the ratings for each painting and then computed correlations between the ratings. Hierarchical clustering was used to determine the underlying structure of the rated dimensions, and stepwise linear regression model was used for predicting which emotional dimensions determine (i) whether a piece was considered as art and (ii) how much it was liked.

## Results

Figure 2 shows distributions of painting-wise mean ratings. Most rated dimensions were relatively

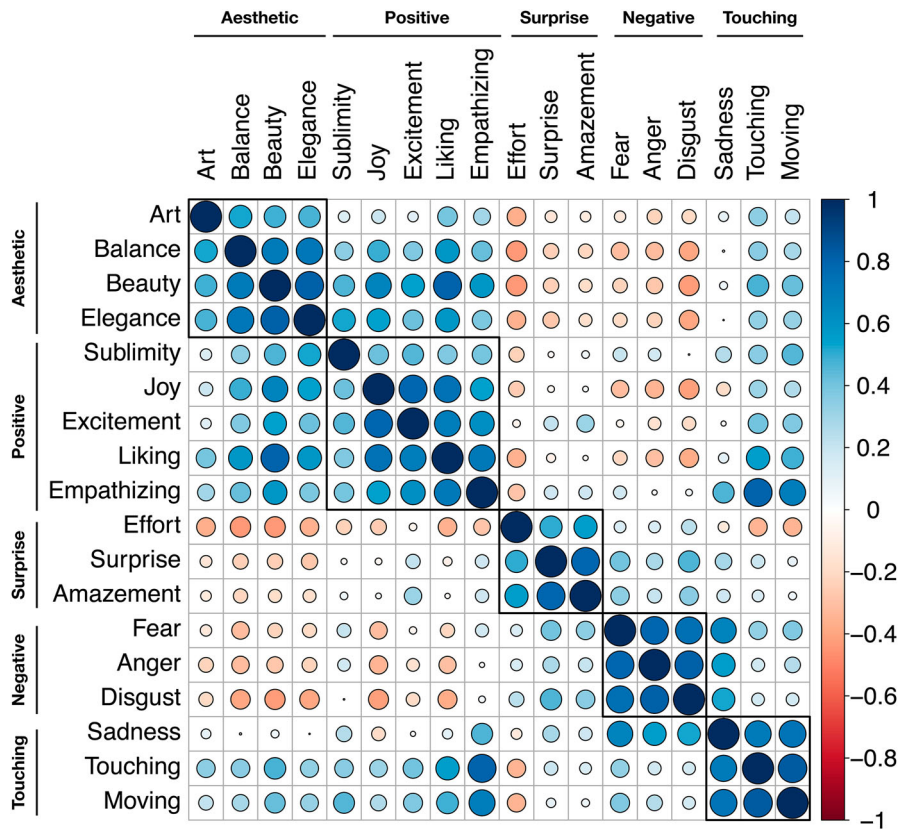


**Figure 2.** Frequency distributions of the rated dimensions of the art pieces.

normally distributed. Subjects considered the pieces generally as art ( $M = 82.24$ ,  $SD = 7.61$ ) and moderately likable ( $M = 54.47$ ,  $SD = 11.23$ ). They also gave high to moderate ratings on aesthetic dimensions such as balance ( $M = 65.87$ ,  $SD = 8.14$ ), beauty ( $M = 56.30$ ,  $SD = 11.43$ ), elegance ( $M = 54.91$ ,  $SD = 11.14$ ), and touching ( $M = 46.66$ ,  $SD = 13.23$ ). Experiences of surprise ( $M = 39.69$ ,  $SD = 9.79$ ) and amazement ( $M = 41.40$ ,  $SD = 9.57$ ) were moderately common, whereas negative emotions such as sadness ( $M = 27.87$ ,  $SD = 13.06$ ) and anger ( $M = 15.64$ ,  $SD = 7.91$ ) were rare despite many paintings displaying clearly unpleasant scenes (e.g. death, funeral, assault).

Correlational and cluster analysis (Ward method with 1-r as dissimilarity metric) revealed a clear five-cluster structure (Figure 3). Aesthetic dimensions (balance, beauty, and elegance) clustered together and were correlated with the art-like quality of the pictures. Positive emotions (joy, excitement, liking) clustered together with empathising and sublimity; dimensions in this cluster were also associated with the aesthetic dimensions. Effort needed to comprehend the artwork, amazement, and surprise formed a third cluster. The dimensions in this cluster were also negatively associated with the aesthetic dimensions and positive emotional experiences. The fourth cluster contained negative emotions (fear, anger, disgust), and the final fifth cluster contained sadness and experiences of touching and moving. The negative emotions were negatively linked with the aesthetic and positive emotions, yet the experiences of being touched and moved were positively associated with the aesthetic and positive emotional qualities.

Next, we modelled – using stepwise multiple regression – the dimensions of aesthetic experience that predicted whether a stimulus was (1) liked and (2) considered as art. To avoid confounds, liking was excluded from the model where art-like qualities were predicted, and *vice versa*. Results for the final models with statistically significant predictors are summarised in Figure 4. For liking, the model fitted the data well,  $F(10,325) = 179.20$ ,  $p < 0.001$ , and explained a high proportion of the variance,  $R^2 = 0.81$ . Of the statistically significant predictors, beauty, empathizing, excitement, touching, and joy had positive regression coefficients (betas), while disgust, fear, and elegance had negative betas. Balance, sublimity, effort, surprise, amazement, anger, sadness and moving were excluded from the model. For art-like qualities, the final model fitted the data well,  $F(10,325) = 23.37$ ,  $p < 0.001$ , and



**Figure 3.** Pearson correlations between the rated dimensions. Black outlines show the clustering of the rated dimensions.

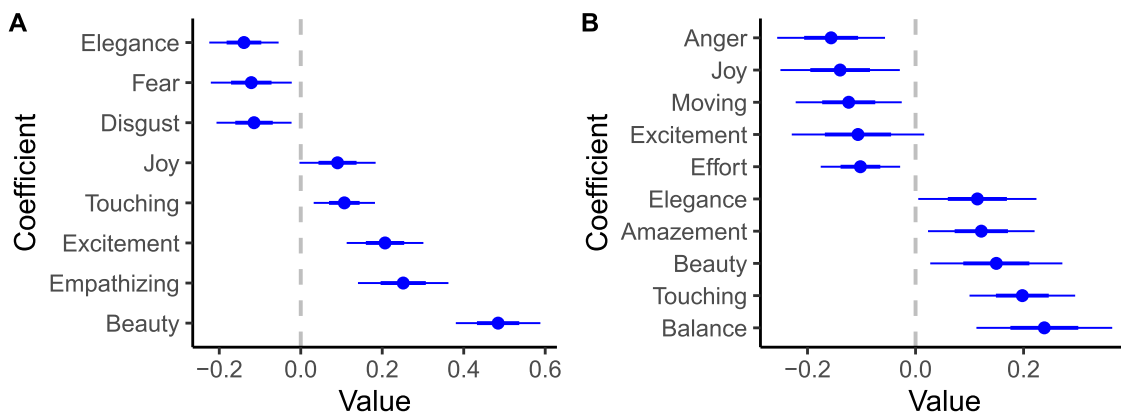
explained almost half of the variance,  $R^2 = 0.42$ . Of the statistically significant predictors, balance, touching, beauty, amazement, and elegance had positive betas and effort, excitement, moving, joy, and anger negative betas. Empathising, surprise, sublimity, sadness, and disgust were excluded from the model.

## Experiment 2: bodily feelings while viewing art

### Materials and methods

We next used the bodily sensation mapping tool (Nummenmaa et al., 2014) and tested whether viewing artworks evokes bodily feelings that would be dependent on the emotional and aesthetic dimensions of the art works (as determined in Experiment 1). The stimuli were the same as in Experiment 1. Data were acquired on the Gorilla platform (<http://gorilla.sc>) and a total of 615 subjects (238 females, 377 males; mean age = 26.27, SD age = 7.62) were

recruited from Prolific. For the sake of subject comfort, the experiment was divided into batches so that each subject reported bodily sensations to 24 paintings. Subjects viewed the paintings on a computer / tablet screen one at a time. A blank human body was shown alongside each painting. Subjects were asked to view each image and colour the regions of the body that they felt being activated while viewing the image. Subjects only reported their bodily sensations and not phenomenological emotional experiences. We adopted this approach to avoid direct semantic confounds between the emotion labels (such as “I am angry”) and corresponding semantic concept of anger in the body (such as “my fists must be clenching”). Based on independent ratings obtained in Experiment 1, the ten paintings with highest score in each dimension (see Figure 2 and Supplementary data 1) were selected for analysis. Data analysis stream has been described previously (Nummenmaa et al., 2014; Suvilehto et al., 2015). Individual bodily responses were rescaled to a standard template (175\*524 px), averaged across subjects for

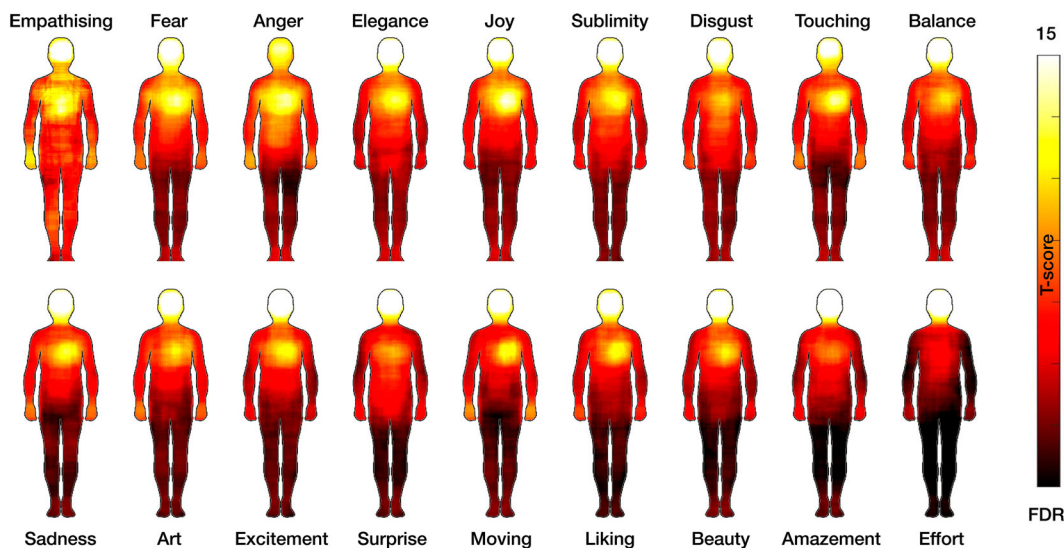


**Figure 4.** Regression coefficients and their 95% confidence intervals for models predicting liking (A) and art-like qualities (B) of the artworks in the stepwise regression models. Coefficients are arranged in ascending order separately for each model.

the ten paintings for each dimension, and pixelwise mass univariate t-tests were conducted to reveal statistically significant activations for each painting. Finally, false discovery rate correction (Benjamini & Hochberg, 1995) was applied to control for false positives.

To assess the link between bodily feelings and emotional and aesthetic evaluations of art, we computed the average number of pixels coloured in the human figures for each painting. These indices, calculated separately for the head and body regions, range from 1 (every subject coloured every pixel) to 0

(no subject coloured any pixel). We considered colouring of the body region to imply embodiment or bodily component of the sensations, whereas colouring of the head region was considered to imply mentation, here called mental component. This distinction was based on our previous work on 100 core feelings that showed that mental phenomenological experience of specific subjective states lacking e.g. facial movements or physiological changes is associated with self-reported sensations in the head area (Nummenmaa et al., 2018). The indices were subsequently correlated with the painting-wise ratings from Experiment 1 to



**Figure 5.** Bodily maps of aesthetic and emotional experiences while viewing art. The maps show the statistically significantly activated regions across subjects for each feeling. The maps are arranged as a function of the mean proportion of significant pixels, and thresholded at  $p < 0.005$ , FDR corrected. Colourbar indicates the t statistic range.

test how the bodily and mental components of feelings link with the consciously accessible emotions while viewing the paintings. Because embodiment might be affected, via mirroring mechanisms, on seeing other humans in the paintings, we also tested whether embodied and mental components would vary across painting types (portraits, people landscapes, objects, and abstract paintings).

## Results

Figure 5 shows the bodily feeling maps of different emotions elicited by viewing art. On average, most consistent bodily feelings were associated with empathising, fear, anger, elegance, and joy. Most of the evaluated dimensions were associated with bodily sensations in the chest area, while feelings in the upper limbs were most salient for anger, empathising, and fear. Experiences of amazement and effort were markedly lacking in the embodied sensations.

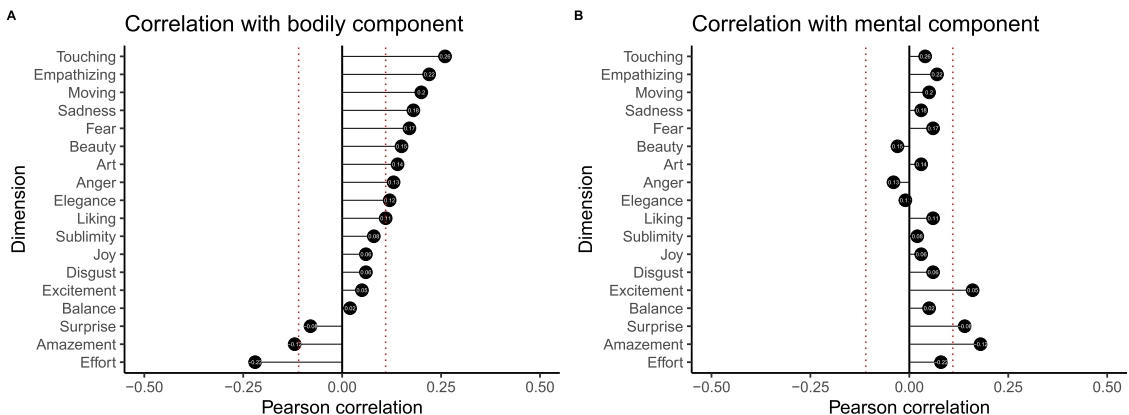
To assess the link between bodily feelings and emotional and aesthetic evaluations of art, we computed the average number of pixels coloured in the head and body of the human figures for each painting. Bodily and mental components were negatively correlated ( $r = -0.28$ ,  $p < 0.001$ ). The bodily component (Figure 6 and Table S-2) was positively correlated with experiences of touching, empathising, moving, sadness, fear, beauty, art, anger, elegance and liking ( $r_s > 0.11$ ,  $p_s < 0.05$ ) and negatively correlated with experiences of amazement and effort ( $r_s < -0.12$ ,  $p_s < 0.05$ ). Mental components showed significantly sparser pattern of associations, with positive correlations for excitement, surprise, and amazement ( $r_s$

$> 0.16$ ,  $p_s < 0.05$ ). Finally, we observed that bodily feelings varied across painting types,  $F(3,332) = 30.06$ ,  $p < 0.001$ ,  $\eta_p^2 = 0.21$ . Bodily sensations were strongest for pictures with people, and bodily sensations for pictures with people differed statistically significantly from those for portraits or those with abstract content ( $p_s < 0.001$ ). The sensations were second strongest for landscapes, which differed from abstract paintings ( $p < 0.001$ ), but not from paintings with people or portraits (Tukey's HSD test). Mental component also varied as a function of painting type  $F(3,332) = 4.76$ ,  $p = 0.002$ ,  $\eta_p^2 = .04$  although less profoundly than for bodily sensations. Mental sensations were strongest for paintings with abstract content versus people,  $p = 0.005$ , and for portraits versus people,  $p = 0.026$  (Tukey's HSD test); no other statistically significant differences were found.

## Experiment 3: what interests us in paintings?

### Materials and methods

Bodily sensation mapping revealed that bodily sensations are key components of emotional responses to art. It further indicated that art pieces with human figures evoked the strongest bodily sensations. Thus, the presence and saliency of humans in the artworks might enhance attention and interest towards the paintings, thus being a potential mediator for art-elicited emotions. This was further tested in Experiment 3. To measure the spatial distribution of top-down saliency or interest in the art pieces and link them with the affective evaluations,



**Figure 6.** Bodily and mental components and aesthetic and emotional evaluations of art. Mean Pearson correlation between bodily (A) and mental (B) sensations and the aesthetic and emotional qualities of the paintings. Red lines show the area of nonsignificant correlations.

we gathered human “interest annotations” for a subset of the paintings ( $n=60$ , chosen to represent various contents and styles) used in Experiment 1 from 306 subjects, and recorded eye movements while a separate sample ( $n=21$ ) of subjects viewed the same paintings.

### *Interest annotations*

Data were acquired on the Gorilla platform (<http://gorilla.sc>) and a total of 306 subjects (134 females, 172 males; mean age = 26.35, SD age = 7.04) were recruited from Prolific. Subjects viewed the paintings on a computer / tablet screen one at time and were asked to colour the most interesting areas from the painting. No specific instructions for what consist of “interesting” were given, the subjects were simply asked to act based on their intuition and gut feelings. The image batch was divided into half, and each subject annotated 30 paintings, thus every painting was annotated by 153 subjects. Painting data were stored as binary (paint vs. no paint) matrices and mean proportion of subjects colouring each pixel in each artwork was computed for generating 2D subjective saliency maps were then analysed. Mean, SD, skewness, kurtosis, RMS contrast (Peli, 1990) as well as the number of peaks in each map were also computed to characterise the spatial distribution of the saliency annotations. Additionally, we computed mean intersubject similarity (based on Spearman correlation) for the painting-specific interest annotation maps to index consistency of the saliency annotations across subjects. To quantify the content of the interest annotation maps, we thresholded the maps at  $> 0.33$ , corresponding to one third of the subjects annotating a pixel as interesting. We then counted the number of interest clusters in each image and counted the number of the resulting clusters. Finally, we categorised the broad content of each cluster (faces, whole human bodies, human body parts (e.g. hands), objects, animals, and landscapes). Each cluster could receive up to three content labels, for example one cluster could contain both human face and human body parts.

### *Eye tracking*

To validate the interest annotation approach and to benchmark visual attentional engagement while the subjects were viewing art, we also conducted an eye movement study. Gaze position reliably indexes direction of attention and subsequently provides a net index of both task-relevant and visually salient

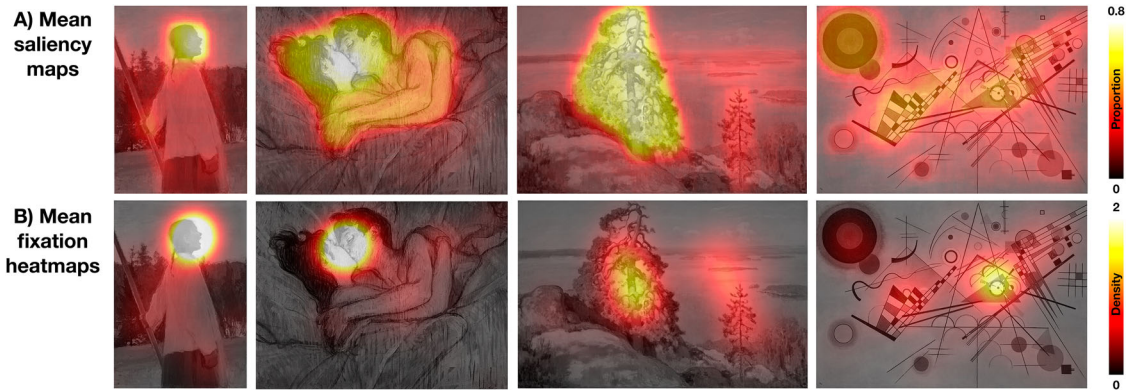
locations in a scene (Henderson, 2003). We presented the same stimuli as used in the interest-annotation experiment to 21 observers (13 females, 8 males; mean age 33.6 years, SD = 8.5) while their eye movements were recorded using Eyelink 1000 tracker (SR Research) at 1kHz sampling rate. Spatial accuracy was better than 0.5 degrees of visual angle. Stimuli were rescaled to 1200 pixels in height and were shown on a 27” screen for 5 s each with drift correction between images. Stimulus order was randomised. Subjects were instructed to view the paintings as they would view images on a computer or tablet screen. We first extracted mean number of fixations and blinks and, average saccade amplitude and pupil size for each trial, and compared these parameters across the a priori painting categories. Subject-wise fixation heatmaps were generated and averaged across subjects for each painting and compared with the interest annotation maps using Spearman correlations. To address the latency at which the manual annotations and eye-movement-based saliency maps coincide, we reconstructed the fixation heatmaps with 1–20 first fixations on the image and computed the similarity index between each reconstruction and the manual annotations.

## **Results**

### *Eye tracking and interest annotations*

Figure 7 shows representative manually annotated interest maps. Visual inspection of the saliency maps revealed that the overall consistency in the saliency annotations across observers was high, that there were one or two clear “hotspots” of annotations for each painting with relatively low saliency ratings in the background, and that the annotations tended to focus on humans whenever those were present in the paintings. These features were confirmed by statistical analysis. On average, the subjects annotated 2.35 regions per image (Figure 8A). Faces were the most commonly interesting target, followed by objects, bodies, and body parts, whereas landscapes and animals were annotated relatively rarely. Mean consistency of the annotations (as indexed by intersubject correlation, ISC) was  $r=0.42$ , confirming that the subjects agreed well with each other regarding the most interesting regions in the paintings (Figure 8B).

Figure 7B shows mean fixation heatmaps for 4 representative paintings, and video S-1 shows mean eye movement patterns while our 21 subjects were

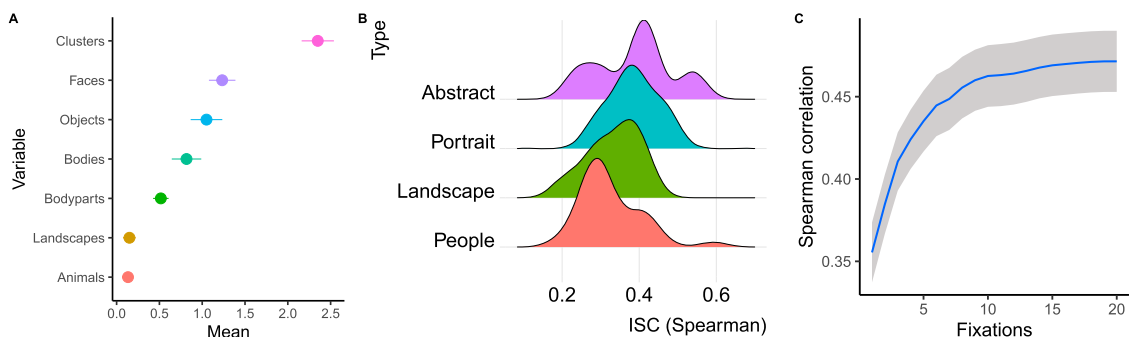


**Figure 7.** Manually annotated mean saliency maps (A) and fixation heatmaps (B) for 4 representative paintings. Colourbars show the proportion of subjects colouring each area (top) and the fixation density estimate (B). Sample paintings from left to right: Kaiku (Ellen Thesleff), Dans le Lit, le Baiser (Henri de Toulouse-Lautrec), Maisema Kolilta (Eero Järnfeldt), Composition 8 (Vasily Kandinsky).

viewing a subset of the artworks. Table S-3 shows correlations between eye movement parameters and ratings of the aesthetic / emotional dimensions of the paintings. On visual inspection, the interest-annotation maps (Figure 7A) matched well with the fixation heatmaps. This consistency was confirmed with formal statistical analysis, showing that the mean Spearman correlation between the fixation heatmaps and interest annotations was 0.49 ( $SD = 0.13$ ) when computed over the whole 5-s trial period. The correspondence between interest annotations and fixation heatmaps increased as a function of time (Figure 8C). This metric plateaued around 10 fixations (corresponding to  $\sim 4$ -s viewing time as mean fixation duration was 402 ms). Fixation count and duration were most consistently associated with the aesthetic and affective dimensions so that fixation count decreased as a function of art-like

quality, beauty, balance, sadness, and moving ( $r_s > 0.28$ ,  $p_s < 0.05$ ). Fixation duration increased as a function of the same variables, except that additional correlation was observed with touching ( $r_s > 0.28$ ,  $p_s < 0.05$ ). Blink rate was positively associated with joy and negatively with disgust ( $r_s > 0.27$ ,  $p_s < 0.05$ ). Pupil size was positively associated with negative emotions of sadness, and fear, anger, and disgust, and negatively with joy ( $r_s > 0.27$ ,  $p_s < 0.05$ ).

Figure S-1 shows mean trial-wise eye movement parameters arranged by painting type. Number of fixations varied as a function of painting type,  $F(3,56) = 5.34$ ,  $p = 0.003$ ,  $\eta_p^2 = 0.23$ . Subjects made more fixations on landscape paintings and paintings with people than on portraits ( $p_s < 0.01$ ). Saccade amplitudes also varied as a function of painting type,  $F(3,56) = 4.58$ ,  $p = 0.003$ ,  $\eta_p^2 = 0.20$ . Subjects made longer saccades on landscape versus portrait



**Figure 8.** Summary of the annotation results. Means  $\pm$  standard errors of mean for the number of clusters and the frequency of the contents for the clusters (A). Distribution of intersubject similarity of the painting annotations ( $n = 336$ ) for different painting types (B). Mean  $\pm$  standard error of mean intersubject correlation (Spearman) between the interest annotations and gaze-based saliency maps from 1–20 first fixations (C).

paintings ( $p = 0.004$ ). Blink counts varied as a function of painting type,  $F(3,56) = 3.93$ ,  $p = 0.01$ ,  $\eta_p^2 = 0.17$ . Subjects blinked more when viewing portrait paintings than paintings with people ( $p = 0.05$ ). Pupil size varied as a function of painting type,  $F(3,56) = 7.53$ ,  $p < 0.001$ ,  $\eta_p^2 = 0.29$  being largest for portraits and second-largest for paintings with people, which differed from landscape paintings ( $p = 0.004$ ). Pupil size was larger for portraits than that for landscape or abstract paintings ( $ps < 0.01$ ).

## General discussion

Viewing visual art pieces evoked a wide range of emotional experiences that formed five broad clusters: (1) aesthetic dimensions, (2) positive emotions, (3) negative emotions, (4) touching feelings, and (5) feelings of surprise and effort. These dimensions predicted how much individual artworks were liked and considered as art. These emotion dimensions were embodied, and subjects reported most widespread bodily feelings associated with them. Empathy, anger, fear, and elegance evoked experiences almost everywhere in the body, whereas liking, beauty, amazement and effort elicited sensations mainly in the head area. The strengths of the bodily feelings were associated with emotions experienced while viewing art. Finally, manual interest annotation and eye-gaze maps confirmed that human faces and bodies were consistently the most interesting features in the paintings.

### *Emotional responses to art*

Emotional experiences evoked by art were consistent across observers. Aesthetic emotions (art, balance, beauty, and elegance) were most prominent, followed by positive emotions (liking, empathising and joy) and empathy. Feelings linked with surprise and effort were moderately common. Negative emotions were rare despite numerous paintings containing unpleasant themes such as death and grief. Some negative emotions were commonly experienced with the aesthetic, non-basic emotions. Sadness was consistently associated with the experience of being touched and moved by the artworks, although these emotions were also consistently associated with joy. This brevity of self-reported feelings go significantly beyond simple liking and arousal (Leder et al., 2012) as well as the putative “basic” emotions (Cordaro et al., 2018; Ekman, 1992; Panksepp, 1982). It rather

accords with the view that mixed positive and negative emotions are a common feature of the aesthetic emotional experiences during art encounters (Meninghaus et al., 2019) and that in the aesthetic experience sadness may be often linked with enjoyment. Multiple explanations have been put forward the human attraction to art that induces negative emotions, ranging from cultural to autobiographical and arousal-based factors, yet the actual biological basis of this phenomenon is not currently fully understood (Eerola et al., 2018).

The cluster structure of the emotions distinguished between the positive and negative emotions, but also the aesthetic and surprising dimensions and the touching qualities of the feelings. The aesthetic dimensions (art, balance, beauty, and elegance) were positively associated with positive emotions (sublimity, joy, excitement, liking and empathising) and negatively associated with surprise, effort, and negative emotions (fear, anger, disgust). However, considering the art pieces touching and moving was positively associated with aesthetic dimensions, as was also to some extent sadness. These data suggest that the constellation of aesthetic dimensions is generally positive in nature. Aesthetic feelings also contributed to liking of the art pieces: the more empathy, beauty, touching, joy, and excitement a painting elicited, the more it was liked. Conversely, negative emotions were negatively linked with liking of the art. Importantly, beauty and touching also predicted whether a piece was considered as art, suggesting that these feelings have a key role in determining the aesthetic response to visual art. This accords with data from functional imaging experiments showing that empathetic responses mediate aesthetic experiences (Ardizzi et al., 2021). Finally, experience of elegance was an interesting exception in the sense that it was negatively associated with liking. This may suggest that people simply do not enjoy this type of “overly effective” stylistic (elegant) presentation, and prefer more natural and complex art works.

Although negative emotions are often argued to increase the enjoyment or likability of artworks (Meninghaus et al., 2017), our data suggest the opposite. Negative emotions may play a role in the aesthetic experience via the embodied feelings they evoke, and in our study anger and fear were associated with widespread bodily feelings. Negative-emotions-eliciting events depicted in visual art may elicit visceral states related to intensive thrill-seeking, which

however do not manifest in the subjective likability of the works. Similarly, likability of art was negatively associated with the effort required to comprehend the work. Although humans associate effort with reward, they also consider effort as costly and avoid it on many occasions (Inzlicht et al., 2018). In the context of art, effort may be considered as an extra cost associated with the aesthetic experience, thus making the artworks less appealing (Reber et al., 2004).

Interestingly, dimensions such as beauty, balance and touching were associated with art-like qualities of the works, while the opposite was true for dimensions such as joy and excitement. Definition of art is somewhat arbitrary to begin with, yet these results show that the layperson's concept of art is clearly linked with specific evaluative structure: Art evokes feelings of beauty and has balanced aesthetic qualities, and it must also be affectively touching, i.e. relatable. According to our results, clearly positive emotions, such as joy, were not directly linked with evaluating something as art. In the future it would be interesting to test whether a similar affective-evaluative pattern generalises to other forms of art and whether it is predictive of e.g. viewing times and interest towards pieces of art. However, it is possible that these results reflect the covariance structure of the predictors. As many of the independent variables correlated with each other, they may also statistically suppress each other in the regression model (Friedman & Wall, 2005).

### ***Bodily responses to art***

Art-evoked emotions were accompanied with bodily feelings, confirming that art perception is also an interoceptive process. Unlike categorical and discrete bodily feelings evoked by survival-salient episodes depicted in e.g. movies (Nummenmaa et al., 2014), the bodily signatures of aesthetic emotions revealed a continuum from the whole-body experiences of empathy, fear, and anger towards the experiences of beauty, amazement and effort that were mostly reported in the head area, possibly reflecting cognitive processing (Nummenmaa et al., 2018). Although the self-report technique cannot discern the underlying brain activation patterns, the relative unspecificity of the bodily signatures accords with brain activation patterns evoked by aesthetic emotions. While emotions elicited by biologically salient events are associated with discernible brain activation patterns (Kragel et al., 2016; Saarimäki et al., 2018, 2016), a similar “decoding” of music-evoked aesthetic emotions cannot be accomplished outside the sensory

and motor cortices (Putkinen et al., 2021). It is thus possible that the emotions evoked by art only engage the low-level pleasure / displeasure and arousal dimension of emotion circuits, although the resulting subjective experience might be affectively vivid and complex. Finally, unlike photographs or videos, the art pieces such as paintings may also fail to pass a “reality check”. For example, a cartoon of an angry dog could be assessed as less threatening than a photograph of a dog or the same dog in real life, because we immediately know that the cartoon dog is neither real nor dangerous. Such regulation processes might explain the less discrete bodily responses of emotions to art versus more naturalistic emotional stimuli.

The magnitude of the art-evoked bodily sensations was associated with the strength of subjective emotional feelings. This effect was strongest for feelings of touching, empathy and moving, and also statistically significant for sadness, fear, beauty, art, anger, elegance and liking. Conversely, experiences of amazement and effort correlated negatively with the bodily sensations. This accords with the models of emotional experiences that posit an important role of interoception and somatosensation in the emotional experience (Craig, 2002; Damasio & Carvalho, 2013), and also with work showing a tight linkage between bodily feelings and emotional experience (Nummenmaa et al., 2018). Because experiences of touching and empathising were significant predictors of whether a piece was considered as art, it is possible that this kind of bodily sensations are an integral part of the subjective evaluative processes when viewing art. It can of course be debated whether these responses pertain to affective versus semantic judgements of the stimulus, and the current design obviously does not allow disentangling the contribution of these two systems. Affect and cognition however interact at multiple levels of scene recognition (Nummenmaa et al., 2010), and the resulting phenomenological and bodily feeling states likely stems from this kind of affect-cognition interactions.

### ***Humans attract attention in visual art***

Other people are our most important “environment”. The human brain has been finely tuned for processing of social information (Hari et al., 2015; Hari & Kujala, 2009) so that mere human features such as faces capture our attention automatically. This profound interest in conspecifics is also reflected in the common themes in visual arts, and a large bulk of

the art pieces studied here represented humans. The interest annotations revealed that human faces were most consistently annotated as interesting. This preference for faces accords with eye tracking work on photographs and art pieces (Nummenmaa et al., 2012; Pihko et al., 2011), and is also in line with previous studies showing how this kind of bottom-up processing contributes significantly to gaze patterns during free viewing of art (Massaro et al., 2012). Despite the complex visual structure of the artworks, annotations were also consistent with mean intersubject correlation of  $r=0.42$ . The interest-annotation maps correlated significantly with eye-movement-based heatmaps, suggesting that reflect sampling of both low-level bottom-up visual features as well goal-relevant information (Henderson, 2003). Pupil dilation reflects emotional arousal and autonomic activation (Bradley et al., 2008; Nummenmaa et al., 2012). Accordingly, we found that pupil size was positively correlated with the negative emotions evoked by the paintings. The aesthetic experiences evoked by the art pieces were associated with longer fixations, indicating stronger attentional engagement (Nummenmaa et al., 2006). Finally, saccade durations were different particularly for portrait and landscape paintings, indicative of differences in focal versus ambient processing (Pannasch & Velichkovsky, 2009).

### Limitations

We did not control for the subjects' familiarity with the artworks, but only a few of the stimuli were well-known paintings. We also focused on self-reported emotions, rather than psychophysiological recordings. Although interoception allows tracking of bodily states (Critchley et al., 2004), self-reported bodily sensation maps cannot provide one-to-one mapping with physiological activation patterns. Instead, the body mapping technique provides a net index of the current, consciously accessible states of various physiological systems in the body, thus constituting an important part of the emotional experience (Nummenmaa et al., 2018). Consequently, our data cannot reveal whether the reported aesthetic experiences are distinct from physiological or neural emotional states during other type of sensory perception (Menninghaus et al., 2019; Skov & Nadal, 2020). Because matching visual properties of the stimuli for the sake of experimental control would significantly alter the aesthetic qualities of the artworks, the pupillometric

effects might be confounded by low-level visual statistics of the images. This is however unavoidable in these types of studies on natural vision. Finally, the stimuli were digitised pictures presented on a computer screen and although our subjects considered these images very much like art pieces, photographs and real paintings differ in many perceptual features, such as texture, size of the painting, and details of color (which depends on the light environment). In the future it might be interesting to test whether these features of actual paintings would lead to differential gaze patterns in comparison with the flat digital images.

### Conclusions

Aesthetic emotional experiences associated with encountering visual arts are strongly embodied and that visual arts can elicit a broad range of emotional feelings that go significantly beyond the canonical "basic" emotions. The strength of these emotions is, in general, linked with the strength of bodily sensations the art pieces evoke. Accordingly, it is possible that the appeal of the visual arts stems partially from art's capability to engage the viewer's body in a manner resembling the bodily signatures of survival-salient emotions.

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### Data availability statement

Data are available from the corresponding author per request.

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