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Physiological Correlates of Aesthetic Perception of Artworks in a Museum

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Arts experts are commonly skeptical of applying scientific methods to aesthetic experiencing, which remains a field of study predominantly for the humanities. Laboratory research has, however, indicated that artworks may elicit emotional and physiological responses. Yet, this line of aesthetics research has previously suffered from insufficient external validity. We, therefore, conducted a study in which aesthetic perception was monitored in a fine art museum, unrestricting to the viewers' freedom of aesthetic choice. Visitors were invited to wear electronic gloves through which their locomotion, heart rate and skin conductance were continuously recorded. Emotional and aesthetic responses to selected works of an exhibition were assessed using a customized questionnaire. In a sample of 373 adult participants, we found that physiological responses during perception of an artwork were significantly related to aesthetic-emotional experiencing. The dimensions "Aesthetic Quality," "Surprise/Humor," "Dominance," and "Curatorial Quality" were associated with cardiac measures (heart rate variability, heart rate level) and skin conductance variability. This is the first evidence that aesthetics can be statistically grounded in viewers' physiology in an ecologically valid environment—the art gallery—enhancing our understanding of the effects of artworks and their curatorial staging.

Keywords: aesthetics, wireless data acquisition, museum research, physiology of phenomenology, fine art exhibition

Aesthetic perception elicited by works of fine art, such as paintings, drawings or sculptures, constitutes a complex response with cognitive, emotional, behavioral and physiological ingredients. This may be a common point of view held by psychologists, yet it is a matter of continuing debate whether aesthetic experience can be investigated using quantitative scientific methods, since these methods may fall short of the semantic complexity of arts and aesthetics (Becker, 1982; Luhmann, 2000). Through investigation, aesthetic experience may even be distorted (Eco, 1989). This is the widely held position in the philosophy of art, which dominates the field of aesthetics in the humanities; this position follows the deductive-aesthetics tradition of Immanuel Kant who, in his Critique of Judgment (1790), defined the constitution of art in a "top-down" manner. In contrast, David Hume argued that beauty is not inherent to the object but dwells in the consciousness of the viewer: "each mind perceives a different beauty." This approach to aesthetics was adopted by experimental psychology in the tradition of Gustav Fechner (1876) and Daniel Berlyne (1960), but did not prevail in art theories of the 20th century. We argue here that it

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is mandatory today to invigorate an empirical, "bottom-up" research of art perception.

There are multiple reasons for a renewed interest in aesthetics. First, the societal system that generates and processes the fine arts is extensive, comprising large numbers of actors and recipients. Second, the system displaying and marketing modern and contemporary art is of considerable, growing economic and cultural impact (Tschacher & Tröndle, 2011a). Third, apart from societal significance, the neurocognitive acts of observing, communicating, and creating artworks appear to be confined exclusively to *homo sapiens*. Given these exceptional attributes, aesthetics has received astonishingly little attention in psychological and biological science.

The 18th-century positions of Kant and Hume entailed opposing methodologies, those of philosophical, object-oriented and psychological, subject-oriented aesthetics. The latter research tradition has capitalized on top-down patterns found in artworks (Arnheim, 1954), on arousal aspects of aesthetic stimuli in a bottom-up "behaviorist" framework (Berlyne, 1960; Krupinski & Locher, 1988), or a cognitive-appraisal framework (Silvia, 2005). Increasingly, research is using neurobiological measures (Sargent-Pollock & Konecni, 1977; Kawabata & Zeki, 2004; Jacobsen, Schubotz, Höfel, & v. Cramon, 2006; Kuchinke, Trapp, Jacobs, & Leder, 2009), predominantly with musical stimuli (Iwanaga, Kobayashi, & Kawasaki, 2005; Grewe, Kopiez, & Altenmüller, 2009; Müller, Höfel, Brattico, & Jacobsen, 2010). Psychological aesthetics research was almost exclusively conducted in the laboratory, an environment very unlike the space of an exhibition. The external and ecological validity of such research is limited, since the "aura" and authenticity of an artwork, its materiality, size, and spatial arrangement, are lost in reproductions displayed on computer screens. This may explain why empirical aesthetics never generated much impact on art theory in the humanities.

Technical developments have recently facilitated the monitoring of an individual's locomotion and physiology in the "psychogeography" of the museum. It is thus possible to better consider the social and environmental context of aesthetic perception. Using wireless data acquisition systems, visitors' physical positions and physiological parameters can be recorded. Measurements can be obtained continuously throughout each participant's visit of an exhibition. Duration of visits may be optional; the visitors are unrestricted in their choice of artworks to be viewed. We established such a monitoring system in an art museum; Figure 1 provides an example of visitors' locomotion trajectories in an exhibition. Trajectories were visualized together with physiological responses of 30 randomly chosen participants.

Face validity indicated that locomotion patterns as well as physiological responses were likely related to the artworks on display; in their vicinity, visitors' paths were densely packed and showed a high concentration of markers. Physiology appeared not to be confounded with locomotion per se. We therefore hypothesized that the visualized maps represented aesthetic-emotional responses to the artworks on display. After the feasibility phase, we decided to test, in a population of museum-goers, whether monitored physiology and aesthetic-emotional experiences were statistically associated in general. This hypothesis was complemented by an explorative ap-

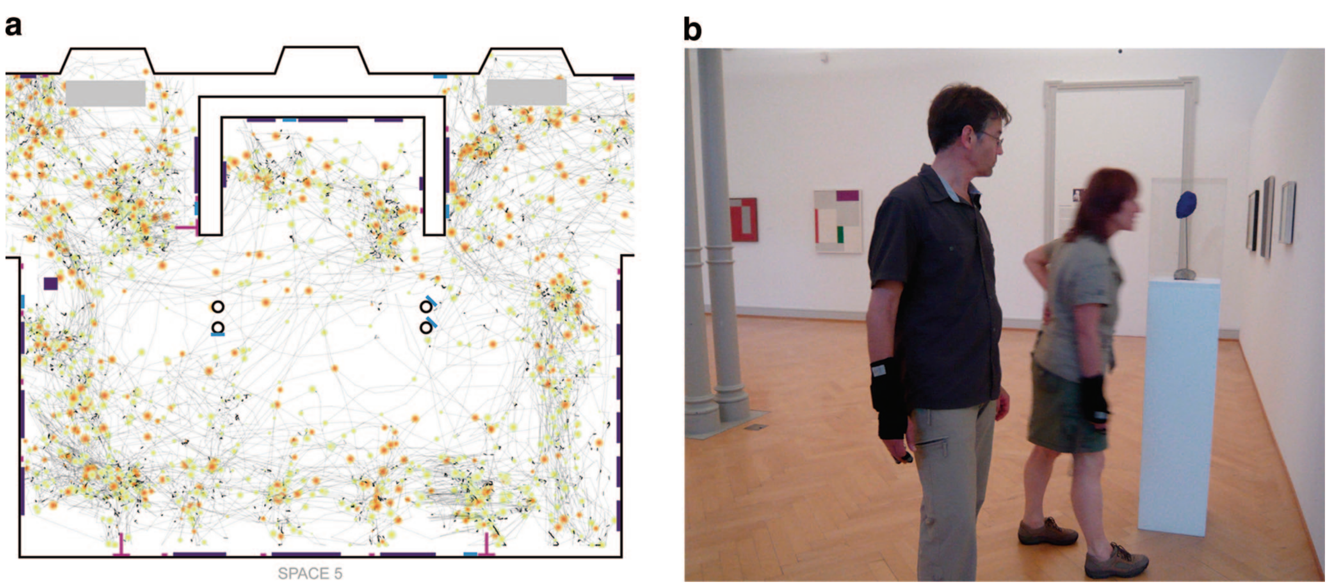

Figure 1. **a.** Map of space #5, one of 7 halls of the exhibition. Black lines represent the walls of the exhibition space (approx. 8 × 10 m) and four columns. Museum visitors enter from the right side. The pictures on the walls are depicted as violet rectangles, the sculpture by Yves Klein as a square. Nine small blue rectangles represent an art intervention by Nedko Solakov. The labels of artworks are represented by small fuchsia rectangles, detailed text posters by fuchsia "⊥"s, two benches by gray rectangles. Gray lines visualize trajectories of 30 randomly selected visitors, with markers indicating the locations of phasic physiological responses: Orange, shifts of skin conductance; yellow, shifts of heart rate. **b.** View inside space #5. Two participants with electronic gloves observe Yves Klein's sculpture "Éponge".

proach—which dimension of aesthetic experiencing of art was linked to which physiological measure?

Method

Artworks

The exhibition titled "11:1(+3) = Elf Sammlungen für ein Museum" ["11:1(+3) = Eleven collections for one museum"] at the Kunstmuseum St. Gallen, Switzerland, was open to the public. It extended over an area of approximately 380 m^2 on seven museum halls and consisted of 76 works of modern and contemporary art, ranging from paintings of Claude Monet, Edvard Munch, Ferdinand Hodler, Le Corbusier, to Paul Klee's drawings; abstract works by Max Bill, Günther Uecker, and Yves Klein; to "pop" works by Andy Warhol and James Rosenquist; and conceptual works by On Kawara. Regions of interest (ROI) were defined for all artworks as the geometric area from which the artwork was viewed.

Participants

Of all visitors to the exhibition, a subgroup was invited to participate. Inclusion criteria were: age ≥18 years, not member of a visitor group or school class, not engaged in a guided tour of the museum, fluency in German or English, and informed consent. Data acquisition was initiated for 517 visitors (61.9% female; mean age 46.2); that is, approximately 60% of all adult nongroup visitors of the museum in the study period (June–August, 2009). Due to data loss in the feasibility phase of the project (malfunction of network, data not stored on server), valid data were sampled for 373 visitors (65% female; mean age 47.4). On average, participants spent 28 min in the exhibition.

Physiological Data

Electrodermal and cardiac physiology was monitored continuously during visits. Participants wore specially manufactured gloves on their right hands that contained two electrodes to measure skin conductance between the middle digit of index and middle fingers. Skin conductance levels (SCL) were obtained by active (0.5V) measurement. Cardiac activity was assessed (sampling rate, 50Hz) by a light-emitting diode and a reflective infrared sensor integrated in the glove to detect capillary perfusion; maxima of blood-flow represent successive heartbeats. Conductance and cardiac signals were preprocessed by a programmable microcontroller (PSoC, Cypress Semiconductor) in the glove. Heart rate (HR) was computed using a moving window with a depth of 192 samples, in which consecutive heartbeats were identified by the autocorrelation function; interbeat intervals were transformed to HR by the microcontroller on a second-by-second basis. Both signals were sent through the WLAN module of the glove using UDP/IP (User Datagram Protocol/Internet Protocol, which is a standard network application to transfer data from clients, here the gloves, to a server). In addition to the two variables HR and SCL, we estimated the variability of each by computing their standard deviations during any participant's stay within any ROI. With respect to heart-rate variability (HRV), we eliminated low-frequency trends from the HR time series. Such trends are likely confounders (Berntson et al., 1997) because HR nonstationarity scales with the length of the measurement period and participants stayed inside ROIs for varying periods of time. We estimated low-frequency oscillations of HR by an interpolation method, so-called splines (cubic splines with stiffness $\lambda = 10{,}000$; JMP8, SAS Institute Inc.). Splines are often used for the smoothing of time series. These spline interpolations were subtracted from the raw HR series, then HRV was determined. This procedure eliminates low-frequency variation from the signal, but preserves the high-frequency information. The physiological dataset finally contained, by ROI and by participant, four variables: mean HR, SCL, HRV, and skin conductance variability (SCV).

The psychological information conveyed by physiological variables is the core issue in psychopsychology. Both the rhythmic activity of the heart and the activation of the sweat glands in the skin are modulated by the autonomous nervous system (ANS), which regulates fundamental vital functions of the body connected to the energy supply and activation of organs and tissues. This regulation is termed *autonomous* because it is largely devoid of conscious or voluntary control. At the same time, there is often an emotional and/or cognitive aspect to ANS activity; for instance, emergency situations (ANS fight/flight response) are also experienced emotionally (angry or fearful affect) and have cognitive implications (alertness, focused information processing). The ANS has two antagonistic branches: the sympathetic branch deals with the mobilization of energy in stressful situations, whereas the parasympathetic system harmonizes and restores body functions in the absence of environmental pressure.

The heart is dually innervated; that is, cardiac dynamics represents, in addition to cortical and endocrinal inputs, both sympathetic (activating) and parasympathetic (balancing, damping) influences (Thayer, Hansen, Saus-Rose, & Johnsen, 2009; Lane et al., 2009). Put very simplistically, HR increase is correlated with arousal and with activating emotions such as joy, anger, or fear, also with aesthetic situations that have expressive features (Nakahara, Furuya, Obata, Masuko, & Kinoshita, 2009). HR is decreased in the orienting response, when novel information is presented (Graham & Clifton, 1966). Orienting responses generate only phasic shifts of HR; enduring ("tonic") lowered HR is found when the parasympathetic influence prevails; that is, during rest and retreat. HRV is a more complex signal, which reflects the antagonistic interplay of the two ANS systems and additionally integrates the phasic shifts of HR. HRV is generally related to health and disease: lowered HRV is commonly linked to reduced affect regulation abilities (Thayer & Brosschot, 2005) and increased depressiveness and anxiety (Shinba et al., 2008). Induction of congruent, positive mood was associated with increased HRV (Kop et al., 2011). Persons with low HRV appear to react more defensively even to nonthreatening stimuli, which corresponds well to findings of positive correlations of HRV with the personality trait of "openness to experience" (Williams, Rau, Cribbet, & Gunn, 2009) and to negative correlations of HRV with neuroticism (Ode, Hilmert, Zielke, & Robinson, 2010).

The electrodermal activity measured by SCL and SCV underlies only sympathetic control; sympathetic activity leads to increased skin conductance of the hands and feet. Thus, SCL is generally indicative of emotional and mental activation, largely irrespective of emotional valence (Sequeira, Hot, Silvert, & Delplanque, 2009), but there are also considerable interindividual differences. The phasic electrodermal responses are reflected in SCV: orienting responses, which entail HR decreases, generate phasic increases of skin conductance; even in the absence of external stimuli, spontaneous fluctuations of skin conductance are common and their frequency correlates with the level of emotional arousal. Anxiety patients, for example, show both more fluctuations and higher SCL. In healthy subjects, affect-inducing photographs lead to electrodermal responses, by which especially sadness and disgust can be distinguished from other emotions (Birbaumer & Schmidt, 2002). Unexpected musical events generate emotional responses that have been detected in electrodermal activity (Koelsch, 2005).

Locomotion Data

We tracked the movement patterns displayed by participants throughout their visits to the exhibition. Tracking was based on a tag (a transponder weighing 25 g, emitting ultrawide band signals of 6–8GHz) integrated in the glove worn by each participant. The tags communicated wirelessly with access points located in all corners of each exhibition hall. From these points, the spatial position of the tag was triangulated, and position data were transmitted via Ethernet connection to servers elsewhere in the building. Positions per second, of up to four participants simultaneously, were identified with a precision of 15 cm. The trajectories of participants were then imaged in maps of the museum space (e.g., Figure 1a). Physiological markers were integrated into the imaging depictions. Markers were shown at those points of the trajectory where HR or SCL deviated, in a moving window of 1 s, by 2% from the global mean of the respective participant.

Aesthetic Assessment

After the visits, the subjective aesthetic experiences of participants were assessed using a questionnaire displayed on a computer terminal with prompted recall of up to six different artworks. Three artworks were automatically selected by the tracking system as those artworks in whose ROIs the respective participant had stayed the longest time, and had pronounced physiological responses. Three artworks were determined in advance by the investigators. In some cases, where the works selected by the system and the predetermined works coincided, fewer artworks were assessed by a participant. Of the 1,413 assessed artworks, 42% were thus predetermined. The questionnaire consisted of 19 items (with 5-point scales each) covering emotions evoked by an artwork (e.g., joyful, sad, angry, frightening, surprising), aesthetic evaluations of an artwork (e.g., beautiful, touching, artistically well done, eminent), and the viewer's general appraisal of an artwork (e.g., dominant, activating, positive, appropriately hung, suitable for gallery context, renown of artist). We thus integrated a wide range of emotion categories (Ekman & Friesen, 1971) and emotion dimensions (Russell & Mehrabian, 1977) into the questionnaire, including negative emotions that are often disregarded in aesthetics research (Silvia, 2009). Principal component analysis with Varimax rotation in a larger dataset of 3,574 single records of questionnaire assessments of artworks yielded five orthogonal factors. For each participant who had viewed an artwork, we used this participant's factor scores as estimations of the aesthetic-emotional properties of an artwork in its context: Aesthetic Quality (the work is rated as pleasing; beautiful; well done with respect to technique, composition, and content); Surprise/Humor (the work is considered as surprising; makes one laugh), Negative Emotion (the work conveys sadness, fear, anger), Dominance (the work is experienced as dominant, stimulating) and Curative Quality (the work is well staged and hung, suitable in the context of other artworks). Each participant's aesthetic and emotional preference of an artwork was hence determined by the scores on these factors.

Statistical Procedures

The complete dataset of physiological and aesthetic-emotional data comprised between 1,306 and 1,413 observations (some observations had missing information in one or more of the predicting variables). This dataset contains statistically dependent data, which is typical of field data devoid of experimental control. In an initial global approach, dependency was neutralized by averaging across participants' aesthetic-emotional and physiological responses to then apply classic multivariate analysis of variance (MANOVA). For this approach, we computed—in each of the 76 artworks of the exhibition—the averages of the five aesthetic-emotional factor scores and the averages of the four physiological variables. Reducing the 1,413 recorded observations to average values per artwork thus yielded a dataset of 76 mean observations.

As a main approach, we applied mixed-models hierarchical analysis to explain the variance of dependent physiological variables (HR, HRV, SCL, and SCV) by the fixed effects (predictors): Aesthetic Quality, Surprise/Humor, Negative Emotion, Dominance, Curative Quality, Age of participant, and Gender of participant. The software packages used were Stata/SE10 (Stata Corp, College Station, TX) and JMP8 (SAS Institute Inc, Cary, NC). In all models, Artwork and Participant were entered as random effects, which define the dependency structure inherent to this hierarchical dataset; the dataset has cross-classified random effects (Snijders & Bosker, 1999; Raudenbush & Bryk, 2002) because each artwork was multiply assessed, and each participant performed multiple assessments. Tables 1, 2, 3, and 4 offer modeling details, separately for each dependent variable. The best-fitting and most parsimonious model was selected with the following procedure: we incrementally entered the predictors (fixed effects) in the sequence listed in Tables 1–4. We applied logLikelihood (a measure of model fit) as a criterion to either keep the current predictor and add the following predictor, or skip the current predictor and enter the following predictor. In this manner, eight models were computed for each dependent variable. Finally, Akaike's (1974) Information Criterion (AIC) was used as the criterion to decide in favor of one of the eight models. The respective AIC-optimal model is printed in bold in Tables 1–4.

Results

The complete dataset of physiological and aesthetic-emotional data comprised up to 1,413 observations of 373 participants. In the averaged dataset, MANOVA indicated a significant overall linkage between aesthetic and physiological variables: $F(20, 223.2) = 2.87$, Wilk's $\lambda = 0.469$, $p < .0001$. Subsequent mixed-models regression analysis allowed modeling this linkage in the hierarchical dataset in more detail and without losing degrees of freedom. Three of the four physiological measures were significantly associated with aesthetic-emotional assessments (Tables 1–4).

Table 1

Parameter Estimates (Standard Errors) for Mixed Effects Models of the Associations Between Heart Rate (HR) and Aesthetic-Emotional Assessments

Dependent variable: HR	Model 1 (n = 1413)	Model 2 (n = 1413)	Model 3 (n = 1413)	Model 4 (n = 1413)	Model 5 (n = 1413)	Model 6 (n = 1413)	Model 7 (n = 1393)	**Model 8** (n = 1384)
	83.141**** (0.66)	83.184**** (0.66)	83.141**** (0.66)	83.125**** (0.66)	83.100**** (0.66)	83.097**** (0.66)	82.614**** (0.67)	85.887**** (1.48)
Fixed effects								
Aesthetic Quality		−0.293 (0.28)						
Surprise/Humor			0.128 (0.39)					
Negative Emotion				−0.246 (0.26)				
Dominance					−0.559* (0.28)	−0.573* (0.26)	−0.662* (0.27)	−0.641* (0.27)
Curative Quality						0.543^{t} (0.28)	0.462 (0.28)	0.508^{t} (0.28)
Gender (2 = Female; 1 = Male)							2.016**** (0.50)	2.022**** (0.50)
Age of Participant								−0.070* (0.03)
Random effects								
Participant Variance (% of Total)	49.8	49.7	49.8	49.7	49.9	50.0	48.2	47.4
Artwork Variance (% of Total)	8.2	8.1	8.2	8.3	8.0	8.1	8.3	8.7
−2logLikelihood	10419.51	10419.12	10420.02	10419.14	10415.87	10412.82	10254.96	**10194.15**
AIC	5724.32	5726.70	5726.55	5726.50	5722.83	5719.80	5649.73	**5620.83**

$^{t}p < .1$. $^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$. $^{****}p < .0001$.

Table 2

Parameter Estimates (Standard Errors) for Mixed Effects Models of the Associations Between Square Root of Heart Rate Variability (HRV-Sqrt) and Aesthetic-Emotional Assessments

Dependent variable: HRV-sqrt	Model 1 (n = 1413)	Model 2 (n = 1413)	**Model 3** (n = 1413)	Model 4 (n = 1413)	Model 5 (n = 1413)	Model 6 (n = 1413)	Model 7 (n = 1393)	Model 8 (n = 1384)
	1.199**** (0.027)	1.191**** (0.027)	1.191**** (0.027)	1.193**** (0.027)	1.193**** (0.027)	1.192**** (0.027)	1.181**** (0.028)	1.300**** (0.051)
Fixed effects								
Aesthetic Quality		0.055**** (0.014)	0.051*** (0.014)	0.051*** (0.014)	0.049*** (0.014)	0.051*** (0.014)	0.047*** (0.014)	0.052*** (0.014)
Surprise/Humor			0.034* (0.013)	0.033* (0.013)	0.033* (0.014)	0.034* (0.013)	0.037** (0.014)	0.033* (0.013)
Negative Emotion				0.016 (0.019)				
Dominance					0.012 (0.013)			
Curative Quality						−0.006 (0.013)		
Gender (2 = Female; 1 = Male)							0.040* (0.015)	0.042** (0.016)
Age of Participant								−0.003** (0.001)
Random effects								
Participant Variance (% of Total)	16.4	17.0	16.9	16.9	16.8	17.0	16.4	15.8
Artwork Variance (% of Total)	12.5	11.8	11.4	12.2	12.1	12.3	12.5	12.4
−2logLikelihood	1743.1	1733.7	1734.3	1739.7	1740.3	1740.9	1735.0	**1723.5**
AIC^{+}	−2575.22	−2591.33	**−2597.98**	−2595.45	−2594.14	−2597.14	−2546.30	−2522.40

Note. $^{+}$ negative AIC is possible, smaller values indicate more preferable models.
$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$. $^{****}p < .0001$.

Table 3
Parameter Estimates (Standard Errors) for Mixed Effects Models of the Associations Between Skin Conductance Level (SCL) and Aesthetic-Emotional Assessments

Dependent variable: SCL	Model 1 (n = 1335)	Model 2 (n = 1335)	Model 3 (n = 1335)	Model 4 (n = 1335)	Model 5 (n = 1335)	Model 6 (n = 1335)	Model 7 (n = 1315)	**Model 8** (n = 1306)
	12761.9**** (595.1)	12774**** (595.0)	12762**** (595.1)	12767**** (595.3)	12762**** (595.1)	12761**** (595.1)	12997**** (628.6)	21439**** (1757.8)
Fixed effects								
Aesthetic Quality		−65.86 (77.88)						
Surprise/Humor			22.95 (76.44)					
Negative Emotion				79.18 (79.18)				
Dominance					−13.96 (72.47)			
Curative Quality						−46.59 (78.02)		
Gender (2 = Female; 1 = Male)							−673.11 (624.52)	−686.77 (605.44)
Age of Participant								−177.71**** (34.76)
Random effects								
Participant Variance (% of Total)	96.8	96.8	96.8	96.8	96.8	96.8	96.8	96.6
Artwork Variance (% of Total)	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
−2logLikelihood	25709.44	25698.23	25698.85	25697.69	25699.00	25698.53	25326.34	**25123.01**
AIC	20245.39	20245.39	20247.92	20246.76	20247.58	20247.32	19958.00	**19823.83**

* $p < .05$. ** $p < .01$. *** $p < .001$. **** $p < .0001$.

Table 4
Parameter Estimates (Standard Errors) for Mixed Effects Models of the Associations Between Skin Conductance Variability (SCV) and Aesthetic-Emotional Assessments

Dependent variable: SCV	Model 1 (n = 1332)	Model 2 (n = 1332)	Model 3 (n = 1332)	Model 4 (n = 1332)	Model 5 (n = 1332)	Model 6 (n = 1332)	Model 7 (n = 1332)	**Model 8** (n = 1332)
	329.47**** (23.72)	326.64**** (23.84)	329.47**** (23.80)	330.84**** (23.66)	330.07**** (23.58)	330.08**** (23.63)	331.27**** (24.41)	682.51**** (52.47)
Fixed effects								
Aesthetic Quality		16.65 (14.70)						
Surprise/Humor			3.64 (14.22)					
Negative Emotion				15.67 (20.16)				
Dominance					27.75* (13.76)	28.03* (13.80)	28.52* (13.90)	30.68* (13.64)
Curative Quality						−6.21 (14.37)		
Gender (2 = Female; 1 = Male)							−0.60 (18.59)	
Age of Participant								−7.41**** (0.99)
Random effects								
Participant Variance (% of Total)	23.77	23.78	23.79	23.83	24.56	24.16	24.03	19.67
Artwork Variance (% of Total)	4.70	4.69	4.76	4.55	4.50	4.54	4.43	5.22
−2logLikelihood	20131.17	20122.67	20123.97	20122.73	20120.02	20112.70	20131.17	**19935.77**
AIC	16044.5	16045.2	16045.7	16046.5	16040.0	16041.4	16056.4	**16037.6**

* $p < .05$. ** $p < .01$. *** $p < .001$. **** $p < .0001$.

HR was best modeled by Dominance (p = .017) and Curative Quality of artworks (p = .075), in addition to Gender ($p < .0001$) and Age of participants (p = .014) (total variance explained by the model 66.8%, variance components of Artwork 8.7% and Participant 47.4%). HRV was predicted by the factors Aesthetic Quality (p = .001) and Surprise/Humor (p = .011) (total variance explained by the model 36.2%, variance components of Artwork 10.8% and Participant 13.1%). A nonlinear transformation of HRV (its square root) was preferable because it yielded normally distributed residuals; the proposed modeling of HRV-sqrt was analogous to the form above: predictors were Aesthetic Quality (p = .0002) and Surprise/Humor (p = .013) (total variance explained by the model 41.8%, variance components of Artwork 12.4% and Participant 16.9%). SCL was best predicted by Gender (p = .257) and Age ($p < .0001$) (total variance explained by the model 97.7%, variance components of Artwork 0.2% and Participant 96.6%). SCV was best predicted by Dominance (p = .025) and Age ($p < .0001$) (total variance explained by the model 39%, variance components of Artwork 5.2% and Participant 19.7%). The portions of variance explained by the different components of these AIC-optimized models are summarized in Figure 2a; variance components with all five aesthetic-emotional factors entered are shown in Figure 2b.

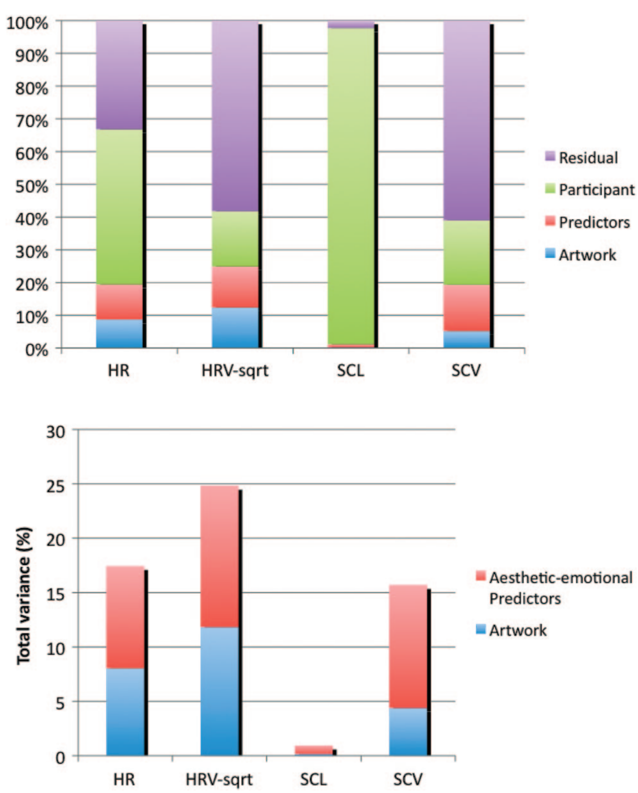

Figure 2. Portions of variance of four physiological measures explained by models of their associations with aesthetics. a (top). Variance components of AIC-optimized models. Predictors are constituted, per physiological measure, by the optimal combination of Age, Gender, Aesthetic Quality, Surprise/Humor, Negative Emotion, Dominance, and Curative Quality. b (bottom). Variance components of models with all five aesthetic-emotional predictors (not Age, Gender) entered.

Thus we found converging evidence of physiological measures linked to predictors of aesthetic-emotional origin. Thirteen percent of total variance of HRV was accounted for by aesthetic-emotional factors: beautiful, high-quality artworks, and surprising/humorous artworks were significantly associated with raised heart rate variability. With a further 11.8% attributed to other, unknown aspects of the exhibited art, HRV was the physiological measure most influenced by aesthetic-emotional variables. Higher SCV was significantly linked to more dominant artworks, 11.3% of the variance was due to the five aesthetic-emotional factors. Total variance of HR of 9.4% was attributable to aesthetic-emotional factors; dominant art was significantly linked to a decrease of heart-rate levels. Only SCL was unassociated with the displayed art and aesthetic-emotional predictors. Over 96% of its variance remained unexplained properties of the participants, likely unrelated to the museum environment.

Discussion

Aesthetic experiences are reflected in observers' physiology. To our knowledge, this is the first study providing statistical support for the embodiment of aesthetics in an ecologically valid context, the fine art museum, and for a large, representative sample of visitors. The applied technology and measures may be implemented not only in art research but also in many related fields such as architecture, design, ecology, or curatorship research, where aesthetic-emotional judgments in natural environments are relevant.

In the museum, the variance of bodily responses contributed by aesthetics was significant in three of four measures, explaining up to 25% of total physiological variance. We think it is essential that this association could be established in the authentic environment of art displays, thus acknowledging the aura of the artwork and the contribution of curatorial staging. This field methodology also considers the recent perspective of embodied cognition, which generally emphasizes the role of context, including the viewer's motor action, in mental processes (Topolinski, 2010; Tschacher & Tröndle, 2011b). Our findings suggest that an idiosyncratically human property—finding aesthetic pleasure in viewing artistic artifacts—is linked to biological markers.

The approach of wireless data acquisition in the field entailed some trade-offs with respect to the physiological signals that can be reliably measured; the presence of uncontrolled sources of noise rules out promising further peripheral signals such as pupil size (Johnson, Muday, & Schirillo, 2010) as well as, at least for the time being, all imaging of central-nervous processes (Jacobsen, 2010). At the same time, with a maximum of 25% explained variance, we have no empirical grounds to claim that aesthetic experiencing could or should be reduced to its physiological embodiment.

The general implications for aesthetics research may be viewed on the background of the discussion on the philosophy of science and on the disciplines that deal with the mind—the duality or plurality of humanistic versus natural sciences as well as the mind–body dualism versus physicalism are perennial fundamental problems. A resolution of these problems is currently not in sight. Quite to the contrary, the discussion has expanded to the philosophy of mind, where a major debate focuses on the naturalization of attributes of the mind such as intentionality and qualia (Chalmers, 1995); psychology is being extended to a neurocognitive discipline, in which cognitive terminology is translated into neurobiological language and research. With respect to a theory of aesthetics, a reductionistic neuroscientific approach would be tempted to explain aesthetic appreciation as nothing but a neurological response. Our own position is, however, that a neurobiological naturalization of the experience of art reception would be premature at least, and very likely even untenable. Here we have found no empirical indications that would support such neurobiological reduction of aesthetic appreciation, but rather evidence that speaks for the use and application of psychophysiological tools to better understand aesthetic experience (cf. Ramachandran, 2001). Our findings on the bioaesthetic linkage complement, yet do not falsify, the current qualitative art-theory discourse, grounding it empirically in the sense of Fechner's (1876) integrative theory of art perception. Now is a good opportunity for art theory to integrate the results of empirical research on aesthetic experiencing and help bridge the philosophical and psychological traditions of aesthetics research.

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