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The Embodied Experience of Abstract Art: An Exploratory Study

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Abstract

Postural control of people looking at paintings of distinct artistic styles (Mondriaan's neoplasticism and Pollock's action painting; Experiment 1) was analyzed, as well as within a more diverse set of 20th-century abstract paintings (Experiment 2). Secondly, we explored the relation between postural control, emotional states of movement (moved by, drawn towards) and aesthetic appreciation (complexity, beauty, quality), in both experiments. Results revealed differences in postural control in Experiment 1, most notably more dynamically complex body sway for Pollocks, which did not generalize to the broader range of paintings in Experiment 2. More variable, dynamically stable, complex and intermittent postural sway was found, however, comparing a subset of high-motion and low-motion paintings. Emotional states of movement and aesthetic appreciation were associated to postural control, both across paintings and across persons in several ways. Together these findings provide preliminary empirical evidence for an embodied art experience.

Keywords

art experience; embodiment; postural control; recurrence quantification analysis; emotion

The embodied experience of abstract art: an exploratory study

Art is well-known for its ability to move people, both literally and figuratively, physically and emotionally. Contemporary theories about art experience have tried to address the importance of movement in various ways, by observing increased activity in brain regions associated with motor control and applying simulation theory, by assessing people's emotional states of movement and bodily sensations, by considering their actual bodily movements of various kind, and by pointing at the role of motion features in the artworks themselves. It remains both intriguing and elusive to art scholars how these different conceptions of movement fit together in the way people experience art. The present study tries to explore the triangular relation between art, body and mind by investigating people's experience of abstract paintings in an empirical way.

Embodied perception of movement and aesthetic appreciation

Theories on art experience stress that bodily movements go hand in hand with embodied perceptions of movement, such as being emotionally moved, and with aesthetic appreciations, such as of beauty (Brinck, 2018; see also Fuchs & Koch, 2014). Gerger, Pelowski and Leder (2018) show that intense bodily reactions are related to emotional intensity as well as higher feelings of being moved and liking. According to Menninghaus and colleagues (2015), the feeling of being moved involves high emotional responses combining positive and negative emotions such as joy and sadness, and is frequently related to lower ratings of causation by oneself and power to change outcomes. Menninghaus et al. (2019) also point at actual bodily movements as an “expression component of aesthetic emotions”, which in turn are related to aesthetic appreciation.

While the perception of being moved may be an emotional response to an artwork, resonating with the viewer, liking along with beauty and goodness, may be described as a hedonic quality of art (Pelowski, Markey, Luring & Leder, 2016). Beauty is frequently

related to heightened bodily activity as well as neural activity involving circuitries associated with reward and pleasure (e.g., Chatterjee, 2013) and processing fluency (Reber, Schwarz & Winkielmann, 2004; Cela-Conde, Agnati, Huston, Mora & Nadal 2011; Graf & Landwehr, 2015).

Embodied art experience

Freedberg and Gallese (2007) argue for an embodied simulation account of aesthetic experience. In response to a painting, a viewer simulates movements and experiences of the subjects depicted and/or of the artist. Cinzia and Vittorio (2009) set forth two arguments for the importance of motor resonance in the study of art experiences. First, there seems to be a close relationship between embodied simulation-driven emotions in the viewer and the representational content, such as the actions, intentions, objects, emotions and sensation portrayed in a given artwork. Second, there seems to be a sophisticated interplay between such emotions and the visible traces of the artist's creative gestures, such as brushwork and signs of the movement of the artist's hand (Cinzia & Vittorio, 2009; Gallese, 2017).

On a phenomenological account, Angelino (2015) argues that movement resides in shapes which are created by the artist, and which, although immobile in reality, create a dynamical (dis)balance in the artwork. This in turn gives rise to distinct bodily movements in the viewer. Art experience is an embodied activity, and the viewer is literally moved by a work of art. Brinck (2018) argues that bodily movements in the art experience are impelled by the viewer and the artwork conjointly. Together the artwork, with its dynamic balance, and the viewer, as an active embodied experiencing organism, form a temporary coupled system. The resulting movement patterns allude to the constitutional capacities of the artwork as well as to the viewer. In turn, these patterns influence and are influenced by the viewer's subjective aesthetic appreciation. An artwork gives rise to movement, both in terms of actual bodily movements and embodied perceptions of movement in the viewer (van Klaveren,

Ueding, & Cox, 2019), also known as the emotionally-driven “being moved” (Pelowski, Markey, Forster, Gerger & Leder, 2017). Some studies have reported how artworks are able to elicit distinct movement patterns in a viewer, such as body sway and eye movements (Ganczarek, Ruggieri, Nardi & Belardinelli, 2015; Kapoula et al., 2011, 2015; Kapoula & Gaertner, 2015; Taylor, Spehar, Van Donkelaar & Hagerhall, 2011), both of which are subtle indicators of people’s attunement to the environment. Nevertheless, people’s actual bodily movements while viewing art have hardly been a topic of systematically empirical investigation.

The present study

The present study explored the embodied experience of art in terms of the postural control (i.e. posturography) of participants looking at abstract paintings. As part of postural control, both leaning posture (Chisholm, Risko & Kingstone, 2013) and postural sway (Pellecchia, 2003; Ramenzoni, Riley, Shockley & Chiu, 2007) have proven to be reflective of people’s cognitive and attentional states and their perceptual attunement to the environment, including those during aesthetic experiences (Ganczarek et al., 2015; Kapoula et al., 2011, 2015; Kapoula & Gaertner, 2015). Postural sway refers to the subtle, continuous and involuntary movements around the body’s center of gravity which one makes while standing, so as to maintain balance and attune to the environment. We also measured participants’ feelings of being moved by and drawn towards the paintings, to assess their emotional state of movement, as well as their aesthetic appreciation of the paintings in terms of beauty, quality and complexity.

Our working hypothesis was that experiencing art is an embodied activity, which entails relationships between patterns of postural control, embodied perceptions of movement, and aesthetic appreciations. We figured that the expressive spatial configurations of abstract paintings, in particular, would lead to detectable effects in the patterns of postural control in

people, as well as provoke considerable differences in aesthetic appreciation. By extension, paintings of markedly different artistic styles, like the neoplasticism by Piet Mondriaan and the action painting by Jackson Pollock, could amplify the differences in postural control, as well as in emotional states of movement and aesthetic appreciation.

Experiment 1

In this experiment we compared a selection of hallmark paintings by Piet Mondriaan and Jackson Pollock. The artistic styles of these painters undeniably differ in many respects. At least this is the case for the works within their oeuvre that signify their famous artistic styles. First and foremost, Pollock's action-art compositions are considerably more spatially complex than Mondriaan's creations consisting of basic geometrical shapes (e.g. Locher, Overbeeke & Stappers, 2005; Taylor, 2002). In addition, Mondriaan's paintings are considered 'low motion', whereas in the same account, Pollock's paintings are labelled as being 'high motion' (Humphries, Rick, Weintraub & Chatterjee, 2021). It can be expected that postural control while looking at compositions of low spatial complexity and low motion is itself lower in complexity and motion, than while looking at compositions of high spatial complexity and high motion (cf. Kapoula & Gaertner, 2015; cf. Kim & Blake, 2007). In other words, the differential art experience related to these two artistic styles is reflected in the spatiotemporal patterns of postural control.

Accordingly, we expected postural-control measures (to be explained in the method section) to be higher when looking at Pollock paintings than when looking at Mondriaan paintings. Specifically we predicted postural sway to be more dynamically complex and variable for the Pollock paintings. Secondly, and more generally, we expected that postural control related to specific paintings would be associated to the embodied perception of movement and aesthetic appreciation of those paintings. Two specific predictions following

from this are that paintings' subjective spatial complexity and the dynamic complexity of the postural control while looking at them would be positively correlated, and similarly for the emotional state of movement and the postural-sway variability across paintings.

Method

Participants. Fifteen undergraduate students of the University of Groningen (aged 18-29 years) participated in this study in exchange for course credits. All participants had normal or corrected-to-normal vision, and none of them reported color blindness. Three participants were discarded from further analyses because of equipment malfunction or dizziness. The twelve resulting participants were 10 females and two males. The study was approved by the local ethics committee from the department of Psychology at the University of Groningen, and written informed consent was retrieved from all participants.

Materials and procedure. While standing without shoes on a Wii Balance Board (WBB; Nintendo Company, Ltd.) at a distance of 1.9 m, participants looked at ten life-sized pictures of paintings in a random order presented on a large monitor (178 × 99 cm; 1920 × 1080 pixels; 60 Hz; Samsung Group). Five paintings were by Jackson Pollock and five by Piet Mondriaan (Table 1). The paintings were presented using OpenSesame (version 3.3.) using the backend *psycho*. This was synchronized with a custom-built software application, communicating with the WBB through a Bluetooth wireless connection, which registered postural-sway data at a fixed sample rate of 100 Hz. The WBB has been proven to be a less expensive, but valid and reliable alternative to the 'regular' laboratory force plates (e.g. Clark et al., 2010, 2018; Koslucher et al., 2012; Pavan, Cardaioli, Ferri, Gobbi & Carraro, 2014). After its presentation the painting disappeared from the screen and the postural sway measurement ended.

Participants were then handed a tablet (iPad; Apple, Inc.) running Qualtrics, on which they answered four questions. The painting was made visible again during this phase. Items

inquired, on a ten-point scale, about participants' emotional state of movement in terms of being 'Moved-By' ("How much are you emotionally moved by the painting that you have just seen?") and being 'Drawn-Towards' ("How much are you emotionally drawn towards the painting that you have just seen?"), as well as about the participants' aesthetic appreciation of the painting in terms of 'Beauty' ("In your opinion, how beautiful is this painting?") and 'Complexity' ("In your opinion, how complex is this painting?"). After the tablet was retrieved from the participant, the next painting was presented. The entire experiment lasted about half an hour, including (optional) break and debriefing.

Table 1. Title, year of production, and dimensions (cm) of the paintings used in Experiment 1. The first five paintings are by Piet Mondriaan; the last five paintings are by Jackson Pollock.

Title of painting	Year	Width	Height
1. (M) Composition with large red plane, yellow, black, gray and blue	1921	59.5	59.5
2. (M) Composition with lines and color: III	1937	77.0	80.0
3. (M) Composition in yellow, blue and white: I	1937	55.2	57.1
4. (M) Composition with red, black, yellow, blue and gray	1921	50.0	80.0
5. (M) Composition with red, yellow, black, blue and gray	1921	38.0	48.0
6. (P) Number 14 Gray	1948	78.5	57.0
7. (P) Free Form	1946	35.5	48.9
8. (P) Number 18	1950	56.7	56.0
9. (P) Silver over black, white, yellow and red	1948	80.0	61.0
10. (P) Number 19	1948	57.4	78.4

Data-analysis. Postural control was analyzed in terms of the center-of-pressure (COP) movement in the medial-lateral (ML; side-to-side) direction and anterior-posterior (AP; back-and-forth) direction. Movement analyses were performed on 30 seconds of measurement, using unfiltered but down-sampled to 50 Hz data streams. In accordance with the explorative

nature of this study, several COP measures were considered. Leaning posture (i.e. the overall tendency of leaning left/right and towards/away) was operationalized as the average of the COP movements in each direction (AV_{ML} and AV_{AP}). The spatial magnitude of the postural-sway variability was operationalized as the standard deviation of the COP movements in each direction (SD_{ML} and SD_{AP}). The dynamic organization of the postural control was analyzed by applying recurrence quantification analysis on the COP movements in each direction separately, as will be explained below.

Recurrence quantification analysis is a nonlinear time-series technique which combines phase-space reconstruction using a delay embedding technique (Takens, 1981) with the quantification of the recurrence plot (RP; Eckmann, Kamphorst, & Ruelle, 1987). RPs are a tool to visualize the behavior of dynamical systems based on recurrences (i.e. revisited points) in their trajectories in reconstructed phase space. From the RP, the dynamical organization of the system can objectively be quantified by means of several recurrence measures. The analysis requires certain parameter to be set, related to the phase-space reconstruction and to the quantification of recurrent patterns. For the first, the delay and the embedding dimension needed to be chosen. Here we used a delay of 50 and an embedding dimension of 4, using the Average Mutual Information (Fraser & Swinney, 1986) and False Nearest Neighbor (Kennel, Brown & Abarbanel, 1992) procedures, respectively. For the second we used a variable radius in phase space, which provided recurrence rates of 0.05 for each trial (cf. Riley, Balasubramaniam, and Turvey, 1999; Wijnants, Bosman, Hasselman, Cox, & Van Orden, 2009). Finally, the minimum length of the diagonal and vertical lines was set to 10 so as to avoid relatively short but random diagonals leading to saturation in the line measures (Almeida et al., 2018, Thiel et al., 2002; Tommasini et al., 2022), and leading to the identification of recurrent patterns of at least 200 ms long. Recurrent patterns indicate

deterministic episodes of various duration in the dynamics of the underlying system, which appear as diagonal and vertical lines in the RP.

The next step in the analysis is to quantify the recurrent patterns in the RP. We considered five recurrence measures, for each COP movement direction: Determinism, Meanline, Entropy, Laminarity, and Trapping Time. Determinism (DET_{ML} and DET_{AP}) is defined as the ratio of the number of recurrent points forming recurrent patterns on diagonal lines of minimally 10 recurrent points over the total number of recurrent points. This measure informs about the extent of deterministic behavior of the system. Meanline (MNL_{ML} and MNL_{AP}) is the average duration of diagonal recurrent patterns during the measurement, that is, the average length of diagonal lines. It is considered a measure of dynamic stability of the system. Entropy (ENT_{ML} and ENT_{AP}) is computed as the Shannon entropy of the distribution of line lengths of the diagonal lines in the RP (cf. Webber & Zbilut, 1994). Entropy quantifies the dynamic complexity of the system. Laminarity (LAM_{ML} and LAM_{AP}) and Trapping Time (TT_{ML} and TT_{AP}) capture the proportion and average duration of laminar states of minimally 200 ms, respectively. Laminar states represent intermittency or rigidity in the system, that is, when the system gets stuck in one or more states for some time. Laminarity is calculated similarly as Determinism except that it reflects the proportion of recurrent points on vertical lines in the RP. Trapping Time is similar to Meanline but quantifies the average vertical line length, and therefore the average duration of vertical recurrent patterns during the measurement. Detailed descriptions of recurrence quantification analysis including descriptions of all measures can be found elsewhere (e.g. Marwan, Romano, Thiel & Kurths, 2007; Riley et al., 1999; Wallot & Leonardi, 2018; Webber & Zbilut, 2005; Wijnants, Hasselman, Cox, Bosman & Van Orden, 2012). The recurrence quantification analysis was performed using custom-made Matlab scripts in combination with a function from Marwan's CRP Toolbox (<http://www.recurrence-plot.tk>).

Because of the relatively small sample size in this experiment and because most of the COP measures were not normally distributed, non-parametric tests were used to check our expectations. For comparing the two artistic styles Wilcoxon signed-rank test with a Monte-Carlo resampling procedure (10000 samples) were used on the seven COP measures in both movement directions (one-tailed), as well as on the ratings of the four questions (two-tailed). In addition, Spearman's rank correlations (ρ) were calculated between the over-participants averaged COP measures and artwork ratings, in order to reveal painting-oriented associations between postural dynamics and evaluations. Extreme outliers with respect to COP total path length were removed beforehand, and width and height of the painting were used as covariate where possible. For all analyses α was set to .05, and in line with the exploratory nature of this study no corrections for multiple comparisons were made (see Armstrong, 2014).

Statistical analyses were done in SPSS.

Results

Table 2 provides an overview of all the COP measures and the ratings to the questions for each of the ten paintings in Experiment 1.

Table 2. Averages (over participants) of the COP measures in both movement directions and of the ratings for the four questions, for each of the ten paintings used in Experiment 1. (MVD=Moved-By; DRW=Drawn-Towards; BTY=Beauty; CPX=Complexity)

Artistic Style	Nr	Medio-Lateral							Anterior-Posterior							Questions			
		AV	SD	DET	MNL	ENT	LAM	TT	AV	SD	DET	MNL	ENT	LAM	TT	MVD	DRW	BTY	CPX
Mondriaan	1	-0.11	0.25	0.21	17.2	2.48	0.31	14.8	3.88	0.43	0.59	22.8	2.97	0.68	17.9	2.50	3.00	3.75	2.75
	2	-0.28	0.23	0.25	18.2	2.50	0.35	14.8	3.82	0.39	0.61	22.9	3.03	0.70	18.4	2.58	2.83	3.17	3.92
	3	-0.23	0.26	0.29	18.3	2.66	0.39	16.1	3.85	0.43	0.59	22.3	3.01	0.68	18.6	3.00	3.08	3.50	4.08
	4	-0.02	0.26	0.24	18.2	2.59	0.34	15.1	3.89	0.35	0.58	23.3	3.03	0.69	18.2	2.08	2.83	3.75	2.83
	5	-0.31	0.25	0.30	19.0	2.66	0.40	16.1	3.92	0.40	0.56	22.4	2.96	0.66	17.9	2.55	2.82	3.45	3.00
Overall		-0.17	0.25	0.26	18.2	2.58	0.36	15.3	3.86	0.40	0.59	22.7	3.00	0.68	18.2	2.58	2.95	3.54	3.36
Pollock	6	-0.07	0.23	0.28	19.3	2.77	0.39	15.7	3.86	0.43	0.61	22.6	3.04	0.70	18.4	4.09	4.00	3.91	5.09
	7	-0.18	0.26	0.31	19.1	2.66	0.41	16.4	3.76	0.43	0.60	24.2	3.07	0.69	19.1	3.73	3.73	4.09	4.91
	8	-0.25	0.26	0.29	19.2	2.78	0.39	16.2	3.50	0.43	0.59	22.7	3.02	0.68	18.6	3.58	4.00	5.25	5.17
	9	-0.37	0.36	0.36	21.1	2.93	0.46	17.5	3.66	0.44	0.59	23.0	3.00	0.68	18.5	3.92	4.67	5.17	5.42
	10	0.21	0.22	0.22	17.7	2.53	0.32	15.0	3.60	0.40	0.60	22.6	3.00	0.69	18.6	3.42	4.50	5.00	5.25
Overall		-0.12	0.28	0.30	19.4	2.74	0.40	16.2	3.60	0.43	0.60	22.9	3.02	0.69	18.6	3.65	4.11	4.63	5.07

Artistic style comparison: Mondriaan versus Pollock. Significant differences were revealed between the two artistic styles for the postural-sway measures DET_{ML} , $Z = -1.73$, $p = .045$, MNL_{ML} , $Z = -1.88$, $p = .034$, ENT_{ML} , $Z = -2.43$, $p = .006$, LAM_{ML} , $Z = -1.73$, $p = .048$, and TT_{ML} , $Z = -2.04$, $p = .022$. Largely in line with our main expectation, looking at Pollock paintings went along with more deterministic, dynamically stable and complex postural sway, which consisted of more and longer intermittent episodes in the dynamics. The leaning-posture measure AV_{AP} was also higher, $Z = 1.73$, $p = .048$, which means that there is a tendency to look at Pollock paintings with a slightly more forward leaning posture.

With respect to the ratings, Wilcoxon tests yielded significant differences between the two artistic styles for all four questions: Beauty, $Z = -2.08$, $p = .042$, Complexity, $Z = -2.12$, $p = .031$, Moved-By, $Z = -2.05$, $p = .039$, and Drawn-Towards, $Z = -2.05$, $p = .040$. This means that Pollocks were regarded as more beautiful and more complex than Mondriaans, and with respect to their emotional states of movement, participants' felt more moved-by and more drawn-towards Pollock paintings.

Across-painting propensities of art experience. In line with our second expectation, emotional states of movement and aesthetic appreciations for the ten paintings, averaged over all participants, were associated to the averages of the COP measures in several ways. Paintings which rated higher in Complexity elicited more forward leaning posture, $\rho(10) = -.82$, $p = .004$ (AV_{AP}), and more dynamically complex postural sway in the medial-lateral direction, $\rho(10) = .64$, $p = .048$ (ENT_{ML}). The correlation between Complexity and TT_{AP} approached significance, $\rho(10) = .72$, $p = .054$. Paintings were also leaned towards more when they were rated higher on Beauty, $\rho(10) = -.73$, $p = .017$, and on being Drawn-Towards, $\rho(10) = -.77$, $p = .009$. For paintings that participants were more Moved-By on average, more dynamically stable and dynamically complex postural sway in the medial-lateral direction was observed, $\rho(10) = .79$, $p = .006$ (MNL_{ML}), and $\rho(10) = .67$, $p = .033$ (ENT_{ML}),

respectively. More emotionally moving paintings also elicited more deterministic and longer laminar anterior-posterior postural-sway patterns, $\rho(10) = .65, p = .043$ (DET_{AP}), and $\rho(10) = .86, p = .002$ (TT_{AP}), respectively. Finally, and quite interestingly, Moved-By was also significantly positively correlated with the variability of the anterior-posterior postural sway, $\rho(10) = .71, p = .021$ (SD_{AP}).

Discussion

Largely in line with our expectations, results show that postural control during art perception appears to have an artistic-style quality to it. That is, COP measures differ, to some extent at least, between two markedly different painting styles, and appear to be related to how paintings are subjectively experienced. Most prominently, we found that participants' sideways COP movements while looking at Pollocks were higher in entropy (ENT_{ML}) than while looking at Mondriaans. Contrary to our prediction however, the spatial extent of postural-sway variability (SD_{ML} and SD_{AP}) was not larger for the Pollocks. This means that the low-motion and high-motion distinction, which has been made between Mondriaans and Pollocks (Humphries et al., 2020), did not directly translate in more or less variable (i.e. less or more stable) postural control. The entropy, as a metric for dynamic complexity of the postural sway, could be revealing that differences in spatial complexity between Pollock paintings and Mondriaan paintings are reflected by differences in the temporal complexity of the embodied aesthetic experience. Importantly, at present it remains speculation whether it is the spatial complexity (or the motion distinction or any other aspect) of the painting that directly leads to the movement patterns. It could merely be a side effect of some other (art-related) perceptual, emotional and cognitive process. To investigate this, additional and more detailed experimental studies are necessary.

Some additional clues about the nature of embodied art experience might partly be provided by the strong correlations which were found between the subjective appraisals of the

paintings and the measures of art-elicited postural control. Surely, subjective appraisals in terms of aesthetic appreciations, like beauty and complexity or their relation (Forsythe, 2011), or emotional states of movement, like feeling moved-by or drawn-towards, are not pure and direct indicators of perceived spatial structure, artistic quality, or any such thing. Nor do they reveal how those things influence bodily movement. In fact, such appraisals attempt to express how people experience art emotionally, cognitively and otherwise. However, we know that they are linked reliably, albeit in a non-obvious often, to various features of artworks (Arnheim, 1974; Van Geert & Wagemans, 2020). In that sense, across-painting correlations like the one found between subjective complexity and the dynamical complexity of postural sway, provide additional hints at a connection between emotional, cognitive, and bodily aspects of the experience. These are likely triggered by the attunement to specific affordances of a painting, which are potentially quite complex and layered. As an additional example, the strong correlation between postural-sway variability and being moved-by indicates that the subjective feeling of movement and the actual bodily movement represent a commonality. As said earlier, what it is in artworks that creates this link or makes it overt in a specific way, clearly warrants more empirical investigation.

Finally, the differences which were found between the Mondriaans and Pollocks with respect to participants' emotional state of movement and aesthetic appreciation, should be interpreted with care. The relatively small and homogeneous sample of participants in this experiment implies that these results cannot be generalized to any type of population. Claims about differences in aesthetic appreciation between Mondriaan and Pollock paintings, or between the artistic movements of 'de stijl' and 'action art' for that matter, are unwarranted. It should be stressed though that the goal of this study was not to investigate such things, but to explore the embodied dynamic nature of art experience and discover potential relationships between people's bodily movements while looking at an artwork and their assessment of that

piece. For that objective the current sample was quite appropriate, as was the choice for the two different painting styles.

Experiment 2

The results of Experiment 1 on art-elicited postural control, solicit the question as to their generalizability, at least to other abstract painting styles. To put it boldly, to what extent is postural control characteristic of a specific abstract painting? It remains to be seen whether other types of expressive spatial configurations used by abstract painters, which vary in more subtle ways, also lead to detectable differences in the postural-control measures. Similarly, do the links between the subjective experience and postural control, as revealed in Experiment 1, generalize to other paintings? To investigate this, in Experiment 2, we selected abstract paintings spanning across a broad range of artistic styles and applied a similar design as in the previous experiment.

We expected postural control, emotional state of movement and aesthetic appreciation to differ between paintings. We also expected the corresponding measures to be associated across paintings like in Experiment 1. In addition to these across-painting associations, we investigated whether individual participant's overall postural-sway patterns and their overall embodied perceptions of movement and aesthetic appreciations would be associated. Note that with this, Experiment 2 has a dualistic focus with respect to the embodied-emotional link in art experience: across-painting propensities and across-person predispositions.

Method

Participants. Data of 46 undergraduate students of the University of Groningen (aged 18-25 years; 38 females and 8 males) was successfully collected, in exchange for course credits. Fourteen more participants were discarded from further analyses because of equipment malfunction or violation of the procedure. All participants had normal or

corrected-to-normal vision, and none of them reported color blindness. The study was approved by the local ethics committee from the department of Psychology at the University of Groningen, and written informed consent was retrieved from all participants.

Materials and procedure. The experimental procedure was similar to that of Experiment 1. Participants looked at 21 carefully selected pictures of abstract paintings. For an overview of all paintings see Appendix 1. All selected paintings were created in the 20th century, and reflected different styles reaching from constructivism to abstract expressionism. Limited by the dimensions of the monitor, the height of all stimuli was set to 90 cm, while keeping the proportions of the original painting intact. Paintings were presented in a random order, in three blocks of seven with a short break between each block. After each postural sway measurement, participants gave four ratings on a ten-point scale using a tablet, with the respective painting being visible. Questions about Beauty and being Moved-By and Drawn-Towards were the same as in Experiment 1. But Quality (“In your opinion, how much aesthetic merit/quality does the painting possess?”) was inquired about here instead of Complexity. The entire experiment lasted about half an hour, including (optional) break and debriefing.

Data-analysis. The same COP measures were calculated as in the previous experiment (i.e. AV, SD, DET, MNL, ENT, LAM, and TT, both for the medial-lateral and anterior-posterior directions), again on 30 seconds of measurement at 50 Hz. To detect differences between paintings, separate non-parametric analyses (Friedman tests with Monte-Carlo resampling) were performed on these COP measures and on the four questions. Similar to what was done in Experiment 1, Spearman’s rank correlations were calculated across paintings between the over-participants averaged COP measures and artwork ratings. In addition to that, Spearman’s rank correlations were calculated across participants between the

over-paintings averaged COP measures and artwork ratings. Extreme outliers were removed. The α was set at 0.05 again, with no corrections for multiple comparisons (Armstrong, 2014).

Results and Discussion

Table 3 shows the postural-control measures and ratings for emotional state of movement and aesthetic appreciation, averaged over all 21 paintings in the experiment with standard deviations. Contrary to what we expected, none of the COP measures significant differed between paintings. However, DET_{AP} approached the significance level, $\chi^2(20) = 30.69, p = .056$. This means that the deterministic structure of the anterior-posterior postural dynamics of participants had a tendency to be slightly different within our sample of abstract paintings.

Next, Friedman tests yielded significant differences between paintings for all questions: Moved-By, $\chi^2(20) = 108.68, p < .001$, and Drawn-Towards, $\chi^2(20) = 100.95, p < .001$, and for Beauty, $\chi^2(20) = 98.45, p < .001$, and Quality, $\chi^2(20) = 106.78, p < .001$. So, on average, some paintings were considered more beautiful and of higher aesthetic quality than others, and some of the paintings caused participants to feel more moved by and drawn towards than others did.

Exploratory analysis: Dynamic versus static paintings. To investigate whether results would emulate those of Experiment 1 when more opposing artistic styles would again be compared, an additional analysis was performed. We decided to further explore the distinction that has been made between ‘low-motion’ and ‘high-motion’ paintings (Humphries et al., 2021). We instructed five researchers (including the authors) to choose the three most dynamic (‘high-motion’) paintings and the three most static (‘low-motion’) paintings out of the 21 in the original sample. The four paintings that clearly stood out were selected for comparison, two being the top-rating dynamic ones (nrs. 11 and 20 in Appendix 1), the other

two being the top-rating static ones (nrs. 3 and 7 in Appendix 1), where the (averaged) postural-sway measures were expected to be significantly lower for the latter motion category. For the average values of all the measures separated for the two motion categories, see the second part of Table 3. One-tailed Wilcoxon tests revealed clear differences for several of the COP measures: MNL_{ML} , $Z = -2.274$, $p = .011$, ENT_{ML} , $Z = -2.709$, $p = .003$, SD_{AP} , $Z = -1.800$, $p = .036$, ENT_{AP} , $Z = -1.936$, $p = .025$, and TT_{AP} , $Z = -1.755$, $p = .039$. This means that the high-motion paintings elicited more dynamically stable, complex and intermittent postural sway, which was also more variable in the back-and-forth direction, than the low-motion paintings did.

Table 3. Averages and standard deviations of the COP measures in both movement directions and of the ratings for the four questions over all the paintings in Experiment 2, as well as separated for the most static (‘low-motion’) paintings and most dynamic (‘high-motion’) paintings.

	Medio-Lateral							Anterior-Posterior							Questions			
	AV	SD	DET	MNL	ENT	LAM	TT	AV	SD	DET	MNL	ENT	LAM	TT	MVD	DRW	BTY	QTX
All paintings																		
Average	-0.79	0.34	0.34	19.9	2.82	0.44	16.6	2.19	0.54	0.68	26.2	3.25	0.76	20.4	4.00	4.16	5.37	5.85
St. Dev.	1.74	0.49	0.21	4.57	0.41	0.21	3.70	1.85	0.35	0.12	5.95	0.28	0.10	3.21	2.33	2.41	2.34	2.18
High-motion paintings																		
Average	-0.68	0.41	0.36	20.7	2.91	0.46	17.1	2.30	0.59	0.69	26.5	3.27	0.77	20.5	4.26	4.15	4.36	5.16
St. Dev.	1.31	0.52	0.19	3.93	0.28	0.19	3.71	1.80	0.38	0.11	5.32	0.25	0.09	2.79	2.17	2.35	1.96	2.01
Low-motion paintings																		
Average	-0.65	0.37	0.34	19.8	2.81	0.44	16.4	2.18	0.54	0.68	25.8	3.22	0.75	20.0	2.93	3.17	4.43	5.04
St. Dev.	1.45	0.48	0.19	3.68	0.31	0.19	2.95	1.90	0.40	0.11	5.10	0.25	0.09	2.57	1.80	1.95	2.08	1.99

Across-painting propensities of art experience. Emotional states of movement and aesthetic appreciations averaged over all participants, were associated to participant-averaged COP measures, across paintings, albeit differently as in Experiment 1. Ratings on the questions of Beauty and Quality were significantly correlated with the average duration of laminar states in the anterior-posterior postural sway (TT_{AP}), $\rho(21) = .51, p = .017$, and $\rho(21) = .44, p = .047$, respectively. This means that longer average intermittent periods in the postural sway, that is, longer periods when postural control gets stuck in a specific state, occurred when looking at subjectively more beautiful and aesthetically more qualitative paintings. Such periods could be interpreted as ‘freezing episodes’ in the art experience, and these correlations show that such episodes are linked to the subjective beauty and quality of paintings. The correlation of Beauty and Quality with Determinism in the anterior-posterior direction (DET_{AP}) approached significance, $\rho(21) = .43, p = .053$, and $\rho(21) = .43, p = .054$, respectively. Also, more emotionally moving paintings were associated with more dynamically complex postural sway in the medial-lateral direction, $\rho(21) = .46, p = .037$ (ENT_{ML}).

Across-person predispositions of art experience. In line with our third general expectation, emotional states of movement averaged over all paintings, were associated, across participants, to some of the painting-averaged COP measures. Specifically, participants who rated paintings higher on being Moved-By and Drawn-Towards, leaned towards these paintings more (AV_{AP}), $\rho(46) = -0.34, p = .023$, and $\rho(46) = -0.30, p = .040$, respectively. For Quality the correlation with AV_{AP} approached significance, $\rho(46) = -0.29, p = .054$. Finally, participants who were more emotionally drawn towards paintings also had more dynamically stable anterior-posterior sway patterns, $\rho(46) = 0.31, p = .039$ (MNL_{AP}). These results indicate a link between postures and movements in people (i.e. leaning and dynamical stability) and their emotional states related to such postures and movements. This link could be art specific,

reflecting an embodied aspect of art experience, such that more art-appreciating and art-emotional people tend move closer to artworks and have more stable posture while looking at art. On the other hand, it might be caused by more straightforward viewing behavior and perception-action processes, such that paintings requiring closer scrutiny, and therefore leaning forward more, are deemed more interesting and therefore rate higher on a variety of questions including the ones asked in this experiment.

General Discussion

Overall, the results of the two experiments presented in this study partially confirm our expectations about embodied art experience of abstract paintings. People looking at paintings of two markedly different artistic styles displayed postural control which differed significantly in some aspects of their dynamic organization. Most notably, complexity of the postural dynamics was found to be higher for Pollock paintings than for Mondriaan paintings. On the other hand, the spatial extent of the postural-sway variability, which was expected to be higher for Pollocks than for Mondriaans, did not diverge. Also postural control did not vary detectably across the larger assortment of abstract painting styles used in Experiment 2, although the deterministic structure of the back-and-forth body sway came close. Zooming in on a subset of high-motion (dynamic) and low-motion (static) paintings, however, exposed differences in several postural-sway measures again. Notably among these are the back-and-forth postural-sway variability which was found to be larger for the high-motion paintings, and the dynamic complexity (in both directions) which showed to be a distinguishing measure for art-related movements again.

It is well-known that postural control is responsive to environmental circumstances, in order to maintain a dynamically stable posture, while at the same time, it serves an explorative function in actively seeking out information (see e.g. Balasubramaniam & Wing, 2002; Riley & Turvey, 2002). Additionally, posture has been shown to be reflective of

cognitive processes (e.g., Balaban et al., 2004; Pellecchia, 2003; Rosenbaum, Mama & Algom, 2017). In this light, the result that dynamic stability and complexity were different between Pollock and Mondriaan paintings is particularly interesting since these correspond with two of the spatial features on which these artistic styles deviate quite considerably. Without intending to oversell these particular findings, this does provoke an interpretation in which the dynamical organization of bodily movements during (abstract) art experience tends to reflect at least some compositional characteristics of the artworks. However, the lack of clear results in Experiment 2 limits this conclusion, and invites more detailed empirical investigation.

Perhaps the most intriguing overall finding of the present study is that across both experiments, the measures of postural control (as a form of bodily movement) correlated in several ways with the measures of the emotional state of movement and aesthetic appreciation. Systematic *across-painting* relations were revealed between people's embodied perceptions and subjective evaluations of the paintings and their postural control while looking at these paintings. For one thing this implies that, not only are the bodily moving and emotionally moving extent of art experiences associated, these associations also seem to be painting specific to some degree. The direction of these association remain unspecified, as already mentioned earlier. In any case, this study adds to the growing body of research, also in the field of art experience, that people's emotions both influence and are influenced by what happens in or to their body, including bodily movements (cf. Fuchs & Koch, 2014).

In conclusion, it is much too early to interpret each and every individual result of this exploratory study and to theorize about their precise meaning in terms of the art-body-mind triangle. First and foremost, the present findings add to the empirical evidence for an embodied and enactive art experience (e.g. Burnett & Gallagher, 2020) and its relation to art-elicited emotional states and aesthetic appreciation. This study also shows that postural

control is a spontaneously occurring and easily accessible form of bodily movement, and that posturography can provide novel insights. Finally, techniques for analyzing the dynamical organization of behavior, for instance recurrence quantification analysis as was used here, are a valuable addition to the toolbox of empirical aesthetics and the scientific study of art.

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