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Uncovering the connection between artist and audience: Viewing painted brushstrokes evokes corresponding action representations in the observer

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A B S T R A C T

Observed actions are covertly and involuntarily simulated within the observer's motor system. It has been argued that simulation is involved in processing abstract, gestural paintings, as the artist's movements can be simulated by observing static brushstrokes. Though this argument is grounded in theory, empirical research has yet to examine the claim. Five experiments are described wherein participants executed arm movements resembling the act of painting horizontal brushstrokes while observing paintings featuring broad, discernable brushstrokes. Participants responded faster when their movement was compatible with the observed brushstrokes, even though the paintings were irrelevant to their task. Additional results suggest that this effect occurs outside of awareness. These results provide evidence that observers can simulate the actions of the painter by simply observing the painting, revealing a connection between artist and audience hitherto undemonstrated by cognitive science.

1. Introduction

> In this gesturing with materials the esthetic, too, has been subordinated. Form, color, composition, drawing, are auxiliaries, any one of which… can be dispensed with. What matters always is the revelation contained within the act (Rosenberg, 1960).

When Harold Rosenberg coined the term "action painting" in 1952 he was making a point about the nature of art. He argued that action painters, such as Pollock and de Kooning, showed how the act of creation was inseparable from the final product. Rather than windows into a still scene, their paintings were physical events. This new style was characterized by the artist's movement: paint was smeared, dribbled, and broadly stroked across canvases. In addition to form, colour, and composition, action painters used their own movement as an element of visual design.

The action painters' departure from a strict adherence to classic technique and design is paralleled by recent developments in theories of cognition and art. Traditionally, these theories have focused on how perception processes visual characteristics of art, such as orientation, grouping, perspective, proportion and colour (Kubovy, 1986; McManus, Cheema, & Stoker, 1993; Ramachandran & Hirstein, 1999; Solso, 1996; Zeki, 1999). Recently, Freedberg and Gallese (2007) expanded on these theories by proposing that viewing art involves perceiving action. Specifically, they proposed that observers implicitly recreate the motor programs of the artist's creative actions while viewing their paintings. Just as the action painters believed that movement was a crucial aesthetic element of *creating* a painting, Freedberg and Gallese proposed that implicit imitation of the act of creation is involved in *perceiving* a painting.

Freedberg and Gallese's proposal is based on research on the perception of action. Observing another person's actions

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automatically activates imitative action representations within our own motor system, a process known as motor simulation (Gallese, 2005; Knoblich & Sebanz, 2006; Wilson & Knoblich, 2005). While most research on motor simulation examines its involvement in the observation of actions, several studies show how motor simulation is also involved when observing the results, or traces, of actions. For example, viewing written symbols evokes simulations of the actions required to draw them (Knoblich, Seigerschmidt, Flach, & Prinz, 2002), and viewing digital text causes simulation of typing in expert typists (Beilock & Holt, 2007). Imaging studies have shown that viewing static letters caused activation in left ventral premotor cortex (BA6), an area that is also active in handwriting (Longcamp, Anton, Roth, & Velay, 2003). The same area is activated in the right hemisphere when left-handers are studied (Longcamp, Anton, Roth, & Velay, 2005). These imaging studies suggest that viewing writing evokes simulation of the actions required to produce the text. These studies support the idea that observers can recover a dynamic motor plan simply by observing its static trace. Based on this research, Freedberg and Gallese (2007) argued that observing paintings that feature deliberate gesture, like the action painters' work, evokes motor simulations.

If merely viewing a painting can evoke simulations of the artists' original actions, then the action painters may have been so evocative because they were tapping into something fundamental about the way we perceive each other's movements. However, if one is to simulate Jackson Pollock's actions it must be done indirectly, as he has been quite dead since 1956, and is therefore inanimate. Fortunately, his paintings persist as a historical record of his actions. Observers can simulate the actions in a painting because the brushstrokes contain information about the artist's movements. The brushstroke as a visual object expresses high correspondence to its parent movements. It specifies the trajectory, force and perhaps even posture of the artist as he created it. In other words, the gestural aspects of the original action that we might consider 'expressive' are all preserved in a brushstroke, as though it were a fossil of the action.

If a brushstroke contains visual signals that describe its parent action, and if these diagnostic signals are associated with brushstroke actions, then vision of the brushstroke may evoke a motor simulation of the parent action. Further support for this notion can be drawn from the common coding hypothesis, which posits that planned actions and their perceivable consequences have a shared, bidirectional representation (Hommel, Musseler, Aschersleben, & Prinz, 2001). At a proximal level, the movement of the arm and the percept of the brushstroke possess exclusive motor and sensory codes, respectively. But at a higher level, these elements may become coded into a shared representation that allows bidirectional associations between the percept and the action. Thus, the perception of a brushstroke would be able to prime actions with shared distal features. In this way, an observer can recover an artist's dynamic motor plan by observing its static trace.

By proposing a role for motor processes in the aesthetic experience of visual art, Freedberg and Gallese (2007) expanded on theories of visual aesthetics in a manner that mirrored the action painters' departure from contemporaneous style: both realized that art was being thought of as a strictly visual subject, and both responded by incorporating action. Regarding gestural art, Freedberg and Gallese's (2007) proposal can be distilled into three components: (1) observing gestural artwork causes motor simulation of the artist's actions; (2) this simulation engages mental states or intentions commonly associated with the simulated actions; (3) accessing these mental states affects aesthetic experience of the painting. As intriguing as this theory may be, to date, there is no empirical evidence supporting (1), the claim that observing art involves motor simulation. Without support for this claim, (2) and (3) cannot stand. To test their first claim, we investigated whether viewing paintings with discernable brushstrokes would influence observers' behaviour in a manner predicted by theories of motor simulation.

2. Experiment 1

Observed actions interfere with the performance of executed actions if they are incongruent (Kilner, Paulignan, & Blakemore, 2003), an effect attributed to competition between motor programs. Here, we examined if observing static, unidirectional brushstrokes automatically activates corresponding motor programs. If so, participants should be slower to make concurrent movements that are incompatible with those brushstrokes and faster to make movements that are compatible.[1] Q4

2.1. Method

2.1.1. Participants

Forty-two students (12 female), aged 18–23 years, participated for course credit.

2.1.2. Materials

Ten original paintings were created. Critically, all brushstrokes in each painting were applied moving left-to-right. Photographs of the paintings were taken and cropped into square details (see Fig. 1). Each image was mirrored, such that there were 10 identical stimuli with brushstrokes moving right-to-left. These 20 images were then duplicated and half were coloured red and half were coloured green.

The stimuli were stretched to fit the entire computer display. Three response buttons, "A" (Left), "H" (Centre) and "" (Right), were situated on a horizontal line in front of the participant and were highlighted by coloured stickers. The two lateral buttons were equidistant (9.6 cm) from centre.

[1] Given that participants were able to extract information about the artist's movement through observation, as shown in Experiments 1 and 2, there must be reliable visual correlates of that gestural information. Here we have shown that brushstroke continuity may play a key role. In Experiment 3, we found that a visual gradient alone was not sufficient to produce the effect. Other candidate visual correlates of brushstroke direction include the trajectory (while all brushstrokes were intended to be horizontal, they must slope slightly up or down), size gradient, or start or end position. Identifying the visual correlates of the gestural information is a promising avenue for future research.

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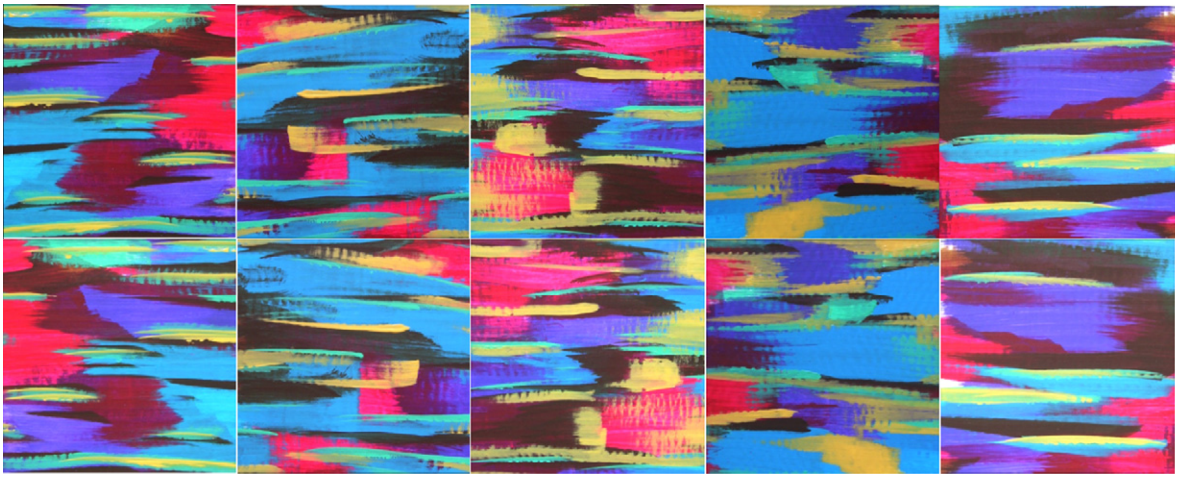

Fig. 1. The stimuli were created from 10 original paintings. Critically, every brushstroke within each painting was created with movement in the same direction. Images of the paintings were cropped and duplicated such that there were 10 with rightward brushstrokes and 10 with leftward brushstrokes. Here, 5 stimuli are oriented rightward (top row) and the same 5 stimuli are oriented leftward (bottom row).

2.1.3. Procedure

Participants completed two phases of the experiment: a speeded response task and an action identification task. The speeded response task was always performed first.

At the beginning of each trial, the display prompted the participant to press the middle button. This initiated a 1000 ms fixation at the centre of the display, followed by the presentation of a painting. Participants responded to the colour of the painting by moving the index finger of the dominant hand from the centre button to the left or right buttons. Thus, the colour of the painting (red or green) was the task-relevant feature of the stimuli. The direction of the brushstrokes (moving left or right) was task-irrelevant. The assignment of colour to response direction was randomized across participants. Response time was measured as the interval between stimulus onset and response at the left or right buttons. Participants completed 40 trials, and the presentation of stimuli was randomized without replacement. On each trial, the response movement could be in the same direction as the brushstroke movement (compatible) or in the opposite direction (incompatible).

For the action identification task, participants were shown the same stimuli used in the previous task in random order and asked to identify the direction of brushstroke movement. Viewing time was unlimited, and participants were instructed to be as accurate as possible. Responses were indicated by pressing the left or right button.

2.2. Results

For the speeded response task, trials where response times were two standard deviations above or below the group mean were removed (2.3% of the trials). All incorrect responses were discarded (<1% of the trials). A 2 (brushstroke direction) × 2 (response direction) ANOVA with response time as the dependent variable revealed a significant interaction, $F(1,41) = 5.39$, $p = .025$, $\eta_p^2 = .12$ (see Fig. 2). Participants were faster to respond in the same direction as the observed brushstroke movement than in the opposite direction. This interaction can also be expressed as a compatibility effect, which is the mean difference between the incompatible and compatible trials ($M = 13.89$ ms, $SE = 5.98$), and was significantly greater than 0, $t(41) = 2.32$, $p = .025$. Post hoc pairwise comparisons reveal that rightward responses were faster to rightward rather than leftward brushstrokes, $t(41) = -2.21$, $p = .032$. The reverse pattern emerged for leftward responses, although the effect was not significant, $t(41) = 1.20$, $p = .236$. There was a trend for participants to respond left faster than right, $F(1,41) = 3.03$, $p = .089$, $\eta_p^2 = .069$.

Although participants were not very good at identifying the direction of brushstroke movement ($M = 55\%$, SD = 12%, range = 25–80%), they were significantly better than chance (50%), $t(41) = 2.68$, $p < .011$. The compatibility effect for response times was not correlated with accuracy in identifying brushstroke direction in either a subject-based

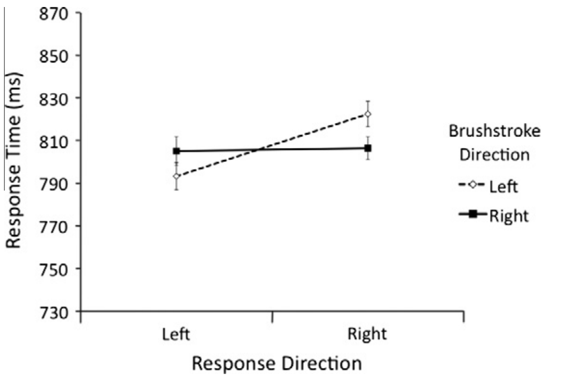

Fig. 2. Mean response times for Experiment 1 as a function of brushstroke direction and response direction. Participants were faster to move in the same direction as the brushstrokes than in the opposite direction. Errors bars represent within-subjects standard error of the mean.

correlation, $r(42) = .15$, $p = .358$, or a painting-based correlation, $r(10) = -.18$, $p = .623$.

2.3. Discussion

The participants' task was to respond to the colour of the paintings, yet the direction of movement in the paintings' brushstrokes affected their responses. Participants were slower to respond when their movement was incompatible with the observed movement of the brushstrokes. This pattern of results is consistent with predictions made by a motor simulation account of action observation, or, in this case, action-effect observation. According to this account, observation of the brushstrokes evoked a simulation of the original actions that generated the painting, and this simulation interfered with participants' concurrent responses.

Looking at the data, it appears there is no effect when the brushstrokes move to the right (see Fig. 2, solid line). This is problematic for our theory because we predicted an effect for brushstrokes in both directions. While the critical test of our theory is the presence of a crossed interaction, which we found, the lack of effect for rightward brushstrokes deserves some discussion. We propose that the effect for rightward brushstrokes is obscured by a tendency for participants to make faster leftward responses. Because responses were made with the dominant hand only, leftward and rightward responses are physiologically asymmetric. These actions employ different sets of muscles, so it not surprising that response times are commensurately asymmetric. With the right hand, a leftward movement from the midsagittal plane is adductive, whereas a rightward movement is abductive. Right-handers make faster leftward movements compared to rightward movements in a reciprocal tapping task, (*adductive superiority*), regardless of the hemispace where the targets are located (Bradshaw, Bradshaw, & Nettleton, 1988), an effect that was replicated in another study that involved a lateral arm response much like the one in the current study (Keulan, Adam, Fischer, Kuipers, & Jolles, 2007). Given that leftward responses are faster than rightward responses, this difference should be reduced or eliminated in situations that prime rightward responses and should be exaggerated in situations that prime leftward responses. This is the exact pattern found in our data. This pattern is also replicated in the following experiments.

Motor simulation is thought to be a covert process that occurs without awareness (Jeannerod, 2001). Consistent with this notion, we found that awareness of brushstroke movement did not correlate with the size of the compatibility effect. This lack of relationship between awareness of brushstroke direction and the impact of observed brushstroke direction on concurrent movements suggests that performance on the two tasks were mediated by separate, independent processes. Furthermore, the correlation was also not apparent at a painting-level, suggesting that paintings for which conscious awareness of the brushstroke direction was available are not more likely to evoke the compatibility effect.

3. Experiment 2

Thus far, the results suggest that people simulate the movements that created the viewed stimuli, even when not explicitly tasked with responding to these movements. To further investigate the automaticity of these effects, we used a task in which the painting was entirely irrelevant to the response and was merely background on which the task-relevant stimuli was presented. Arbitrary symbols were superimposed upon the paintings to indicate which direction participants should respond. Results showed that participants were faster to respond when their movement direction was compatible with the brushstroke movement in the task-irrelevant paintings.

3.1. Method

3.1.1. Participants

Seventeen Purdue University students (2 female), aged 18–22 years, participated for course credit.

3.1.2. Materials

The original colour of the paintings from Experiment 1 was restored, and one of two targets, a plus sign (+) or an asterisk (*), was superimposed on the centre of the stimuli to indicate whether participants should respond left or right. Thus, the task-relevant feature was the target whereas the task-irrelevant feature was the direction of the brushstrokes.

3.1.3. Procedure

Participants initiated each trial by pressing and holding the centre button. This caused a painting to appear onscreen. The target appeared after a delay of 750 ms or 1000 ms, so participants could not predict stimulus onset. The computer recorded the interval between target onset and the depression of the left or right buttons as response time. Participants performed four trials for each of 10 paintings oriented in both directions (left and right) for each target stimulus (+ or *) for a total of 160 trials. After the speeded response task, participants performed the action identification task, where they viewed each stimulus again and had to identify the direction of the brushstrokes.

3.2. Results

All trials above or below two standard deviations from the group mean were removed (3.1%). All incorrect responses were discarded (<1%). There was an effect for the duration of painting presentation before target onset (750 ms vs. 1000 ms), $F(1,16) = 6.07$, $p = .025$, $\eta_p^2 = .27$. However, this factor did not interact with brushstroke direction, response direction, or their interaction, $ps > .05$, so subsequent analyses do not include this variable.

A2 (brushstroke direction) × 2 (response direction) ANOVA with response time as the dependent variable revealed a significant interaction, $F(1,16) = 8.30$, $p = .011$, $\eta_p^2 = .34$ (see Fig. 3). Participants were faster to respond when they moved in the same direction as the original brushstrokes. When expressed as a compatibility effect

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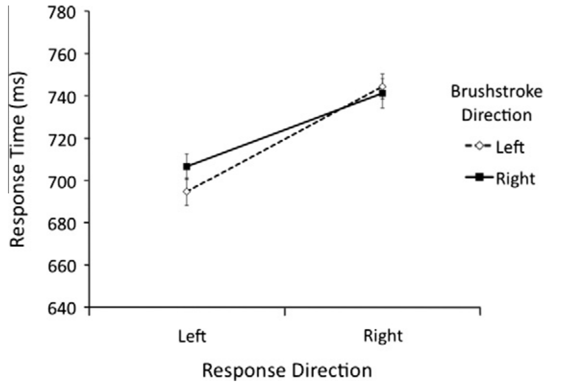

Fig. 3. Mean response times for Experiment 2 as a function of brushstroke direction and response direction. Participants were faster to move in the same direction as the brushstrokes than in the opposite direction. Errors bars represent within-subjects standard error of the mean.

(M = 7.54 ms, SE = 2.62), the effect was significantly greater than 0, $t(17) = 2.88$, $p = .011$. Post hoc pairwise comparisons revealed that leftward responses were faster to leftward rather than rightward brushstrokes, $t(16) = 2.69$, $p = .016$. The reverse pattern did not emerge for rightward responses, $t(16) = -0.58$, $p = .568$. There was a main effect for direction of response movement, $F(1,16) = 12.83$, $p = .002$, $\eta_p^2 = .44$. Participants were faster to make arm movements across the body's midline.

Numerically speaking, the compatibility effect was greater when the painting was relevant to the task (as in Experiment 1) than when it was not (as in Experiment 2). However, when we ran a three-way ANOVA comparing experiment (1 vs. 2), direction of response movement, and direction of brushstroke movement, the three-way interaction failed to reach significance, $F(1,57) = 0.44$, $p = .511$, $\eta_p^2 = .01$. Furthermore, as shown in Experiment 5, we obtained a compatibility effect similar in numeric size to Experiment 1 using the same procedure as in Experiment 2. This suggests that the task-relevance of the painting does not impact these results.

Participants were significantly above chance in identifying the direction of brushstroke movement, $t(16) = 3.92$, $p = .001$ (M = 62%, SD = 12%, range = 39–85%). However, accuracy in identifying the direction of brushstroke movement was not correlated with the compatibility effect for response time for either a subject-based correlation, $r(17) = .28$, $p = .27$, or a painting-based correlation, $r(10) = -.26$, $p = .462$.

3.3. Discussion

These results replicate the effect in Experiment 1. Participants viewing paintings with left- or right-moving brushstrokes were faster to make concurrent movements in the same direction as the original movement of the artist, even though these brushstrokes were irrelevant to their task. The finding that this effect occurs even when the painting was irrelevant to the response suggests that the effect occurs automatically.

As in Experiment 1, participants were able to identify the direction of movement in the paintings with accuracy better than chance, so it is possible that this knowledge affected the response times. However, the lack of correlation between accuracy on this task and the compatibility effect from the speeded movement task indicates that the response times were not informed by awareness of the brushstrokes' direction. Indeed, conscious awareness of the brushstrokes' direction seems unnecessary to elicit the effect.

4. Experiment 3

The results of Experiments 1 and 2 show that observing brushstrokes, the traces of actions, interfered with concurrent opposing actions. We argued that the visual information in the brushstrokes that specified the gestural information enabled simulation of the observed action. However, the brushstrokes also contained asymmetric visual information that could have led to a purely visual effect. A canonical brushstroke begins with a heavy application of paint and thins as the painter draws the brush across the canvas. The result is a reliable, asymmetric pattern of a thick-to-thin paint gradient as the action progresses. This asymmetry in the stimuli raises the alternative explanation that the participants' responses were affected by the visual information rather than the recovered gestural information in the paintings. This could be caused by a left/right imbalance in saliency. Additionally, the asymmetrical pattern of the brushstrokes could have caused an impression of implied motion, as a thick-to-thin gradient resembles motion blur. Motion blur is a static cue that implies motion, usually depicted by a blurred region trailing the object (like a comet). Importantly, hypotheses based on asymmetries in visual saliency or motion blur would predict a pattern of results opposite to what we found in Experiments 1 and 2: We would expect that participants' movements would be faster in the same direction as the implied motion of the object (toward the thick end) rather than the implied action of the brushstroke (toward the thin end). However, we cannot be confident that a purely visual effect (due either to saliency or motion blur) should bias participants' actions differently than the gestural information of a brushstroke without first conducting an experiment where stimuli with visual asymmetries are presented without any gestural information.

We created a set of artificial brushstrokes that mimicked the visual properties of a typical brushstroke – heavy at one end and thin at the other – but were devoid of gestural information. We used these stimuli in the same design employed in Experiment 1. To preview the results, we found that participants who viewed these artificial brushstrokes responded faster to the heavy side of the image, which is the opposite pattern of results obtained in Experiment 1. This suggests that the results of Experiment 1 were not caused by visual asymmetries or implied motion of the brushstroke patterns.

4.1. Method

4.1.1. Participants

Twenty-three students (8 female) participated for course credit. They ranged in age from 18 to 23 years. All participants had normal or corrected-to-normal vision.

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4.1.2. Materials

A new set of stimuli was created for Experiment 3. These stimuli were designed to contain similar visuospatial asymmetries as the canonical brushstrokes, but without any gestural information. These stimuli were long, oblong shapes of a single colour with a saturation gradient from fully saturated to white along a horizontal axis (see Fig. 4). Like Experiment 1, each of the 10 images were duplicated into mirror images along the *y*-axis, and then duplicated again in green or red filters. The result is 40 unique stimuli that vary along two dimensions: colour and direction of "paint" gradient.

4.1.3. Procedure

The procedure for Experiment 3 was identical to the procedure used in Experiment 1, except that the 40 images described above were used instead.

4.2. Results

All trials above or below 2 standard deviations were removed (3.3%). All incorrect responses were discarded (<1%). The data entered into a 2 (direction of artificial movement) × 2 (direction of response movement) ANOVA with response time as the dependent variable. Results reveal a significant interaction between the two factors, $F(1,22) = 24.96$, $p < .001$, $\eta_p^2 = .53$, see Fig. 5. When expressed as a compatibility effect ($M = -33.14$, $SE = 7.51$), the effect was significantly less than 0, $t(22) = -4.41$, $p < .001$. Participants were faster to respond when the direction of their movement was towards the more visually salient, "heavy" end. Post hoc pairwise comparisons reveal that rightward responses were faster to leftward rather than rightward brushstrokes, $t(22) = -4.47$, $p < .001$. The reverse pattern emerged for leftward responses, $t(22) = 2.68$, $p = .014$. There was a main effect for direction of response movement, $F(1,22) = 8.12$, $p < .001$, $\eta_p^2 = .27$. Participants were faster to move left than they are to move right.

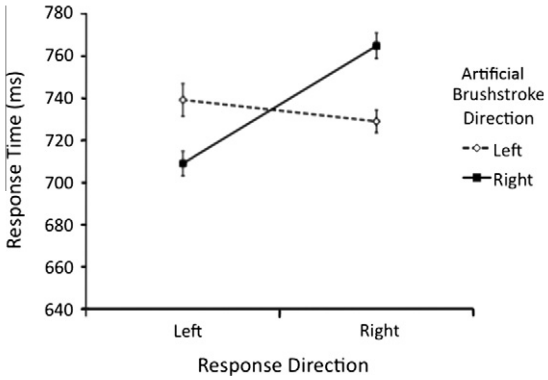

Fig. 5. Mean response times for Experiment 3 as a function of artificial brushstroke direction and response direction. Participants were faster to make movements in the opposite direction of the artificial brushstrokes. Note that this is the opposite pattern than that observed in Experiments 1 and 2. Error bars represent within-subjects standard error of the mean.

4.3. Discussion

Despite the visual similarities between the stimuli in Experiments 1 and 3, the stimuli elicited opposite patterns of results. Whereas participants were faster to move in the direction of the "tail" end of the stimuli in Experiment 1, they were faster to move in the direction of the "head" end of the stimuli in Experiment 3. The critical difference between the stimuli was that gestural information was present in Experiment 1 but not in Experiment 3. If visual and gestural information both influence the latency of a given response, and if they influence response times in opposite directions, as the results of the present experiment indicate, then the effect size found in Experiment 1 is perhaps an underestimate of the true size of the gestural effect. Critically, the result from Experiment 3 suggests that the result obtained in Experiment 1 was due to gestural information rather than to visual saliency or cues for object motion.

Importantly, the pattern of faster leftward responses was still observed in Experiment 3, even though the stimuli were different, and even though the interaction reversed.

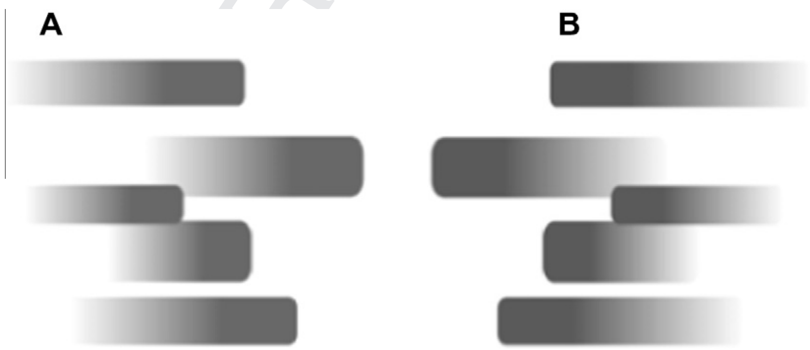

Fig. 4. Example stimuli for Experiment 3. These images were designed to be "artificial brushstrokes," that is, to contain the visuospatial asymmetries of the brushstrokes used in Experiment 1 without any of the gestural information. 10 unique sets of horizontally oblong objects were created. These stimuli had heavy density at one end, and progressively lighter density along the object's horizontal axis. If these objects were actual brushstrokes, the heavier density side would correspond to the beginning of the motion; (A) would be a leftward movement and (B) would be a rightward movement.

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This result suggests that the faster leftward responses are simply an artifact of the one-handed lateral responses. This explains the apparent lack of effect for rightward brushstrokes in Experiments 1 and 2, and supports the argument that a skewed, crossed interaction is the predicted result in those experiments.

5. Experiment 4

The stimuli in Experiment 3 were created to resemble the visual signature of actual brushstrokes without any gestural information. These stimuli evoked the opposite pattern of results as was found in Experiments 1 and 2. This suggests that visual properties of brushstrokes cannot account for the findings of Experiments 1 and 2. To further investigate the role of gestural information on these responses, we modified the original stimuli so that the gestural information was degraded. We created pointillist versions of our paintings, such that the overall patterns were the same, but the continuity of each brushstroke was disrupted. While this may not have eliminated the gestural information embedded in the brushstrokes entirely, as the global patterns of each brushstroke are still present, it should have at least degraded this information. We predicted that these stimuli with degraded gestural information should weaken or erase the compatibility effect between brushstroke direction and the direction of the response. Such a result would also suggest that the results from Experiments 1 and 2 are driven by the gestural information embedded in each brushstroke.

5.1. Method

5.1.1. Participants

Forty-one Purdue University students (16 female), aged 18–22 years, participated for course credit.

5.1.2. Materials

Using Photoshop, we applied a pointillism filter to the stimuli from Experiment 2. Thus, the paintings appeared to have been created by dabbing the paintbrush on the canvas instead of sweeping arm movements (see Fig. 6).

5.1.3. Procedure

The procedure was identical to Experiment 2 except that there was no action identification task after the speeded response task.

5.2. Results

All trials above or below two standard deviations from the group mean were removed (2.7%). All incorrect responses were discarded (<1%). There was an effect of direction of response movement, $F(1,39) = 7.47$, $p = .009$, $\eta_p^2 = .16$. Participants were faster to make leftward arm movements. There was no effect of brushstroke direction, $F(1,39) = 0.43$, $p = .520$, $\eta_p^2 = .01$. The interaction between brushstroke direction and response direction did not reach significance, $F(1,39) = 2.70$, $p = .110$, $\eta_p^2 = .06$ (see Fig. 7). When expressed as a compatibility effect ($M = 5.59$ ms, $SE = 3.40$), the effect was not significantly different than 0, $t(39) = 1.64$, $p = .108$.

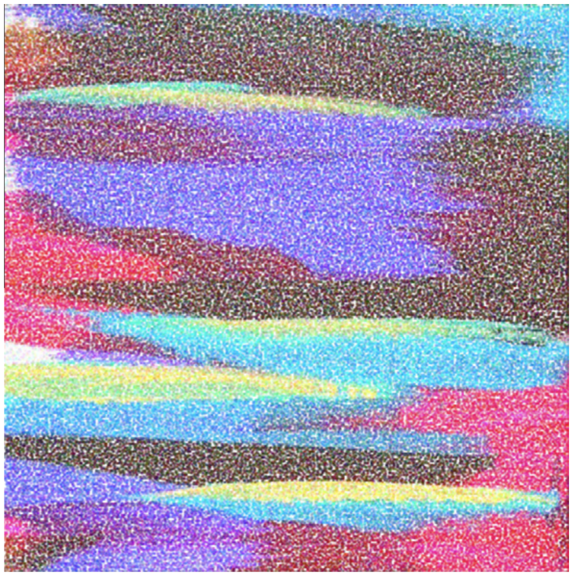

Fig. 6. Example stimulus for Experiment 4. Images of the paintings used in Experiments 1 and 2 were passed through a pointillism filter in Photoshop. The resultant images are paintings that appear to be created by dabbing rather than brushstrokes.

5.3. Discussion

In this experiment, the stimuli were altered such that the continuity of each brushstroke was broken into many tiny dots. We reasoned that this would degrade the gestural information available in the display. Consistent with our prediction, results showed that the compatibility effect failed to emerge. However, the effect was trending in the same direction as the effect described in Experiment 1. Indeed, a comparison of the compatibility effects in Experiments 1 and 4 revealed that they were not significantly different from one another, $t(80) = 1.19$, $p = .237$. This does

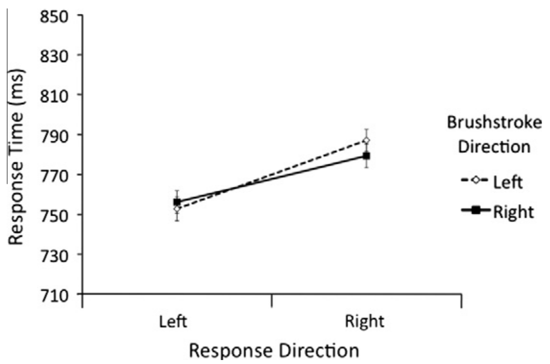

Fig. 7. Mean response times for the pointillist stimuli in Experiment 4 as a function of original brushstroke direction and response direction. A non-significant trend emerged to respond faster when moving in the same direction as the original brushstrokes. Errors bars represent within-subjects standard error of the mean.

not support the conclusion that the compatibility effect of 5.59 ms in Experiment 4 was demonstrably weaker than the compatibility effect of 13.89 ms in Experiment 1. However, cross-experiment comparisons should be interpreted with caution, and in this case, sufficient power might not have been achieved to obtain between-experiment comparisons.

While the intention of the pointillist paintings was to degrade the gestural information, the gestural information could possibly be obtained from a more global perspective of the paintings as the degradation only occurred at the more local level. The pointillist paintings led to reduced compatibility effect, at least numerically speaking, although the effect was still in the positive direction. Perhaps the positive trend and non-significantly different result from Experiment 1 was due to the retention of gestural information at the global level, and the reduced numeric effect that was not significantly different from 0 was due to the elimination of gestural information at the local level. However, without further testing, such claims are mostly speculative.

While converting the stimuli into the pointillist style appears to have influenced the gestural information embedded in the brushstrokes, it is possible that the new stimuli implied a different action altogether. Specifically, pointillist artworks are created with precise dabbing motions made perpendicular to the canvas. According to our theory, these stimuli might evoke simulations of such actions. In this case, however, the simulations are unlikely to interfere with the responses because the responses required movements parallel to the display.

6. Experiment 5

The evidence presented thus far is consistent with the idea that viewing a painting engages observers in a motor simulation of the artist's actions (Freedberg & Gallese, 2007). If observers are truly engaged in a motor simulation, then the reported compatibility effect in Experiments 1 and 2 should vary as a function of the similarity between the observed and executed actions. Conversely, these compatibility effects could be caused by stimulus–response (S–R) compatibility between the spatial distribution of the response and a spatial feature (such as "left") of the stimuli (Kornblum, Hasbroucq, & Osman, 1990). In this case, motor simulation would not be required to explain the results of Experiments 1 and 2.

In this final experiment, we examined whether our compatibility effects are due to motor simulation or to S–R mappings. Participants responded to stimuli using the same lateral movement as in the previous experiments or by making lateralized button presses for which there was no lateral movement. Both types of response are distributed in space across the left/right dimension, and both types of response are known to elicit S–R compatibility (for review, see Proctor & Vu, 2006), but only the lateral movement response involves a motion that is similar to those used to paint horizontal brushstrokes. If the button press responses also reveal a compatibility effect related to the paintings, this would suggest that the gestural information in the display activates a spatial code, and thus leads to S–R compatibility effects. In contrast, if the compatibility effect is apparent for lateral movements but not button presses, this would suggest that the paintings activate a motor simulation of the original action, rather than activating an S–R mapping.

6.1. Method

6.1.1. Participants

Twenty-nine students (13 female), aged 18–25 years, participated for course credit.

6.1.2. Materials

The same stimuli from Experiment 2 were used in Experiment 5.

6.1.3. Procedure

The procedure was identical to the procedure in Experiment 2, with an additional within-subjects factor of response type. The two response types were the lateral dominant arm movements described in previous experiments or a button press response on either the left or right side with the index finger of either the left or right hand, respectively. Response type was blocked, and order was randomized across participants. Participants completed 2 trials for each of10 painting stimuli in both directions (left and right) for both target stimuli (+ or *) in each block (lateral movements and button-press) for a total of 160 trials.

Following the speeded task, participants identified the direction of brushstroke movement in the paintings. The procedure was identical to Experiment 2, except that participants could only view the stimuli for 1600 ms. While viewing time was limited, response time was not. Whereas participants previously had unlimited viewing time, we were interested in whether participants could identify the direction of brushstroke movement in a viewing window equal to what they might see during the speeded response task. The duration of 1600 ms was chosen because it is approximately equal to the mean visible duration of the painting stimuli during the speeded response task of Experiment 2 (mean time from painting onset until final response). If participants were unable to identify the direction of brushstroke movement in a period of time equal to what they experienced during the speeded response task, then knowledge of this movement could not inform the compatibility effect between the response movement and brushstroke movement in the speeded response task.

6.2. Results

We first analyzed lateral movement responses to ensure that we replicated previous findings. All trials above or below two standard deviations from the group mean were removed (3.8%). All incorrect responses were discarded (<1%). There was an effect for the duration of painting presentation before stimulus onset (750 ms vs. 1000 ms), $F(1,16) = 6.07$, $p = .025$, $\eta_p^2 = .27$. However, duration never interacted with brushstroke direction, movement direction, or the interaction between them, $ps > .05$. Given these

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results, all subsequent analyses do not include this variable. A 2 (brushstroke direction) × 2 (response direction) ANOVA with response time as the dependent variable revealed a significant interaction between the two factors, $F(1,28) = 7.28$, $p = .012$, $\eta_p^2 = .21$, see Fig. 8. This compatibility effect ($M = 11.91$ ms, $SE = 4.41$) was significantly greater than 0, $t(28) = 2.70$, $p = .012$. Participants were faster to respond when the direction of their movement was in the same direction as the movement in the brushstrokes. Post hoc pairwise comparisons reveal that leftward responses are faster to leftward rather than rightward brushstrokes, $t(28) = 2.58$, $p = .015$. The reverse pattern emerged for rightward responses, although the effect was not pronounced, $t(28) = -1.39$, $p = .176$. Again, there was a main effect for direction of response movement, $F(1,28) = 13.07$, $p < .001$, $\eta_p^2 = .32$. This is the same pattern displayed in previous experiments.

For the button-press responses, all trials above or below two standard deviations from the mean were removed (2.2%). All incorrect responses were also discarded (<6%). Two participants were removed from this analysis because they responded with less than 50% accuracy on this task. There was an effect for the duration of painting presentation before stimulus onset (750 ms vs. 1000 ms), $F(1,29) = 19.39$, $p < .001$, $\eta_p^2 = .41$. However, duration never interacted with brushstroke direction, response side, or the interaction between them, $ps > .05$. Given these results, all subsequent analyses do not include this variable. A 2 (brushstroke direction) × 2 (response side) ANOVA with response time as the dependent variable revealed no interaction between the two factors, $F(1,26) = .11$, $p = .740$, $\eta_p^2 = .004$, see Fig. 8. This compatibility effect ($M = 1.82$ ms, $SE = 5.51$) was not significantly different from 0, $t(26) = .33$, $p = .740$, indicating that there was no difference between the compatible and incompatible trials when making button press responses.

Participants were above chance in identifying brushstroke direction, $t(29) = 3.99$, $p < .001$ ($M = 60\%$, $SD = 14\%$, range = 25–80%). However, accuracy in identifying the direction of brushstroke movement was not correlated with compatibility effect size in the lateral movement response task for either a subject-based, $r(29) = -.02$, $p = .940$, or a painting-based correlation, $r(10) = .03$, $p = .927$, nor was it correlated with the compatibility effect size in the button-press task for either a subject-based, $r(29) = .29$, $p = .140$, or a painting-based correlation, $r(10) = -.29$, $p = .415$.

6.3. Discussion

The influence of brushstroke direction on observers' movements depended on the type of response being made. Brushstroke direction affected responses when the motion was similar to the actions that generated the paintings – as in the case of the lateral movements. However, when the response was a button-press on the left or right side, a compatibility effect was not observed. If the effect had been due to visuospatial S–R mappings, there should have been a compatibility effect in the button-press response condition, where "leftness" and "rightness" were preserved. Instead, the results suggest that the paintings elicited simulations of the original movements.

The critical manipulation was whether or not the response set contained a movement that mimicked painting actions. The results are consistent with the idea that the brushstrokes elicited a motor simulation of the original painting movements. However, the manipulation of response set was confounded with the number of hands used to respond. However, had the compatibility effect observed here been an instance of a standard S–R compatibility effect, the number of hands should not have changed the effect. It is well established that effects of spatial S–R compatibility emerge with button-presses made by the left and right hands as well as with responses made with just the right hand (Proctor & Vu, 2006). Had the paintings denoted the spatial feature of 'leftness' or 'rightness', the results should have emerged even with the button-press responses.

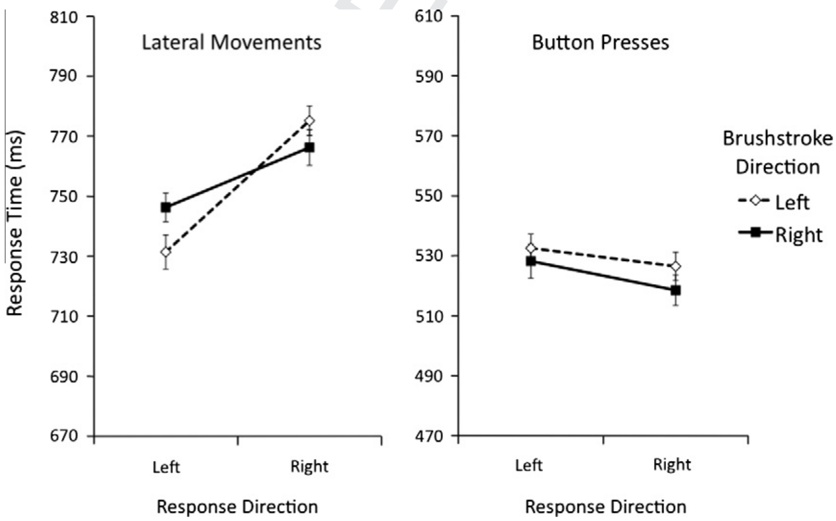

Fig. 8. Mean response times for Experiment 5 as a function of responding with lateral movements (left) or button presses (right). With making lateral movements, participants were faster to respond in the same direction as the brushstrokes. When pressing buttons, no compatibility effect was observed. Errors bars represent within-subjects standard error of the mean.

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Therefore, although the number of hands differed between the two response types, this difference is unlikely to account for our effects.

Another potential confound between the two types of responses is that participants were much faster to make button-press responses than lateral movement responses. Thus, it is possible that participants' responses were too fast for the paintings to exert their influence on the responses. However, the results from Experiment 1 speak against this possibility. In Experiment 1, participants responded as soon as the painting was present, and the mean duration of viewing time prior to their response was 807 ms. This was much shorter than the mean duration of viewing time in the button-press response condition of the current experiment, which was approximately 1401 ms. Thus, even with viewing durations of less than one second, compatibility effects emerged. The speed for which these effects occurred in Experiment 1 discounts the possibility that there was not enough time for the paintings to cause a compatibility effect when making button-press responses.

Therefore, despite other differences between the two types of responses, the critical difference is likely that the lateral movements coincided with the original movements used to create the paintings, resulting in a compatibility effect, whereas the button-press movements did not. Although the lateral movements were not identical to actual brushstroke motions, they were similar enough to elicit the compatibility effect. Theoretically, a more brushstroke-like response – perhaps with a stylus – might elicit stronger compatibility between the observed and executed movements.

The results of the current study also eliminate the possibility that the observed effect is caused by compatibility between the spatial distribution of the response and implied motion, rather than implied action. Because the brushstrokes appear to "trail off", they may imply motion in one direction or another, despite being static. However, although moving stimuli evoke compatibility effects with lateralized moving responses (Michaels, 1988), these stimuli also show the same effects for stationary button-presses (Proctor, Van Zandt, Lu, & Weeks, 1993). Static stimuli that imply motion, such as arrowheads, also show the same compatibility effect with button press responses (Proctor et al., 1993). Therefore, if the brushstrokes had implied motion in a similar way as objects, they should have evoked the compatibility effect in the button press condition. Instead, the specificity of the compatibility effect to movements that are like painting actions suggests a different kind of compatibility effect.

When participants were asked to identify the direction of the brushstrokes, performance was above chance, although performance was still poor. The results obtained here confirm the results obtained in Experiments 1 and 2. Interestingly, participants were still able to perform this task just as well with a limited viewing time. Whatever process informed their judgments did not improve performance after 1600 ms. As before, there was still no correlation between accuracy on this task and compatibility effect size in the speeded response task, confirming the notion that these effects are mediated by independent processes.

7. General discussion

The present results suggest that art is not perceived independently of the actions that created it. Observers automatically simulated the actions implied by a painting's brushstrokes, revealing a connection between the artist and audience never before demonstrated by cognitive science. This result confirms the action painters' anecdotal insight that action is expressed through painting. It is remarkable because it implies a new aspect of the cognitive processing of abstract, gestural art. These processes can no longer be limited to strictly visual patterns on the canvas; instead, we have shown that an artist can resonate with her audience via her action. Consequently, attempts to understand the cognitive processing of gestural art should include the science of action observation.

In these experiments, participants made movements to left or right locations from a central position in response to the colour of the painting or an arbitrary target. The task-irrelevant feature was the gestural information embedded in the brushstrokes. Even though these brushstrokes were irrelevant to the participants' task, responses were slower when they were incompatible with the movements that created the brushstrokes. We attribute this effect to competition between motor programs of the observed movements (brushstrokes) and executed movements (responses).

These findings are the first empirical evidence for Freedberg and Gallese's (2007) framework for the role of simulation in the aesthetics of visual art. The artist's actions were implicitly processed by the observers. We have interpreted this as evidence that observers simulated the artist's actions. Future studies are needed to further evaluate Freedberg and Gallese's claims that this simulation influences the aesthetic experience. According to their theory, simulating action establishes an empathic link, accessing the emotions associated with expressive actions. This intimate connection could account for the profound emotion conveyed by simple, yet dramatic strokes of paint. Simulation occurs involuntarily, so observers may be immediately and perhaps invasively confronted by the feelings artists portray. Future research will have to examine these ideas directly. Here, we have validated the possibility of their candidate mechanism in the observation of art. This is an important step in supporting the theory that motor simulation can play a role in aesthetic experience of visual art.

Further support for the involvement of motor simulation was provided by testing and ruling out alternative explanations. One alternative was that these compatibility effects were driven by visual properties – rather than gestural properties – of the stimuli. However, when we used stimuli devoid of gestural information, we found the opposite pattern of results. In addition, when gestural information was degraded, the compatibility effect failed to emerge (although we temper this interpretation with a reminder that the effect in Experiment 4 was not significantly smaller than in Experiment 1). Thus, visual features of the stimuli cannot account for our results.

Another alternative was that the gestural information might have specified a spatial feature such as "left" or "right" without evoking a motor simulation of a leftward or rightward movement. However, when participants made handed button-press responses, which typically evoke spatial compatibility effects, we did not observe compatibility effects related to the movement of the brushstrokes. This demonstrates that our compatibility effect is specific to responses that involve lateral movements, presumably because of the involvement of a motor simulation of the original painting movements.

Participants were also asked to identify the direction of the brushstrokes. Because motor simulation is thought to be an involuntary, covert process, recognition of the brushstrokes' movement should not be necessary to perform a given simulation. Participants consistently identified the brushstrokes' movement above chance, indicating that participants had some knowledge of the artists' actions. However, the size of the compatibility effect was unrelated to identification of brushstroke direction in all of the experiments, for both subject-based and painting-based analyses. Given that recognition of the brushstrokes' direction never correlated with the compatibility effect, we conclude that simulation and identification of the movement in these brushstrokes are mediated by separate processes.

7.1. Conclusions

All painting is the result of action. Fittingly, art is not processed independently of those actions that created it. While the framework proposed by Freedberg and Gallese (2007) was supported by literature in related domains, these experiments are the first to provide evidence that the mere viewing of paintings engages the observers' motor system. Motor simulations give artists the ability to reach out to their audience across great distances and even generations via paint and canvas. This emphasis on the role of action in abstract art is longstanding wisdom within artistic circles – the evidence presented here resonates with the philosophical approach to art the action painters have espoused for decades.

8. Uncited reference

Q5 Freedberg and Gallese (1997).

Acknowledgments

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