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Viewing Images of Jagged Texture in Digital Artwork Affects Body Sensations: A Virtual Reality Study

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One of the topics recurring in contemporary aesthetics is haptic visuality—a sense of physical touching, or being touched, induced by exposure to a purely visual stimulus. In this study we attempt at an empirical evaluation of this elusive concept, and specifically address the role of visual texture in inducing bodily sensations. We carried out a virtual reality experiment in which 144 participants could see their virtual hands and use them for interaction. Inside the virtual reality experience, the participants viewed four contemporary art images that were preselected as fostering haptic visuality. After viewing each image, the participants immediately performed a simple motor task and answered a few questions. The motor task comprised picking a virtual ball and placing it in a designated place, and in half of the cases their virtual arm was threatened by a virtual chainsaw. Our main hypothesis was supported—art stimuli depicting a jagged object reduced the perceived threat to the virtual arm, indicating a decrease in ownership of the virtual body. Interactions with body awareness as trait were also revealed.

Keywords: haptic visuality, rubber hand illusion (RHI), art, Ori Gersht, virtual body ownership

Surfaces, textures, and touch have become foci of interest in contemporary aesthetics, and skin, both as a material medium and as a motif, is ubiquitously present in art installations in a variety of media (Aldouby, in press; Benthien, 2002; Flanagan & Booth, 2009; Hansen, 2010; Rosenthal & Vanderbeke, 2015). Additionally, we witness a growing desire by artists and art audiences to generate and experience as-if tactile, embodied engagements with art objects (Bruno, 2014; Szymanek, 2020; Vi et al., 2017; Wegenstein, 2006).

However, little is known whether visual texture in artworks affects the viewer's bodily sensations in practice, and how. The present study aims to fill this gap by investigating the effect of an image of a jagged object in an artwork on participants' body awareness. Our study is premised on the assumption that suggestively rough or abrasive visual surfaces and objects in an artwork may play a key role in fostering bodily arousal in viewers, consequentially elevating their awareness of their own physical body. It is doubly interesting to test this hypothesis with regard to digital photography. Bruno (2014, p. 2) has proposed that "a reinvention of materiality in our times . . . is visibly and actively pursued in the arts." In other words, the growing trend of "body discourses" (Wegenstein, 2006), and the emphasis on surfaces and textures in contemporary art and visual culture (Bruno, 2014), reflect the overwhelming sense of disembodiment and fragmentation of the body at the turn of the millennium. Here, we opted to investigate one strategy that contemporary art might be deploying in its quest for stronger embodied engagement with immaterial digital images.

In the last two decades, phenomenological theorists of screen-based art (Barker, 2009; Marks, 2002; Sobchack, 2004) have put forth a concept of *haptic visuality*, which involves "thinking with your skin" (Marks, 2002, p. 18). Marks defines haptic perception as "the combination of tactile, kinesthetic and proprioceptive functions" (p. 2). Both Marks (2002) and Barker (2009) regard rough texture as a key component driving haptic visuality and arousing haptic perception, in that texture draws viewers' attention to surfaces rather than entire images, compelling the gaze to scan textures with a "caressing look" (Marks, 2002, p. 8), as if manually palpating them. More recently, Gallese and Guerra (2019) reviewed haptic visuality from a cognitive neuroscience perspective, proposing that it is possible to hypothesize as-if tactile engagement between image and viewer. This is consistent with several studies focusing on participants' significant preference of smoothly curved shapes and objects, and aversion from, or dislike of angular shapes, associated with unpleasant sensations and negative emotions (Bar & Neta, 2006, 2007; Bertamini & Sinico, 2021; Blazhenkova & Kumar, 2018; Sinico et al., 2021; Vartanian et al., 2019). This effect has been explained as stemming from viewers' implicit perception of sharp elements as conveying potential threat (Bar and Neta, 2007).

Nevertheless, the workings of haptic visuality in art have been very scarcely investigated in empirical studies. In particular, the possible effect of visual texture and jagged objects in art images on participants' body sensations calls for investigation. If, as Zeki (2002;

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p. 918) proclaimed, "visual artists are, in a sense, neurobiologists of vision," it should be of interest to decipher their (probably intuitive) deployment of texture as a conduit to haptic arousal. Such arousal, we hypothesize, would lead to feeling physically embodied, or being present in one's skin, as it were. This study thus investigated one of art's routes to the sense of bodily awareness.

The phenomenological concept of aesthetic experience (Johnson, 1993) implies multisensory engagement between artwork and viewer, regardless of whether physical stimulation occurs. In this view, aesthetic experience builds on sensory anticipations—whether the object of potential contact is materially available or only suggestively present. *Aisthêsis*, the etymological source of the concept of aesthetics, involves "the experience of the possible, [. . .] a consciousness in the mode of the as if" (Brudzińska, 2010, p. 11). Here, it is useful to recall Damasio's (2010, pp. 102–103) "as-if body loops," through which "the brain can *simulate*, within somatosensory regions, certain body states, *as if* they were occurring."

Based on these previous works, we hypothesized that anticipation of contact with suggestively textured art images (such as the shards of a broken cup) might enhance participants' awareness of their body. The artist Ori Gersht, whose works were selected as stimuli for this study, represents a wider trend of textural or haptic emphasis in early 21st century art (Aldouby, 2019; Bruno, 2014; Marks, 2002). Gersht's digital photography and video installations strongly emphasize texture and surface, through which he seeks to invest his digital art with a suggestion of materiality. For example, in the video *The Offering* (2011), the screen is filled with close up shots of deeply scarred wooden surfaces (Figure 1a). In the video triptych *On Reflection* (2014), several shots focus on the jagged surface of a fractured mirror, that was blown-up by explosion (Figure 1b; for an extensive analysis of this video installation, see Aldouby, 2019).

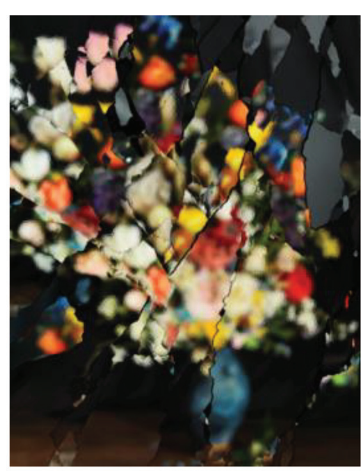
In Gersht's art, materiality and texture are foregrounded and privileged over narrative clarity (Aldouby, 2019). In Marks's (2002, p. 132) terms, Gersht could be "pushing texture out to meet the viewer," and thus calling on palpation to substitute for seeing. *New Orders* (2018), by Gersht, is a digital photographic series emulating an oil painting by the seventeenth-century Spanish artist Francisco de Zurbarán: *A Cup of Water and a Rose* (ca. 1630). Gersht produced physical replicas of Zurbarán's cup and saucer especially for the photographic setup, and then fractured the cup by gunshot (see Figure 2). The event, which transpired in a split second, was captured in an extremely high frame rate, so as to reveal invisible increments of the occurrence that cannot be perceived by the naked eye. These liminal moments lie between the real and the virtual, rendering visible increments of time on the verge of total collapse, when the fragmented cup still impossibly holds the body of water.

Our pivotal research question focused on the strong material suggestiveness of these images, particularly the cracks and sharp slivers of broken cup, whether these might augment viewers' haptic sensation and consequently their sense of inhabiting a physical body in space, or in other words the sense of embodiment. Here, we rely on Gumbrecht's (2004) phenomenological theory of aesthetics, premised on a conception of aesthetic experience in terms of bodily intensity. *Presence effect*, in Gumbrecht's terms, implies a state of bottom-up processing of sensory input, activating "a layer in our existence that simply wants the things of the world close to our skin" (Gumbrecht, 2004, p. 106). *Presence effect* thus has to do with heightened sensory arousal. In discussion with the artist Ori Gersht, his interest in this effect has come up very strongly (Calbi et al., 2019). Furthermore, the artist was fully involved in the present study, and articulated his desire to endow digital art with a physical body, as it were, to which he referred as "fetishization" of the image (Calbi et al., 2019).

Among other examples of contemporary art's emphasis on texture, one might consider the work of South African artist Mohau Modisakeng, who resorts to coal, melted asphalt, and bare skin, in a postapartheid investigation of Blackness in postcolonial Africa. The

Figure 1
Ori Gersht Works


a


b

Note. (a) *The Offering* (2011), still from triple channel video. (b) *On Reflection* (2014), still from triple channel video. Images courtesy of Ori Gersht. Copyright by Ori Gersht. All rights reserved, Design and Artists Copyright Society 2022. Reprinted with permission. See the online article for the color version of this figure.

Figure 2
Ori Gersht, From the Series New Orders (2018)

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installation *Lefa la Ntate* (My Father's Legacy, 2016; Figure 3), for example, includes a photographic series in which the artist's face and hands are barely emerging from under a surface of coal lumps in an explicit hint at burial, invoking South Africa's traumatic history—at the intersection of an extensive mining industry entangled with crimes of racial discrimination (Modisakeng, 15 September, 2020). The haptic suggestiveness of Modisakeng's photographs builds strongly on the meeting of coarse coal lumps with black skin, arousing tactile sensations. In an interview, the artist indicated that his large-scale prints are indeed meant to foster full-body engagement of precisely this type (Modisakeng, 10 September, 2020).

Figure 3
Mohau Modisakeng, Lefa 5 (2016)

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Yet another example of this trend, though stylistically different, is Israeli artist Ronen Sharabani's recurrent use of sand tables, which he manipulates digitally toward different textural effects. On the resultant postapocalyptic wastelands, Sharabani superimposes ghost landscapes created by means of virtual simulation (Figure 4; Aldouby, 2020). Textural emphasis and haptic suggestiveness endow Sharabani's digital prints with the sensually "transactive" nature that art historian Jill Bennett (2011) has attributed to trauma-related art. Bruno (2014) discusses several more examples from contemporary art, whether in architecture, painting, or video installations, in which emphasis is put on surfaces and textures. In turn, Aldouby (in press) reviews a trend of skin-related art, in which artists deploy various skin-like materials as an aesthetic means of arousing viewers' haptic perception.

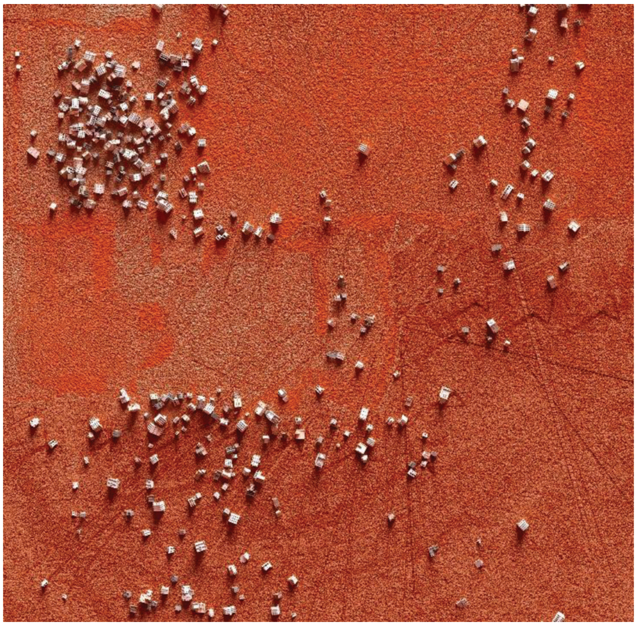
Empirical Background and Operationalization of Haptic Visuality

The current study was designed to explore the concept of "haptic visuality" empirically; specifically, whether digital-born visual art with emphasized visual texture, such as jagged shards, affects our awareness of our own body.

First, we show that this assumption is consistent with evidence from neuroscience. Next, we present our operationalization of this question in the context of an empirical study, using virtual reality (VR).

A simplistic view of brain organization is that each sense is associated with a specific cortical region, which implies that visual art should only activate the visual cortex, whereas tactile stimuli would only be processed in somatosensory regions. In fact, many subsystems in the brain perform multisensory integration, and these are also involved in top-down processes. It is not unlikely that some cortical region that is considered sensory is activated by internal input from other brain regions, rather than by external sensory stimulation. Most sensory areas are organized in hierarchy from bottom (close to the sensory organ) to the top (so-called high-level sensory processing), and other than very low-level areas there is ample evidence of processing in 'sensory' areas that were not induced by direct external sensory input (e.g., Harmelech et al., 2015). In fact, although much more controversial, it has been shown that even V1, an area assumed to be involved explicitly in low-level visual processing, can be modulated by high level

Figure 4
Ronen Sharabani, Virtual Territories #2 (2019)



Note. Images courtesy of Ronen Sharabani. Copyright by Ronen Sharabani. All rights reserved. Reprinted with permission. See the online article for the color version of this figure.

processes (Shibata et al., 2011). Moreover, some even challenge the existence of 'sensory' brain regions, suggesting that the organization is task-related (Heimler et al., 2015). In cognitive science, this has long been studied under the framework of affordances (Gibson, 1977; Greeno, 1994), stressing that the agent is situated in the environment, and perception is a process of interacting with the environment. Thus, each object in the environment is primarily perceived in terms of what can be done with it (or what it can do to the organism), which is consistent with "haptic visuality." Thus, it is not surprising that merely watching a visual stimulus, such as a painting, photograph, or video, can result in cognitive processing of touch, or in the activation of brain regions typically involved in haptic or somatic tasks.

Gallese and collaborators have studied these neural responses to haptic artistic stimuli, empirically. Specifically, studies from this group demonstrated premotor cortical activity in response to traces of brush movements in abstract paintings by Franz Kline (Sbriscia-Fioretti et al., 2013), or in response to knife-slashed canvases by Lucio Fontana (Umiltá et al., 2012). There are two important differences between these studies and the current study. First, those studies were designed in the context of embodied simulation theory (Gallese, 2005), suggesting that body awareness, or brain-related tactile processing, are a result of action observation, or in these cases implied action observation—even though no actor is visible, the brush strokes and knife slashes imply motion by others, which activates the viewer's body through embodied simulation. In contrast, our study adopts a broader approach, based on the notion of affordances (Gibson, 1977; Greeno, 1994), that is, we do not assume that visual art activating the body necessitates a social process. In our case the stimulus is a broken cup; it is not likely that this triggers processing of the action of breaking a cup, but rather it triggers processing of the unique tactile properties of the broken cup. The second difference is that we focus on texture rather than on motor actions, that is, we suggest that the activation of body awareness is attributable to prediction of abrasive contact with the jagged texture.

Indeed, other studies indicate that visual induction of sense of touch (and related brain activation) does not require action observation, that is, that the affordance of touching or being hurt by an object is enough, and that texture plays a central role. Sun et al. (2016) have shown in an fMRI study that observing and processing visual texture involves a visual-somatosensory cross-modal network. Furthermore, they found different patterns of somatosensory activation between responses to rough and smooth textures, explained as predicting the different potential outcomes of contact with these textures. Similar responses to images of sharp or spikey objects, in somatosensory cortical areas, have been shown by Smith and Goodale (2015), and Morrison et al. (2013). This is consistent with several studies focusing on the significant preference of smoothly curved shapes and objects, and aversion from, or dislike of angular shapes, which are associated with unpleasant sensations and negative emotions (Bar & Neta, 2006, 2007; Bertamini & Sinico, 2021; Blazhenkova & Kumar, 2018; Sinico et al., 2021; Vartanian et al., 2019). This effect has been explained as stemming from viewers' implicit perception of sharp elements as conveying potential threat (Bar & Neta, 2007).

The general research question underlying the present study is whether the image of broken shards and cracked surface might also affect viewers' awareness of their body, indicating that such artistic stimuli can indeed serve as an antidote to "disembodiment." We approach this question utilizing the experimental paradigm of the rubber hand illusion (RHI; Botvinick & Cohen, 1998), adapted to VR (Sanchez-Vives et al., 2010; Slater et al., 2008).

In Botvinick and Cohen's (1998) seminal experiment, participants watched an experimenter stroke a rubber hand that was placed on a table next to their own left hand. The real hand, resting behind a screen and thus hidden from view, was stimulated in synchrony with the rubber hand. In this condition, participants' sense of body ownership was extended to the artificial limb.

Interoceptive body awareness has also been studied as a trait, and the multidimensional assessment of interoceptive awareness (MAIA) has been developed and validated (Mehling et al., 2012), and later refined (Mehling et al., 2018). The main motivation for its development was the growing recognition that interoception plays an important part in mental health, but it has been deployed in various fields, including the study of the rubber arm illusion (e.g., Xu et al., 2018).

The RHI has been adapted to VR, which allows systematically exploring a variety of parameters, as well as illusions extending beyond a single hand. This has led to the study of virtual body ownership—what exactly contributes to the illusion that the virtual body is one's own body, and to what extent? For example, while the original RHI allowed for testing visuotactile illusions, VR allows for a virtual arm (or whole body) that moves in synchrony with your own movements, and it turns out that such visuomotor illusions are stronger in generating body ownership illusion.

Our working assumption was that the conflict between the real and the virtual body may work both ways. In other words, the typical framework shows how the virtual body illusion can come at the expense of the information you have about your real body; for example, in the RHI the rubber arm reduces your awareness of where your real arm is. However, we suggest that this also goes the other way, that is, if one is more aware of one's real body, they might be less susceptible to the RHI. Although this has not been tested directly, evidence for such tradeoff emerges from previous studies. For example, Kállai et al. (2015) report that individuals high on harm avoidance report lower RHI than individuals high on novelty seeking. Individuals with high motor abilities, such as professional pianists (Pyasik et al., 2019) as well as expert meditators (Xu et al., 2018) report a much reduced RHI, whereas neural damage attributable to stroke and lesion increases the reported ownership of the rubber arm (van Stralen et al., 2013), and the same is observed in individuals with body image problems (Mussap & Salton, 2006).

As elaborated in the section that follows, our hypothesis was that jagged textured visual stimuli, such as described above, would increase participants' awareness of their physical body, and that this would lead to reduced susceptibility to the RHI, resulting in a decrease in the degree of ownership over the virtual arm. In other words, we predicted that the strongly suggestive texture would elicit anticipation of skin contact with the cracked and potentially abrasive object, and consequently increase body awareness. We further expected that this would weaken the participants' illusion of ownership over the virtual arm and thus reduce their perception of threat to the virtual arm, posed by a rotating chainsaw.

Hypotheses

Our main hypothesis was that watching art images depicting jagged objects or surfaces would lead to an increase in awareness of the physical body, due to arousal related to anticipation of abrasive or otherwise harmful or unpleasant contact. This hypothesis is in accord with Bar and Neta (2007), who argued for "an elevated level of arousal in the presence of sharp-angled features . . . that stems from an implicit association of these sharp features with threat and danger" (Bar & Neta, 2007, p. 2191). In our study, this led to two specific hypotheses:

H1: Exposure to a jagged (visual) object would lead to higher reported state body awareness; and H2: Exposure to a jagged (visual) object would lead to lower reported perceived threat from a virtual chainsaw. H1 is based on explicit self-report, which is limited in such contexts. Thus, the experiment was designed to include a more indirect measurement, inspired by the RHI paradigm. The rationale behind H2 is that the increase in awareness of the physical body attributable to haptic sensations induced by viewing the jagged object would weaken the illusion of ownership over the virtual body (or specifically, over the virtual hand). Furthermore, a decrease in the illusion of ownership of the virtual hand would in turn lead to a decrease in the sensation of threat to that hand. In other words, in our paradigm the virtual arm ownership illusion serves as a surrogate for measuring awareness of the virtual body, as a state, implicitly. In addition, we hypothesized that individual differences in trait body awareness would influence the level of state body awareness, and we thus used the MAIA scores as a covariate.

Method

The study followed a 2 × 2 within-subject design, with the two variables: Texture (jagged vs. smooth) and Drift (a deliberate displacement of the virtual hand). The drift was introduced as an exploratory variable; since it did not yield any results and did not interact with texture it is not further discussed.

Participants

The study included 144 undergraduate students (114 women, 30 men, four unspecified) between the ages of 18 to 45 years (M = 22.74, SD = 2.75). A power analysis using G*Power software (Faul et al., 2009) revealed that an estimated sample size of N = 138 is required to detect a small effect and we have included a few more in case some participants would need to be removed due to technical difficulties, which was not the case. Participants took part in the study in exchange for credits and gave written informed consent. All participants were right-handed and had normal or corrected to normal vision. The required sample size was estimated a priori using G*Power 3.1 (Faul et al., 2009) for repeated-measures ANOVA with within-subject factors. The power analysis revealed a required sample size of N = 138 to detect a small effect (f = .1), assuming an α error probability of .05 and power of .80. The study received ethics approval from the local institutional review board.

Material

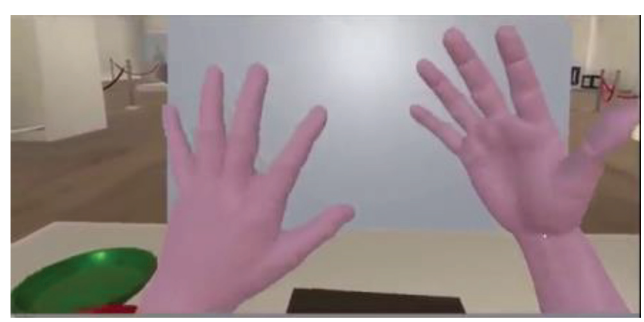
Apparatus

During the experiment, participants were immersed in a virtual environment using an HTC VIVE (HTC, Taiwan) VR headset with a Leap Motion (Leap motion, CA) hand-tracking device, such that the participants could see their virtual hand (e.g., Figure 5). The VR experience was developed using Unity and driven by a Windows PC with a GTX 1080 graphical processing unit, which ensured a constant 75Hz.

Art Stimuli

We selected four images from the series *New Orders* (2018) by Ori Gersht as stimuli, based on their excessive material and textural suggestiveness. These images were chosen as representative of the emphasis on suggestively rough surfaces and jagged objects, which we highlighted above as a trend in digital art-photography and video. We regarded the cracked and broken cup as especially compelling, and its jagged surfaces as most pronounced, thus best suited to examine the effect of viewing jagged objects in an artwork on the viewer's bodily sensations. Moreover, comparison with an image of a nonbroken cup was possible; the series *New*

Figure 5
A Snapshot of the Virtual Hands as Seen by the Participant



Note. See the online article for the color version of this figure.

Orders encompasses different stages of a cup breaking event, beginning with the intact cup, used here as a control image (Figure 6B). The second control image was a reproduction of the original painting by Zurbarán, which the photographic series emulates. The images from *New Orders* were optimally suited for testing our hypothesis, based on the combination of jagged and potentially harmful surface (Morrison et al., 2013; Sun et al., 2016), the cup as a broken/nonbroken familiar graspable object (Smith & Goodale, 2015), and the artist's aesthetic concerns with the materiality of digital images (Aldouby, 2019).

VR Environment and Hands Embodiment

The VR environment depicted a virtual art gallery. The participants were standing and their hands were tracked, such that they could see realistic virtual hands move with their own hands inside the VR field of view. The scenario included four repetitions of a pick and place task.

Pick and Place Task

In this task participants were asked to Use their virtual hand to pick up a virtual ball and move it from one side to another, first passing over a stack of books, then passing over a loud rotating chainsaw, suggesting potential danger to the virtual hand (see Figure 7).

Procedure

On arrival in the laboratory, participants read and signed an informed consent form and were briefed about the VR equipment. After placing the VR headset, all instructions were given in a standardized way by a (female) voice within the virtual environment. In an initial adaptation phase, participants were instructed to look at their virtual hands and move them to familiarize themselves with their virtual hand representation. Participants had three practice sessions of a pick-and-place task to get used to the hand control and the VR. The experiment then proceeded in four repeated blocks, each starting by viewing an art stimulus, performing the pick and place task, and answering several questions that were presented within the VR environment. The questions were displayed on a floating panel in the virtual "air," and the participants was required to select the relevant answer using their virtual hand (see Figure 8). The Likert-scale questions were presented on the panel in the VR and the participants answered by pointing with their fingers ("pushing" virtual buttons). Each participant saw one of the broken and one of the nonbroken cups (in randomized order), such that each picture was presented twice in randomized order. The time for viewing the artistic stimulus was 40 seconds in its first appearance and 15 seconds on the next three repetitions.

After removing the VR headset, participants completed the demographic and trait body awareness questionnaires.

Measurements

State body awareness was measured using a three-item variable rated on a six-point scale; 6 indicating full agreement with the statement. The items were: (a) *When I was observing the picture, I could almost feel touch*; (b) *When I was observing the picture, I felt sensations on my skin*; and (c) *When I was observing the picture, I became aware of the weight of my body*. The three items showed high overall internal consistency (across all conditions): Cronbach's α = .89. Perceived threat was measured using a single item: *For a moment I thought my real hand might be hurt by the chainsaw*, rated on a 6-point scale, with 6 indicating full agreement with the statement.

Participants' interoceptive awareness was assessed in the end of the experiment using the Multidimensional Assessment of Interoceptive Awareness (MAIA) questionnaire (Mehling et al., 2018). MAIA is a 32-item self-report questionnaire that measures eight facets of interoceptive body awareness: (a) noticing, (b) not distracting, (c) not worrying, (d) attention regulation, (e) emotional awareness, (f) self-regulation, (g) body listening, and (h) trusting. In the present study we used the overall score calculated by averaging the items of the MAIA questionnaire. It has been first published in 2012, and a modified version was suggested in 2018 based on feedback from multiple studies. The 32 items show a high level of internal consistency (Cronbach's α = .89).

Results

State Body Awareness

A Repeated Measures ANOVA was used to test main effect of Texture (jagged vs. smooth) on state body awareness. H1 was not supported: no statistically significant differences were found between the jagged texture images (M = 2.78, SD = *1.12*) and the smooth texture images (M = 2.78, SD = *1.14*) regarding the

Figure 6

The Images Used in the Study, From Ori Gersht' New Orders Series

Note. (A) Visual stimuli for jagged texture. (B) Visual stimuli for smooth texture. The right image in B is a reproduction of the original painting, which the artist emulated using digital photography (left image). Gersht images courtesy of the artist. Zurbaran is public domain, taken from Wikimedia Commons. Images courtesy of Ori Gersht. Copyright by Ori Gersht. All rights reserved, Design and Artists Copyright Society 2022. Reprinted with permission. See the online article for the color version of this figure.

Figure 7

VR Art Gallery With Virtual Hand Performing Pick-and-Place Task

Note. VR = virtual reality. Left: neutral obstacle, right: threatening obstacle. See the online article for the color version of this figure.

reported (state) body awareness: $t(143) = .02$, $p = .99$. However, a repeated-measures ANOVA with texture as the within-subject factor and trait body awareness (MAIA scores) as a covariate, and state body awareness as the dependent variable, revealed a significant interaction effect: $F(1, 141) = 4.25$, $p = .04$, $\eta^2 = .03$.

To test the direction of the interaction effect, we used a mean split to divide participants into two groups: high body awareness (MAIA scores $>$ 3.108) and low body awareness (MAIA scores $<$ 3.108). Figure 9 shows the interaction effect of jagged (broken) vs. smooth (nonbroken) art and high vs. low MAIA scores regarding the body awareness ratings after the trials during the VR task: The repeated measures ANOVA also showed a significant main effect of Trait Body Awareness (MAIA scores) on State Body Awareness: $F(1, 141) = 10.27$, $p = .002$, $\eta^2 = .07$, indicating that participants with a natural disposition of higher body awareness also reported stronger body awareness in the experiment after viewing the art stimuli, irrespective of the type of the picture.

Perceived Threat to the (Real) Hand

H2 was supported. The perceived threat by the rotating chainsaw in the pick-and-place task following the viewing of jagged-texture artwork ($M = 4.00$, $SD = 1.42$) was significantly lower than the perceived threat reported after viewing the smooth textured artwork ($M = 4.23$, $SD = 1.44$), $t(145) = -2.35$, $p = .02$, 95% CI [−.42, −.04], $d = .20$.

A repeated-measures ANOVA with texture (jagged vs. smooth) as the within-subject factor and trait body awareness (MAIA scores) as a covariate, and perceived threat as the dependent variable, revealed no significant interaction: $F(1, 141) = 2.53$, $p = .11$. Hence, the effect of texture on perceived threat appears to be independent of participants' dispositional (trait) body awareness. As found for state body awareness, the analysis also showed a significant main effect of trait body awareness (MAIA) on perceived threat: $F(1, 141) = 9.53$, $p = .002$, $\eta^2 = .06$, indicating that participants with higher levels of trait body awareness reported greater perceived threat than those with lower levels of trait body awareness, irrespective of texture.

Figure 8

A Snapshot From the VR Scenario, Showing in-VR Likert Scale Questions (the Text is in a Non-English Language)

Note. VR = virtual reality. See the online article for the color version of this figure.

Discussion

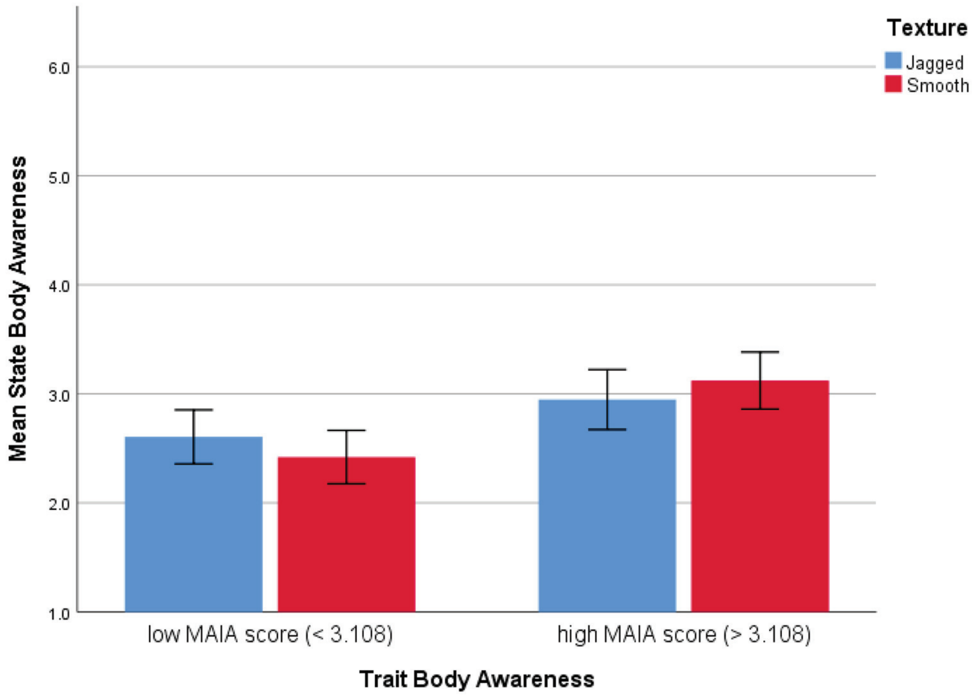
Our overall hypothesis was that art images presenting jagged or abrasive objects or surfaces would induce a higher sense of body awareness. Since we anticipated that explicit self-reports (H1) might not capture such a subtle effect, which is potentially beyond participants' conscious awareness, we also tested this question using an indirect measurement. Specifically, we speculated that the increased awareness of the real body would reduce the illusion of ownership over a virtual hand. Indeed, following the exposure to the jagged object participants reported lower perceived threat to their hand from a chainsaw (H2; i.e., the "rubber arm" [in this case virtual arm] illusion was reduced).

Additionally, we found that individual differences in trait body awareness played an important role in the results. Individuals with higher trait body awareness reported higher state body awareness and higher perceived threat from the chainsaw, regardless of the exposure to art stimuli. We thus suggest that it is an important variable to include in "embodiment" studies (see Gonzalez-Franco & Peck, 2018), as well as in studies of "embodiment" and aesthetic experience, such as Freedberg and Gallese (2007), Umiltá et al. (2012), or Sbriscia-Fioretti et al. (2013). The most plausible explanation is that body awareness served as a moderating variable. However, because we administered the MAIA questionnaire after the VR experience, it is also possible that the VR experience influenced the reported body awareness.

Our study has a number of limitations. The selection of stimuli was limited to a single photographic series from the oeuvre of a single artist. This choice enabled us to present a concise set of stimuli, with the broken and nonbroken cup being an integral part of the artwork, the images of broken cup strongly suggesting jaggedness. Although we argued that Gersht's work is representative of a "haptic" trend in contemporary art, our choice of stimuli might raise the question of whether wider encompassing conclusions can be drawn from a single

Figure 9

Responses to Jagged Versus Smooth Textures, for Individuals With Either Low or High MAIA Scores



Note. MAIA = Multidimensional Assessment of Interoceptive Awareness. Error bars indicate the standard deviation; the interaction is statistically significant. See the online article for the color version of this figure.

test case. A follow-up study would require a more diverse corpus of artworks, yet it would be more complicated in terms of designating appropriate control images. A question that also remains open is whether viewing suggestively abrasive (visual) textures, rather than 3D objects like the broken cup, would have the same effect.

An additional aspect to be further considered is that our study includes a nontypical setup, where visual art is viewed inside virtual reality whereas this was clearly not intended by the artist. There is no prior study on the differential effect of virtual reality on the experience of art, but there would clearly be some differences. For example, the HMD resolution is limited (1,080 × 1,200 per eye), and the color reflectance is very different from real world conditions. A follow-up study would require presenting the stimuli in more ecologically valid conditions as close as possible to gallery viewing. Studies of art experience in actual museum settings were carried out by Babiloni et al. (2013), Vi et al. (2017), and Szubielska and Niestorowicz (2020), among others.

Another aspect of the virtual reality setting that might be considered a limitation is the somewhat unrealistic appearance of the virtual hands, in terms of color and gender specificity. However, a long tradition of VR studies has established that behavioral realism does not require photorealism. Specifically, see Lugrin et al. (2015). Additionally, note that the virtual hands were consistent in all conditions (i.e., they had the same color and appearance for all participants in all conditions).

With the increasing popularity of VR there is growing interest in body ownership illusions and their possible impact on our body awareness (Kilteni et al., 2015), or even suggesting they may be used to transform our sense of "self" (Slater & Sanchez-Vives, 2014). Because VR may become popular this could also lead to significant ethical and social risks (Madary & Metzinger, 2016). Our study used the virtual body ownership illusion as a dependent variable, but indirectly it also points to the necessity for exploring the factors that can serve to increase or decrease such illusions; our study suggests that (a) specific visual stimuli may serve to decrease virtual body ownership in general and (b) that body awareness as a trait is an important covariate in the extent to which people may experience virtual body ownership illusions.

Our interpretation of the main finding is that a pronounced visual emphasis on texture can, by itself, increase body awareness, which is reflected in rejecting the virtual body. Moreover, this effect was achieved by contemporary art stimuli. Our point in using artworks as stimuli was to highlight artists' use of this effect, probably based on their intuition of its power to augment viewers' sense of presence in their physical body. We suggest that this establishes an empirical support for the aesthetic concept of "haptic visuality": the sense of tactile stimulation induced by a visual-only medium.

Contemporary art manifests a strong desire to engage the viewer bodily (Bruno, 2014), arguably as a counterreaction to the ongoing social and cultural process of dis-embodiment, which is itself a result of the information revolution (Hayles, 1999). Growing global mobility and mass migration might also be responsible for the increasing desire for reembodiment, which in contemporary art takes the form of textural excess and skin-related aesthetics (Aldouby, in press). Interestingly, this study has shown that the "haptic" power of artistic stimuli still prevails over the suggestive power of virtual body ownership illusions. Furthermore, whereas Vi et al. (2017) have attempted to actually stimulate museum visitors' hands by means of midair haptic technology while they were viewing a painting, we propose that visual art in itself still remains extremely potent in inducing tactile sensations and enhancing body awareness by appealing to viewers' haptic perception. We did not ask participants to rate their perception of threat or danger from the broken shards of the cup, so as to not influence their intuitive response and create artifacts due to social desirability. Instead, we relied on the ample evidence that viewing broken glasses and other sharp or rough objects (Morrison et al., 2013; Smith & Goodale, 2015), as well as angular lines or shapes (Bar & Neta, 2006, 2007; Bertamini & Sinico, 2021; Blazhenkova & Kumar, 2018; Sinico et al., 2021; Vartanian et al., 2019), induces anticipation of threat, or otherwise unpleasant encounters (Bar & Neta, 2006, 2007; Bertamini & Sinico, 2021; Blazhenkova & Kumar, 2018; Sinico et al., 2021; Vartanian et al., 2019).

Conclusion

"Art can . . . turn stomachs, elicit goose bumps, and send shivers down spines," thus concludes Eskine and Kozbelt's (2015) review of aesthetics and embodied cognition.

This study was premised on the assumption that haptic visuality (Marks, 2002) might induce an aesthetic effect of bodily arousal, and thereby strengthen viewers' feeling of inhabiting a body in space. This might be one apparatus through which the sought-after effect of embodiment is achieved in contemporary art. At an age when the notions of presence and embodiment have themselves migrated to virtual reality (Hansen, 2012; Sanchez-Vives & Slater, 2005), what if art were able to reanchor its viewers in their physical bodies? Most probably, this *presence effect*, to adopt Gumbrecht's terminology (Gumbrecht, 2004), does not outlast the fleeting moment of a gallery encounter with the work. Nevertheless, the restorative effect of reembodiment offered by haptically suggestive artworks warrants further empirical investigation. We suggest that this could be taken up in further studies, not only in the domain of aesthetics but also for its possible therapeutic applications.

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