The aesthetics of verticality: a gravitational contribution to aesthetic preference

Maria Gallagher[1] and Elisa Raffaella Ferrè[1]

(1) Department of Psychology, Royal Holloway University of London, Egham, UK

Corresponding Authors:

Elisa Raffaella Ferrè

Department of Psychology

Royal Holloway University of London

Egham, Surrey TW20 0EX, UK

Telephone: +44 (0) 1784 443530

Email: E.Ferre@rhul.ac.uk

Abstract

Verticality plays a fundamental role in the arts, portraying concepts such as power, grandeur, or even morality, however, it is unclear whether people have an aesthetic preference for vertical stimuli. The perception of verticality occurs by integrating vestibular-gravitational input with proprioceptive signals about body posture. Thus, these signals may influence the preference for verticality. Here we show that people have a genuine aesthetic preference for stimuli aligned with the vertical, and this preference depends on the position of the body relative to the gravitational direction. Observers rated the attractiveness of lines that varied in inclination. Perfectly vertical lines were judged to be more attractive than those inclined clockwise or anticlockwise only when participants held an upright posture. Critically, this preference was not present when their body was tilted away from the gravitational vertical. Our results showed that gravitational signals make a contribution to the perception of attractiveness of environmental objects.

Keywords:

Verticality, Aesthetic preferences, Gravity, Aubert Effect

Word Count: 4,915

Introduction

For Dutch artist Daniel Humbert de Superville, *verticality* symbolised an absolute place for man between the centre of the Earth and towards the heavens (Humbert de Superville, 1827). The vertical dimension plays a significant role in the arts, portraying concepts such as power, grandeur, or even morality (Parsons, 2010). However, an open question remains whether people have a genuine aesthetic *preference* for the vertical.

Previous research has identified several properties which are consistently perceived as more attractive (Palmer, Schloss, & Sammartino, 2013). Perfectly symmetrical, complex, or curved stimuli, for example, are likely to be perceived as more attractive than other stimuli (Jacobsen & Hofel, 2002). However, little research has been conducted on aesthetic judgements of vertical stimuli. It has been suggested that painters tend to use more vertical and horizontal lines in paintings (Latto & Russell-Duff, 2002). In addition, observers prefer abstract Mondrian style paintings with vertical and horizontal components over paintings with oblique components (Latto, Brain, & Kelly, 2000). Thus, previous explanations of aesthetic preferences have focused on the properties of the stimulus itself. For example, it has been argued that people tend to prefer stimuli they frequently encounter in the world (Palmer et al., 2013). However, to our knowledge, little focus has been given to the role of the observer's sensory afferents in the formation of aesthetic judgements.

What is the vertical? Verticality defines what is "up" and what is "down" and deviations thereof, in a gravitational field. On Earth, humans are very accurate in estimating verticality; upright standing participants perceive the visual vertical within a few degrees of the gravitational direction, even without external environmental cues (Kaptein & Van Gisbergen, 2005). However, how the brain builds up a representation of the vertical has been a topic of continuous debate. In 1935, Koffka hypothesised that the sense of the vertical is strictly determined by the elements that characterise the visual field, such as walls, floors and trees. Accordingly, objects would be perceived as upright or tilted only in relation to this visual reference frame. By contrast, Gibson and Mowrer (1938) argued that the vertical is not determined by visual cues but by postural stimuli, and ultimately by the force of gravity acting on the body. In case of a discrepancy between these visual and postural-gravitational inputs, the brain learns to use the reliable cues and to neglect the unreliable ones (Gibson, 1952). Gibson's hypothesis has been corroborated by more recent studies, indicating that several types of visual and non-visual signals contribute to vertical estimates (Angelaki, Gu, & DeAngelis, 2009; Harris, Jenkin, Dyde, & Jenkin, 2011; Howard, 1982; Lackner & DiZio, 2005; Mittelstaedt, 1983).

On Earth, gravity is an *always on* perceptual signal. Reference to gravity is essential to assess the orientation of the body and limbs in space, to maintain postural equilibrium and move around, to explore and interpret the external environment[1]. Linear acceleration caused by gravity is detected by the vestibular organs in the inner ear. The vestibular receptors comprise of semi-circular canals (anterior, posterior and horizontal), which detect angular rotations of the head around three cardinal axes (yaw, roll, pitch), and otolith organs, which detect linear acceleration and gravity (utricle and saccule). Vestibular organs are extremely sensitive to even the slightest changes in rotation and linear movement of the head. For instance, when the head moves with respect to the gravity vector, otoliths shift with the direction of gravity, moving specialised hair cells and signalling to the brain head position relative to gravity (Barra et al., 2010; Tarnutzer, Bockisch, Straumann, & Olasagasti, 2009). These vestibular-gravitational signals are integrated with sensory signals from vision,

[1] We note that in weightlessness astronauts can still interact with the external environment in absence of gravity signals, relying on visual and proprioceptive cues for orientation. Critically, this occurs only after a period of adaptation to the gravity-free environment. Weightlessness disorientation is very common in the initial days of exposure microgravity (Clément, Reschke, & Wood, 2005), highlighting the importance of gravity to spatial orientation.

proprioception, and viscera, as well as prior information about the normal upright stance of the body to form an internal model of gravitational direction (Lacquaniti et al., 2014, Lackner & DiZio, 2005; Mittelstaedt, 1992).

The key role played by vestibular-gravitational signals in the perception of the vertical has been supported by several clinical reports. Patients with vestibular peripheral disorders or selective lesions affecting the vestibular nuclei show biases in reporting the subjective vertical (Bisdorff, Wolsley, Anastasopoulos, Bronstein, & Gresty, 1996). Similarly, artificial activation of the peripheral vestibular organs leads to biases in verticality judgement: estimates of the subjective visual vertical during galvanic vestibular stimulation are biased towards the anodal side of stimulation (Mars, Vercher, & Popov, 2005; Volkening et al., 2014).

In addition to vestibular signals, body-postural information can also influence the perception of the vertical. Participants asked to align an initially tilted line with the estimated earth-vertical (subjective visual vertical) typically deviate by <2° compared to the actual direction of gravity (Dyde, Jenkin, & Harris, 2006; Mittelstaedt, 1983). However, when people are roll-tilted, i.e. tilted to the left or right from vertical, the subjective perception of verticality shifts away from the gravitational vertical (De Haes, 1970; Vingerhoets, De Vrijer, Van Gisbergen, & Medendorp, 2009). For body tilts larger than 60°, the physical vertical direction is misperceived, and the subjective visual vertical is systematically biased towards the head and body orientation, the so-called *Aubert-effect* (Aubert, 1861; Groberg, Dustman, & Beck, 1969). Importantly, patients who have reduced somatosensory perception appear immune to this effect, and tend to perceive the vertical as the true gravitational direction (Yardley, 1990). Thus, the perception of verticality seems to include a strong prior that the body is upright, as well as gravitational afferent information.

Here, we investigated whether people had an aesthetic preference for simple vertical stimuli, and whether this aesthetic preference could be influenced by the current posture of the body with respect to the gravitational vector. In Experiment 1 we explored the aesthetic preference for verticality. Participants judged the attractiveness of tilted or vertical lines while in an upright posture. We predicted that the vertical stimuli would be rated as more attractive than the tilted stimuli. In Experiments 2 and 3 we manipulated the participants' body posture to explore the influence of online vestibular-gravitational signals on the aesthetic judgements. Participants completed the aesthetic judgement task while they were standing with the head and torso roll-tilted away from the gravitational vertical. We predicted that the participants would no longer have an aesthetic preference for vertical stimuli when both vestibular organs and body axis were incongruent with the direction gravity. Finally, in Experiment 4 we controlled for non-specific gravitational effects. Participants performed the aesthetic judgement task in the roll-tilted posture, looking at vertical, tilted and horizontal lines. We predicted that non-specific gravitational effects, such as the position of the stimuli on the retina, would lead to higher attractiveness judgements for horizontal stimuli over vertical and tilted stimuli.

Experiment 1

Methods

Participants

Twenty healthy participants (4 male, age M = 24.85 SD = 4.80) volunteered for the study. The sample size was decided a priori based on similar psychophysical experiments. The a priori established sample size was also used as data-collection stopping rule, i.e. when 20 participants were administered with the task, no more volunteers were recruited for this study. All participants were right-handed according to their Edinburgh handedness inventory scores. Exclusion criteria were any history of neurological, psychiatric or vestibular disorders. The experimental protocol was approved by the local ethics committee (Royal Holloway University of London) and the study was conducted in line with the Declaration of Helsinki.

Procedure

Verbal and written instructions about the task were given to participants at the beginning of the experimental session.

The participant's head was fixed on a chinrest in an upright posture (Figure 1). Thus, both the gravity vector and body axis were congruent. Participants were asked to judge the attractiveness of lines presented on a screen. The stimuli were dark-grey lines displayed on a light-grey background at the centre of the screen. The lines measured 50 mm in length and 1 mm in width. The screen was an LCD computer monitor, with 1280 x 1080 resolution and refresh rate of 60 Hz. The line was viewed through a shroud creating a circular aperture (diameter 18.5 cm) which occluded peripheral vision and prevented participants using environmental cues for verticality. The entire apparatus was adjusted so that the centre of the line was aligned with the nose of the participant with a viewing distance of 30 cm. Lines were displayed either with no inclination (vertical, 0^{o}) or tilted clockwise ($+5^{o}$, $+10^{o}$, $+15^{o}$, $+20^{o}$, $+25^{o}$, $+30^{o}$, $+35^{o}$, $+40^{o}$, $+45^{o}$) or anticlockwise (-5^{o}, -10^{o}, -15^{o}, -20^{o}, -25^{o}, -30^{o}, -35^{o}, -40^{o}, -45^{o}), giving a total of 19 stimuli. Stimuli were displayed on screen for 1500ms, and then disappeared. A numerical scale was then presented until participants expressed their aesthetic judgements. The scale ranged from 0 ("Strongly dislike") to 7 ("Strongly like"). Each line was shown four times in a random order in a single block with a total of 76 trials.

The following instructions were adapted from the original procedures described in Friedenberg and Bertamini (2015): *"In this task, you will see a number of lines presented on* *the screen. You need to rate the attractiveness of the line on a 0 to 7 scale, where 0 means you strongly dislike the line and 7 means you strongly like it. It is important that you don't think of 'attractiveness' as it would be used to judge human figures, but rather a more abstract sense of attractiveness relating to how pleasant you find the image, or how much you like the image for example. There is no right or wrong answer, so just answer according to your personal judgement."* No further details were given to participants.

Results

The average attractiveness rating given according to each line orientation was calculated for each participant. A 2 (Direction: clockwise vs anticlockwise) x 9 (Line Inclination: 5 to 45 degrees) ANOVA revealed no significant main effect of Direction on attractiveness ratings ($F(1,19) = 1.54$, $p = .23$, $\eta_p^2 = .08$) (Table 1). A significant main effect of Line Inclination was found ($F(1.69, 32.08) = 3.60$, $p < .05$, $\eta_p^2 = .16$). No significant interaction between Direction and Line Inclination was found ($F(4.31, 82.97) = 0.99$, $p = .42$, $\eta_p^2 = .05$). Further *t*-tests revealed no significant differences in attractiveness at each level of inclination ($p > .12$ for all comparisons; Bonferroni-corrected for multiple comparisons). The absolute inclination at each level was therefore adopted for comparisons with the vertical stimulus.

***** Please insert Table 1 here*****

The vertical line was considered more attractive compared to all other inclinations when the participants' body axis was aligned with the gravity vector (data can be seen in Figure 1). A one-way ANOVA on the ratings in the absolute inclination revealed a significant main effect of Line Inclination ($F(2.49, 47.38) = 9.97$, $p < .001$, $\eta_p^2 = .34$) with the vertical line consistently rated as more attractive than all tilted lines ($p \leq .002$ for all comparisons; Bonferroni-corrected for multiple comparisons, Table 2).

***** Please insert Table 2 here*****

Discussion

We aimed to explore whether participants had an aesthetic preference for simple vertical stimuli. Participants judged the attractiveness of vertical or tilted lines while they were seated upright, so that the body axis and gravitational vector were congruent. As predicted, participants rated the vertical stimulus as more attractive than all other tilted stimuli. Hence, it appears that participants have a genuine aesthetic preference for verticality. In Experiment 2 we aimed to explore whether the preference for vertical stimuli would also be present when the participants' head and body were no longer congruent with the gravitational direction. We predicted that participants would no longer consider the vertical stimulus more attractive than inclined stimuli.

Experiment 2

Methods

Participants

Twenty healthy participants (3 male, age $M = 20.00$, $SD = 3.57$) took part in this study. All participants were right handed according to their Edinburgh Handedness Inventory scores. Exclusion criteria were as Experiment 1. None of the participants had taken part in the previous study.

Procedure

Verbal and written instructions were as Experiment 1. Participants stood with head and body roll-tilted 90^{o} to the right, with head fixed in a chin-rest (Figure 1). Hence the body axis and gravity vector were incongruent. Stimuli and procedure were as Experiment 1.

Results

A 2 (Direction: clockwise vs anticlockwise) x 9 (Line Inclination: 5 to 45 degrees) ANOVA revealed a main effect of Direction (F(1, 19) = 11.84, p = .003, η_p^2 = .38) and no significant main effect of Line Inclination (F(2.83, 53.75) = 0.30, p = .82, η_p^2 = .02). No interaction between Direction and Line Inclination was found (F(3.33, 63.21) = 0.32, p = .96, η_p^2 = .02). Further *t*-tests revealed no significant differences in attractiveness at each level of tilt between clockwise and anticlockwise line inclinations (p > .005 for all comparisons; Bonferroni-corrected for multiple comparisons, Table 3). The absolute inclination at each level was therefore adopted for comparisons with the vertical stimulus.

***** Please insert Table 3 here*****

A one-way ANOVA on the ratings in the absolute inclination revealed no significant effect of Line Inclination (F(2.58, 48.97) = 0.78, p > .250, η_p^2 = .04) (Figure 1). Hence, participants did not rate any line inclination as more attractive than any other.

Discussion

We investigated whether participants would have an aesthetic preference for verticality when their body posture was incongruent with the physical direction of gravity. Participants rated the attractiveness of vertical or tilted lines while they were standing with head and body roll-tilted to the right. In contrast to Experiment 1, no aesthetic preference emerged for the vertical stimulus. Thus, it appears that the aesthetic preference for verticality is only present when participants themselves are aligned with the gravitational direction. These findings therefore provide evidence for the role of online vestibular-gravitational signals in aesthetic judgements. In Experiment 3, we controlled for specificity of body posture, and investigated whether similar results would emerge when participants were roll-tilted towards the left. We predicted that, as the participants' body axis was not congruent with gravity, no preference for vertical stimuli would be apparent.

Experiment 3

Method

Participants

Twenty healthy participants (6 male, age M = 21.20, SD = 2.82) took part in Experiment 3. All participants were right handed according to their Edinburgh Handedness scores. Exclusion criteria were as Experiment 1.

Procedure

Verbal and written instructions were as Experiment 1. Participants stood with head and body roll-tilted 90^{o} to the left, with head fixed in a chin-rest (Figure 1). Hence the body axis and gravity vector were incongruent. Stimuli and procedure were as Experiment 1.

Results

A 2 (Direction: clockwise vs anticlockwise) x 9 (Line Inclination: 5 to 45 degrees) ANOVA revealed no significant main effect of Direction ($F(1,19) = 0.73$, $p = .40$, $\eta_p^2 = .04$) (Table 4), no significant main effect of Line Inclination ($F(3.06, 58.14) = 1.34$, $p = .27$, $\eta_p^2 = .06$), and no significant interaction ($F(2.41, 45.85) = 0.94$, $p = .41$, $\eta_p^2 = .05$). The absolute inclination at each level was therefore adopted for comparisons with the vertical stimulus.

***** Please insert Table 4 here*****

A one-way ANOVA on the ratings in the absolute inclination revealed no significant effect of Line Inclination (F(2.74, 51.97) = 0.76, p > .250, η_p^2 = .04) (Figure 1). Thus, as Experiment 2, participants did not rate any line inclination as more attractive than any other stimulus.

Discussion

We explored whether the aesthetic preference for verticality would be cancelled when the participants' body axis was orthogonal to the gravity vector by standing tilted to the left. As Experiment 2, no aesthetic preference emerged.

Between-Experiments Comparison

To directly compare the aesthetic preferences across the three experiments, we conducted a 3 (Body Posture: upright, right-tilted, left-tilted) x 10 (Line Inclination: 0° to 45°) ANOVA. The main effect of Body Posture was not significant (F(2, 57) = 1.48, p = .24, η_p^2 = .05). The main effect of Line Inclination was significant (F(3.36, 191.37) = 5.47, p < .01, η_p^2 = .09), with post-hoc t-tests indicating that the vertical line was rated significantly more attractive than the 5°, 10°, 15°, and 20° lines (p < .05, Bonferroni-corrected for multiple comparisons). The two-way interaction between Body Posture and Line Inclination was significant (F(6.72, 191.37) = 4.04, p < .001, η_p^2 = .12), with higher ratings for vertical stimuli only when participants were in the upright posture (Experiment 1).

We also estimated the "vertical attractiveness index" based on the difference in the ratings between vertical and tilted lines, averaged across line inclinations. A one-way ANOVA revealed a significant main effect of Body Posture (F(2, 57) = 6.43, p = .003, η_p^2 =

.18). The vertical attractiveness index was significantly higher in upright posture (1.49, *SD* = 1.29) compared to both right-tilted (0.33, *SD* = 0.97; $t(38) = 3.23$, $p = .003$, Cohen's $d = 1.02$, 95% *CI* [0.34, 1.65]) and left-tilted postures (0.14, *SD* = 1.56; $t(38) = 3.00$, $p = .005$, Cohen's $d = 0.94$, 95% *CI* [0.27, 1.58]). No difference in the vertical attractiveness index emerged between Experiments 2 and 3 ($t(38) = 0.47$, $p > .250$, Cohen's $d = 0.15$, 95% *CI* [-0.24, 0.54]).

Discussion

The participants' aesthetic preference for vertical stimuli was present only when they themselves were upright and aligned with the gravitational vertical. While these results highlight the role of gravitational signals in aesthetic judgements, we cannot yet exclude non-specific gravitational effects: for instance, participants might prefer stimuli which appear upright on the retina or on the visual field, rather than stimuli aligned with the true gravitational vertical. As the stimuli in Experiments 1 through 3 only ranged between ±45°, there was no condition in which the line appeared upright in visual coordinates when participants were roll-tilted 90° left or right. To differentiate between these two explanations (gravitational signals versus retinal coordinates), we ran a control experiment in which participants judged the attractiveness of vertical (0°), clockwise-tilted (+5° to +85° in 5° increments), and horizontal (90°) lines while they were roll-tilted 90° to the right. If the participants' aesthetic preference for vertical stimuli in Experiment 1 depended on the orientation of the vertical line on the retina or on the visual field, rather than gravitational signals, then we would expect the horizontal stimulus to be rated as more attractive than all other stimuli while participants were roll-tilted 90°. If, however, the aesthetic preference depended on gravitational signals, we would predict no preference for any stimulus, as in Experiments 2 and 3.

Experiment 4

Methods

Participants

Twenty-one healthy participants (5 male, age *M* = 21.52, *SD* = 3.45) took part in the control experiment. One participant had to be excluded from the analysis as they did not follow the task instructions correctly and had to be replaced. All participants were right handed according to their Edinburgh Handedness scores. Exclusion criteria were as the previous experiments.

Procedure

Verbal and written instructions were as Experiment 1. Participants stood with head and body roll-tilted 90^{o} to the right, with head fixed in a chin-rest, as Experiment 2. Lines were displayed either with no inclination (vertical, 0^{o}) or tilted clockwise (+5^{o}, +10^{o}, +15^{o}, +20^{o}, +25^{o}, +30^{o}, +35^{o}, +40^{o}, +45^{o}, +50^{o}, +55^{o}, +60^{o}, +65^{o}, +70^{o}, +75^{o}, +80^{o}, +85^{o}, +90^{o}) giving a total of 19 stimuli which were presented four times in a random order in a single block.

Results

A one-way ANOVA revealed a significant main effect of Line Inclination ($F(3.85, 73.17) = 5.86$, $p < .001$, $\eta_p^2 = .24$) (Figure 2). The vertical stimulus was rated significantly less attractive than lines tilted greater than +55^{o} (except for the +65^{o} line, Table 5) ($p \leq .002$, Bonferroni-corrected for multiple comparisons).

***** Please insert Table 5 here *****

***** Please insert Figure 2 here *****

Importantly, the 90^o stimulus, which in the roll-tilted body posture appears upright on the retina and on the visual field, was not rated more attractive than any other stimulus ($p \geq .002$, Bonferroni-corrected for multiple comparisons, Table 6), except for the 0^o stimulus ($p = .001$). These results suggest that an explanation based on the aesthetic preference being driven by the location of the stimuli on the retina or on the visual field is unlikely.

***** Please insert Table 6 here *****

Discussion

In Experiments 1 to 3, we found that participants had an aesthetic preference for vertical stimuli, but this preference was only present when the participants themselves were upright and thus aligned with the gravitational vector. While these results suggested that gravitational signals influenced aesthetic judgements, it was possible that participants simply preferred stimuli which appeared upright on the retina or on the visual field. In Experiment 4, we presented vertical, tilted, and horizontal lines to participants who were roll-tilted 90^o to the right. There was no preference for the horizontal stimulus over other tilted stimuli. Thus, our results cannot be interpreted in terms of an aesthetic preference for lines which appear upright on the retina or on the visual field.

General Discussion

Participants preferred vertical visual stimuli when their head was upright and disliked them when their head was roll-tilted away from the gravitational vertical. Participants in all experiments completed an aesthetic judgement task, rating the attractiveness of simple vertical and inclined lines. When the participants' body axis was upright and congruent with the gravitational vector (Experiment 1), a clear preference for the vertical stimulus emerged, rating it more attractive than all other inclinations. In Experiments 2 and 3, participants completed the task while standing roll-tilted 90° right or left. In both cases, no aesthetic preference for any stimulus was found. A control experiment in which participants rated vertical, tilted, and horizontal lines while roll-tilted 90° to the right ruled out non-specific gravitational explanations, such as the position of the stimuli on the retina. Our results therefore suggest for the first time a gravitational contribution to aesthetic preferences.

Gravitational signals are constantly coded by vestibular otolith receptors in the inner ear. Resting atop of thousands of tiny hair cells, microscopic crystals move and bend these hair cells signalling to the brain head movement and position with respect to the gravitational vector (Berthoz, 1996). Neuroimaging studies using artificial vestibular stimulation have revealed widespread vestibular projections reaching many areas of the cerebral cortex, such as the retroinsular cortex, the superior temporal gyrus, the temporo-parietal cortex, the basal ganglia and the anterior cingulate (Bense, Stephan, Yousry, Brandt, & Dieterich, 2001). Critically, recent studies suggested that otolithic gravitational inputs in the vestibular system have a direct influence on cognitive tasks (Clément, Fraysse, & Deguine, 2009; Clément, Skinner, Richard, & Lathan, 2012; Harris & Mander, 2014; Török et al., 2017).

Verticality defines what is up and what is down in a gravitational field (Benson & Bodin, 1966). It requires vestibular-gravitational inputs to be integrated with signals from other sensory modalities, such as vision, touch and proprioception (Bronstein, 1999; Gentaz & Hatwell, 1996; Yardley, 1990). In the absence of gravity, there is no vertical: the eyes send signals that confuse the brain because the vestibular references on which we rely are missing. These mismatched sensory inputs lead to the well-known Space Adaptation Syndrome experienced by astronauts in zero-gravity. “The way to feel better (in outer space) is to lose up,” American astronaut Marsha Ivins observed, “to convince your visual system that up is wherever you point your head and down is where your feet are” (Roper, 2014).

Humans can accurately estimate the direction of verticality while on Earth. Gibson (1952) suggested that the vertical is determined by visual and postural (gravitational) cues. In case of a discrepancy between these cues, the brain learns to use reliable cues and to neglect unreliable ones. Gibson's hypothesis has been corroborated by recent studies, which indicate that several types of visual and non-visual sensory signals contribute to the subjective estimate of verticality (Harris, Jenkin, Dyde, & Jenkin, 2011; Lackner & DiZio, 2005; Mittelstaedt, 1983). Vestibular-gravitational information is therefore constantly integrated with proprioceptive cues regarding the position of the body in space. Accordingly, when people lay horizontally, their perception of the vertical shifts away from the gravitational vector and towards the orientation of the body axis, the well-known Aubert Effect (Aubert, 1861; Yardley, 1990). Thus, it might not be surprising that participants' aesthetic preference for vertical stimuli was only present when they were upright, diminishing when the head and body were roll-tilted to the left or right. The preference for the vertical cannot be accounted for by other factors, such as symmetry (Jacobsen & Hofel, 2002), as the stimuli were constant across the three experimental manipulations, nor the position of objects on the retina, as no aesthetic preference for a horizontal line emerged when participants were 90 degrees roll-tilted in Experiment 4. Hence, our findings suggest that gravitational signals contribute to the way we judge the attractiveness of environmental objects.

Here we showed that people have an aesthetic preference for vertical stimuli when they themselves were aligned with the gravitational vector. Although no statistical differences emerged between the preferences for the inclined lines, an interesting pattern in the non-vertical stimuli emerged when visually exploring the data (Figure 1). Lines close to, but not exactly vertical, were preferred less. This seems to suggest a sort of *lateral inhibition* (Blakemore, Carpenter, & Georgeson, 1970) triggered by the vertical stimuli: stimuli that are close to but not vertical are disliked in favour of the vertical ones. However, caution needs to be taken while interpreting non-significant results and further studies might consider this more appropriately.

The psychology of aesthetics has a long tradition of studying how low-level stimulus features influence aesthetic perception and preference. Research on aesthetics has studied people's preferences for lines, forms, colours, and shapes (Gordon, 1909; Valentine, 1962). This tradition has recently involved empirical studies on whether people prefer symmetry (Locher & Stappers, 2002), contrast (Specht, 2007), colour (Polzella, Hammar, & Hinkle, 2005), and geometric orientation (Miller, 2007) in visual artwork. Although the value of the vertical dimension has long been implied in the arts (Parsons, 2010; Still, 2001), no previous studies have linked gravitational signals to the aesthetic preference for verticality. The present study provides the first experimental evidence of an aesthetic preference for vertical stimuli.

Aesthetic preferences are often linked to familiarity: people prefer objects with which they are more familiar (Zajonc, 1968; Palmer et al., 2013). In natural scenes, vertical lines are observed more frequently than lines at other inclinations (Switkes, Mayer, & Sloan, 1978). For instance, Mondrian paintings which notably contain horizontal and vertical components are preferred over the same paintings rotated which therefore present oblique components (Latto, Brain & Kelly, 2000). Since observers naturally see more vertical than oblique lines, the preference for paintings with vertical components was explained as due to familiarity with lines at these orientations (Palmer et al., 2013). Importantly, participants in the present study had a preference for verticality only when they themselves were aligned with the gravitational vector, suggesting that familiarity with vertical lines is not an exhaustive account for the observed aesthetic preferences.

Similarly, aesthetic preferences might be influenced by fluency, such that observers might prefer stimuli which are more easily processed (Palmer et al., 2013). In general, observers are more accurate at perceiving contours oriented horizontally and vertically than those oriented diagonally: the well-known oblique effect (Nasr & Tootell, 2012). Mondrian-style paintings might be preferred with vertical components rather than diagonal components because vertical and horizontal lines are easier to process (Latto, Brain, & Kelly, 2000; Palmer et al., 2013; Plumhoff & Schirilloô, 2009). Critically, in our study, the preference for verticality was present selectively when participants were upright (Experiment 1), but lines placed upright on the retina were not preferred over tilted lines (Experiment 4). Our results suggest that the preference for simple vertical stimuli depends not on the ease of visual processing of the stimuli, but on the orientation of the body relative to gravity.

Embodied cognition has associated abstract concepts to physical sensations experienced through the body (Barsalou, 1999). For example, people in an upright posture express more pride than those who are slumped (Stepper & Strack, 1993), and recall more positive memories when they perceive themselves moving upwards (Seno, Kawabe, Ito, & Sunaga, 2013). In art, verticality has been used to portray powerful abstract concepts, such as power, status, morality, and grandeur (Parsons, 2010). In addition, implicit associations between 'up as good' and 'down as bad' seem to be very common (Gottwald, Elsner, & Pollatos, 2015; Meier, Hauser, Robinson, Friesen, & Schjeldahl, 2007). Thus, it is possible that the upright posture of participants in our study was implicitly associated with the abstract concepts relating to verticality, leading to the higher attractiveness ratings of the upright stimuli in upright posture.

Conclusion

Previous accounts of aesthetic preferences have considered how low-level properties of the stimulus itself contribute to aesthetic judgements (Friedenberg & Bertamini, 2015; Jacobsen & Hofel, 2002). For example, curves are in general felt to be more beautiful than straight lines (Gordon, 1909). In our experiment these low-level factors were minimized: the stimuli presented were identical in the three body postures (upright, titled to the left, tilted to the right). Our results therefore suggest that the low-level visual features of the stimuli need to be integrated with the position of the perceiver. We show a gravitational modulation of aesthetic preference which depends on on-line vestibular-postural signals. Consequently, our judgments of attractiveness may owe more to multisensory-gravitational perception than has been previously thought.

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Authorship

All authors contributed to the study design. M. Gallagher set up the experiments and data analysis. M. Gallagher drafted the manuscript, and E.R. Ferre provided critical revisions. All authors approved the final version of the manuscript for submission.

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Legend for figures

Figure 1. **Experimental conditions and results.**

Participants viewed vertical (0^o) and inclined ($\pm5^o$ to $\pm45^o$ in 5^o increments) lines through an occluded visual field while seated upright (gravity-congruent) or with head and body roll-tilted to the left (gravity-incongruent-L) or right (gravity-incongruent-R). In the gravity-congruent condition, both body axis and gravitational vector, sensed by the vestibular organs, were aligned in the same direction. In both gravity-incongruent conditions, the body axis was orthogonal to the gravitational vector. Participants were asked to rate the attractiveness of each line using a 0-7 scale. In the gravity-congruent condition, participants rated the vertical stimulus as significantly more attractive than the inclined lines. This preference was cancelled in the gravity-incongruent conditions. Error bars represent standard error of the mean.

Figure 2. **Results of Experiment 4.**

Participants viewed vertical (0^o), inclined ($\pm5^o$ to $\pm85^o$ in 5^o increments) and horizontal ($+90^o$) lines through an occluded visual field while with head and body roll-tilted right. Thus, the body axis was orthogonal to the gravitational vector, and the horizontal line was congruent with the body axis and upright on the retina and on the visual field. Participants were asked to rate the attractiveness of each line using a 0-7 scale. No preference for the horizontal stimulus emerged over any other stimulus, except the vertical line. These results suggest that the preference for a vertical stimulus in Experiment 1 was therefore not driven by the orientation of the stimulus on the retina or on the visual field. Error bars represent standard error of the mean.

Table 1

Direct comparisons (t-tests) between anticlockwise (ACW) and clockwise (CW) ratings for Experiment 1. Corrected for multiple comparisons.

ACW– CW	Mean	SD	*t*	*p*	*Cohen's d*
$-5^o - 5^o$	0.088	0.68	0.57	.57	0.06
$-10^o - 10^o$	-0.05	0.85	-0.26	.80	0.04
$-15^o - 15^o$	-0.18	0.86	-0.91	.37	0.16
$-20^o - 20^o$	-0.21	0.72	-1.32	.20	0.24
$-25^o - 25^o$	-0.09	0.74	-0.53	.60	0.10
$-30^o - 30^o$	-0.24	0.90	-1.17	.26	0.24
$-35^o - 35^o$	-0.19	0.86	-0.97	.34	0.19
$-40^o - 40^o$	-0.43	1.17	-1.63	.12	0.41
$-45^o - 45^o$	-0.26	0.97	-1.21	.24	0.21

Table 2

Mean differences between vertical and tilted stimuli for Experiment 1

Vertical - Tilted	Mean	SD	*t*	*p*	*Cohen's d*
0^o - 5^o	1.97	1.67	5.27	< .001	1.23
0^o - 10^o	1.85	1.51	5.48	< .001	1.27
0^o - 15^o	1.70	1.52	5.01	< .001	1.22
0^o - 20^o	1.62	1.37	5.30	< .001	1.20
0^o - 25^o	1.41	1.39	4.52	< .001	1.05
0^o - 30^o	1.24	1.44	3.87	.001	0.91
0^o - 35^o	1.23	1.52	3.61	.002	0.91
0^o - 40^o	1.15	1.36	3.79	.001	0.85
0^o - 45^o	1.28	1.25	4.59	< .001	0.88

Table 3

Direct comparisons (t-tests) between anticlockwise (ACW) and clockwise (CW) ratings for Experiment 2. Corrected for multiple comparisons.

ACW-CW	Mean	SD	*t*	*p*	*Cohen's d*
$-5^o - 5^o$	-0.69	1.41	-2.19	.04	0.52
$-10^o - 10^o$	-0.56	1.03	-2.44	.03	0.48
$-15^o - 15^o$	-0.40	1.23	-1.46	.16	0.36
$-20^o - 20^o$	-0.43	0.83	-2.30	.03	0.48
$-25^o - 25^o$	-0.73	1.04	-3.11	.01	0.65
$-30^o - 30^o$	-0.44	0.83	-2.34	.03	0.40
$-35^o - 35^o$	-0.54	1.01	-2.37	.03	0.46
$-40^o - 40^o$	-0.63	1.27	-2.20	.04	0.50
$-45^o - 45^o$	-0.43	1.52	-1.25	.23	0.33

Table 4

Direct comparisons (t-tests) and mean differences between anticlockwise (ACW) and clockwise (CW) ratings for Experiment 3. Bonferroni-corrected for multiple comparisons.

ACW - CW	Mean	SD	*t*	*p*	*Cohen's d*
-5° – 5°	-0.33	2.37	-0.61	.55	0.21
-10° – 10°	-0.03	1.60	-0.07	.95	0.02
-15° – 15°	0.35	2.06	0.76	.46	0.28
-20° – 20°	0.25	2.04	0.55	.59	0.18
-25° – 25°	0.31	1.93	0.72	.48	0.24
-30° – 30°	0.45	1.65	1.22	.24	0.37
-35° – 35°	0.18	1.69	0.46	.65	0.15
-40° – 40°	0.39	1.65	1.05	.31	0.31
-45° – 45°	0.74	1.70	1.94	.07	0.54

Table 5

Mean differences between vertical and tilted stimuli for Experiment 4

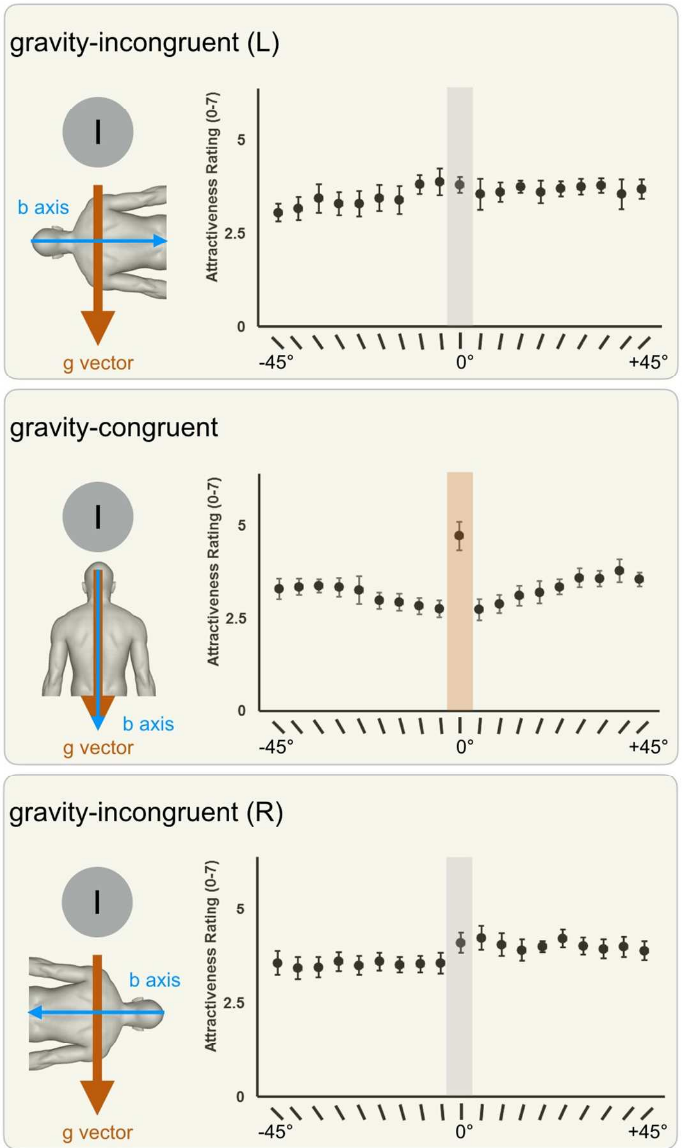
Vertical – Tilted	Mean	SD	*t*	*p*	*Cohen's d*
0° - 5°	-0.24	0.95	-1.12	.28	0.14
0° - 10°	-0.26	1.07	-1.10	.29	0.16
0° - 15°	-0.53	1.18	-1.98	.06	0.32
0° - 20°	-0.31	1.03	-1.35	.19	0.20
0° - 25°	-0.38	1.07	-1.56	.14	0.24
0° - 30°	-0.49	1.33	-1.63	.12	0.33
0° - 35°	-0.35	1.52	-1.03	.32	0.26
0° - 40°	-0.88	1.23	-3.16	.005	0.63
0° - 45°	-1.01	1.35	-3.35	.003	0.73
0° - 50°	-0.99	1.52	-2.91	.009	0.69
0° - 55°	-1.16	1.45	-3.59	.002	0.87
0° - 60°	-1.18	1.46	-3.61	.002	0.88
0° - 65°	-0.93	1.97	-2.10	.05	0.69
0° - 70°	-1.48	1.66	-3.98	.001	1.08
0° - 75°	-1.44	1.74	-3.69	.002	1.08
0° - 80°	-1.34	1.68	-3.56	.002	0.95
0° - 85°	-1.43	1.70	-3.76	.001	0.97
0° - 90°	-1.43	1.68	-3.79	.001	0.87

Table 6

Mean differences between horizontal and tilted stimuli for Experiment 4

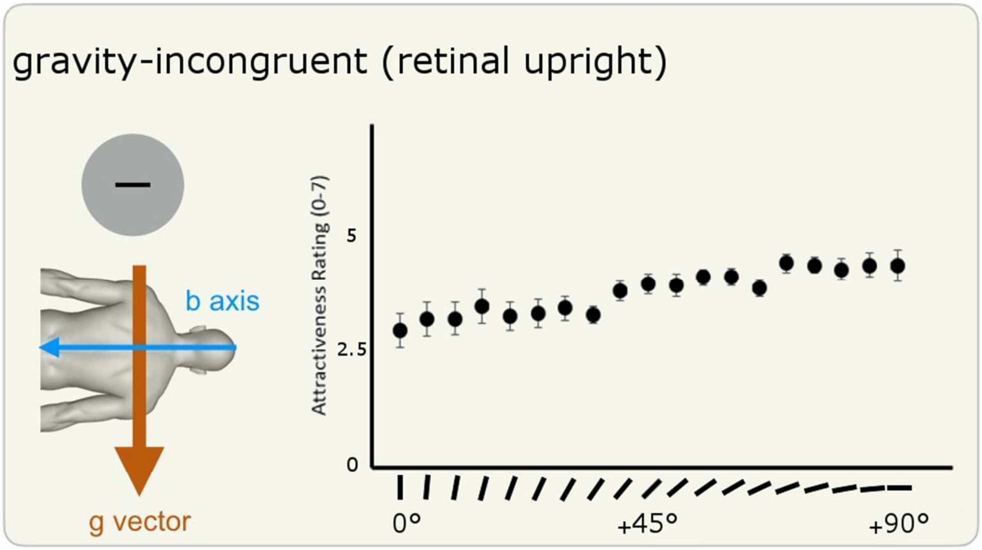
Horizontal – Tilted	Mean	SD	*t*	*p*	*Cohen's d*
90° – 0°	1.43	1.68	3.79	.001	0.87
90° - 5°	1.19	1.76	3.02	.01	0.74
90° - 10°	1.16	1.60	3.24	.004	0.75
90° - 15°	0.90	1.79	2.24	.04	0.57

90^o - 20^o	1.11	1.70	2.93	.01	0.76
90^o - 25^o	1.05	1.60	2.93	.01	0.72
90^o - 30^o	.938	1.70	2.47	.02	0.69
90^o - 35^o	1.08	1.63	2.95	.01	0.86
90^o - 40^o	0.55	1.43	1.72	.10	0.42
90^o - 45^o	0.41	1.41	1.31	.21	0.32
90^o - 50^o	0.44	1.55	1.27	.22	0.33
90^o - 55^o	0.26	1.45	0.81	.43	0.21
90^o - 60^o	0.25	1.33	0.84	.41	0.20
90^o - 65^o	0.50	1.77	1.27	.22	0.40
90^o - 70^o	-0.05	1.56	-0.14	.89	0.04
90^o - 75^o	-0.01	1.60	-0.04	.97	0.01
90^o - 80^o	0.09	1.48	0.27	.79	0.07
90^o - 85^o	0.00	1.19	0.00	1.00	0.00



Participants viewed vertical (0°) and inclined (±5° to ±45° in 5° increments) lines through an occluded visual field while seated upright (gravity-congruent) or with head and body roll-tiled to the left (gravity-incongruent-L) or right (gravity-incongruent-R). In the gravity-congruent condition, both body axis and gravitational vector, sensed by the vestibular organs, were aligned in the same direction. In both gravity-incongruent conditions, the body axis was orthogonal to the gravitational vector. Participants were asked to rate the attractiveness of each line using a 0-7 scale. In the gravity-congruent condition, participants rated the vertical stimulus as significantly more attractive than the inclined lines. This preference was cancelled in the gravity-incongruent conditions. Error bars represent standard error of the mean.

86x143mm (300 x 300 DPI)



Participants viewed vertical (0°), inclined (±5° to ±85° in 5° increments) and horizontal (+90°) lines through an occluded visual field while with head and body roll-tilted right. Thus, the body axis was orthogonal to the gravitational vector, and the horizontal line was congruent with the body axis and upright on the retina and on the visual field. Participants were asked to rate the attractiveness of each line using a 0-7 scale. No preference for the horizontal stimulus emerged over any other stimulus, except the vertical line. These results suggest that the preference for a vertical stimulus in Experiment 1 was therefore not driven by the orientation of the stimulus on the retina or on the visual field. Error bars represent standard error of the mean.

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