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When Viewing Variations in Paintings by Mondrian, Aesthetic Preferences Correlate With Pupil Size

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Observers consciously prefer Mondrian's paintings in their original orientation compared with a rotated position—the "oblique effect" (Latto, Brain, & Kelly, 2000). However, this finding's premise, that all vertical–horizontal orientations of the thick black lines in Mondrian's oeuvre are preferred, overlooks the fact that the overall balance of these images is also altered when they are reoriented. Thus, balance may regulate the oblique effect, which might influence conscious aesthetic preferences. To address this issue, we explore Hess's (1965, 1972) claim that observers will unconsciously increase their pupil diameter to pleasing images and constrict it to unpleasant images. We overcame Hess's methodological limitation of not keeping his images' luminances and contrast constant across conditions by presenting eight Mondrian paintings (1921–1944) to 30 observers on a CRT for 20 s each in either their original or seven rotated positions. Simultaneously, we measured their pupil size while asking them to report how (dis)pleasing they found each image. We found both evidence for the oblique effect (where image rotation hampers preference) and a correlation between this consciously reported aesthetic preference and unconsciously derived pupil size.

Keywords: Mondrian, pupil diameter, aesthetic ratings, oblique effect, balance

In 2000, Latto, Brain, and Kelly extended the psychophysical "oblique effect" phenomenon, otherwise known as *meridonal anistrophy*, to the field of aesthetics. Coined by Stuart Appelle (1972), the psychophysical oblique effect states that "our perception of oblique or diagonal lines is slightly inferior to our perception of horizontal and vertical lines" (p. 982). The later abstract paintings (1921–1944) of Piet Mondrian (1872–1944) contain only horizontal and vertical lines (even when the paintings tilt 45° in a lozenge), which Latto et al. had observers rate for pleasingness either in their original or in rotated positions. They found that observers preferred the original (i.e., horizontal and vertical line) positions. However, rotating Mondrian paintings may also have upset the balance of the works (Locher, Overbeeke, & Stappers, 2005), obscuring what may underlie these differential aesthetic verbal reports. Given the potentially divergent explanations for Latto et al.'s findings, we circumvented the limitations of using only conscious verbal judgments by also using a low-level unconscious indicator of preference, pupil size (Hess & Polt, 1960; Janisse, 1974; Loewenfeld, 1999).

Eckhard Hess (1965, 1972) influenced the field of aesthetics by claiming that pupils enlarge when viewing pleasant images and constrict when viewing unpleasant images. For example, Hess and Polt (1960) found that compared with male observers, female observers had larger pupil dilation to images of a baby, a baby and mother, or a nude male. Conversely, men had larger pupil dilation to a nude female. Likewise, Hess, Seltzer, and Shlien (1965) were able to differentiate homosexual and heterosexual individuals on the basis of pupil diameter while they viewed nude images of same- or opposite-sex individuals. Thus, Hess and others concluded that pupil dilation is a reliable index of interest, emotion, and motivation (Fitzgerald, 1968; Goldwater, 1972; Hess, 1965; Hess et al., 1965; Simms, 1967).

However, pupil size varies with luminance (Goldwater, 1972; Janisse, 1973, 1974, 1977; Loewenfeld, 1966, 1999; Loftus, 1985; Woodmansee, 1966), and because Hess compared different images that had different intensities and contrast levels, his work was hopelessly confounded (Kohn & Clynes, 1969; Locher, 1996; Miller, 1967). In essence, Hess measured pupil size to appealing images (evoking dilation) and then measured pupil size to unappealing images (evoking constriction). However, these were different images. Thus, the changes in pupil size may have been the result of different images having different luminances and contrast. This is a fatal confound; pupil size differences may not have been the result of the appeal of the images per se. Our study overcomes Hess's limitations by using a new methodology that compares pupil diameter with verbal reports of aesthetic pleasingness between original and rotated paintings. That is, in our experiment the same image was rotated so that its luminance and contrast did not vary. This way, when measured across these images, any pupil-size fluctuations are not the result of changes in luminance or contrast. This is what Hess did not control for.

Moreover, although most investigations found pupil dilation to positive stimuli, many were unable to support Hess's claim that the pupil constricts to negative stimuli (Andreassi, 2000; Goldwater, 1972; Janisse, 1973, 1974; Loewenfeld, 1999; Nunnally, Knott, Duchnowski, & Parker, 1967; Peavler & McLaughlin, 1967). Our

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new methodology allows us to reexamine these earlier works that disagree with Hess's findings, such as Woodmansee's (1967) and Tinio and Robertson's (1969) suggestion that pupil dilation may occur to unpleasant stimuli or Libby, Lacey, and Lacey's (1973) report that they could not define the effective characteristics of those stimuli that produced constriction.

Mondrian's early works were naturalistic and realistic, consisting largely of landscapes, and the color and tone of his paintings were predominantly darker shades and lower intensity. However, after becoming interested in the theosophical movement launched by Helena Petrovna Blavatsky in the late 19th century (Blavatsky, 1960), he joined the Dutch Theosophic Society in 1909. Blavatsky (1960) believed it was possible to acquire knowledge of nature more profound than that provided by empirical or scientific means, and much of Mondrian's work for the rest of his life was inspired by his search for that spiritual knowledge. By 1913, he began to fuse his art and his theosophical studies into a theory that signaled his final break from representational painting, and by late 1919 he began producing his renowned grid-based paintings. As Mondrian eventually abandoned all representation of natural form, he quoted Cezanne, who said, "Beauty in art is created, not by the objects of representation but by the relationships of line and color" (Esman, 1994, p. 337).

The doctrine Mondrian developed was called *Neoplasticism*. He and other artists (in particular, Theo Van Doesburg) created works of art that collectively became known as *De Stijl* (The Style) around the time of World War I. Proponents of *De Stijl* sought to express a new utopian ideal of spiritual harmony and order (Fauchereau, 1994). Toward that end, they advocated pure abstraction and universality by a reduction of form and color to their essentials. The crucial tenets of Neoplasticism were that (a) only the primary colors of red, blue, and yellow or the noncolors of black, gray, and white were permissible; (b) aesthetic balance must be achieved via the use of opposition, (c) compositional elements must be straight lines or rectangular areas; (d) symmetry was to be avoided, and (e) balance and rhythm were enhanced by relationships of proportion and location. Therefore, Mondrian's desire was to posit balance in the strict verticality and horizontality of all lines and planes. This contributed to a certain fixed relation between the composition and the viewer, to whom an upright orientation is a fundamental condition. Mondrian argued for the importance of such an orientation: "Man's eye is not yet free from his body. Vision is inherently bound to our normal position" (Mondrian, 1926/1970, p. 12). Thus, Mondrian felt that balanced relations could be obtained using pure form and colored surfaces. He felt that placing horizontal and vertical grids on a diagonal would destroy a painting's balance, just like using colors other than primaries. Mondrian felt so strongly about using only horizontal and vertical lines that when Theo van Doesburg insisted on using diagonals, Mondrian broke off their friendship and left the *De Stijl* movement (Esman, 1994, p. 332).

Thus, Mondrian was preoccupied with the specific proportions of his colored regions and their relationship to his bold horizontal and vertical lines (Nodine & McGinnis, 1983). Locher et al. (2005) altered compositions by Mondrian by swapping the colors in the colored regions. This altered the amount of each color (because each colored region differed in size), which the researchers claimed changed the perceived weight of the areas and thus the location of the balance centers of the compositions. They showed that manipulating these regions influenced observer's perception and evaluation of Mondrian's work. Because Mondrian's desire was to create balance and harmony in his works, we claim that such effects can be detected in observers' aesthetic evaluations. Thus, the oblique effect might influence balance, which might consequently influence aesthetic preferences. This may be because that rotation may disrupt the balance of Mondrian's images. It is important to realize that preferred and nonpreferred images are simply rotations of each other, leaving no a priori reason to expect differences in pupil size. Thus, we hypothesize that compared with nonpreferred images, preferred images should produce larger pupil diameters.

Perhaps the earliest mention of the oblique effect was by Mach (1861, as cited in Westheimer, 2003), who found that observers were more accurate at matching a line parallel to a horizontal or vertical comparison line than to an oblique line. Likewise, Jastrow (1893, as cited in Appelle, 1972) found that observers required to reproduce lines were markedly superior with horizontal and vertical stimuli than with oblique stimuli. Higgins and Stultz (1949) also found that observers had 20% higher visual acuity when lines passing through their visual field were horizontal or vertical rather than oblique.

Latto et al. (2000) claimed that the psychophysical oblique effect may give rise to an aesthetic oblique effect, which is the notion that people prefer vertical and horizontal lines over oblique lines. They explored this possibility by examining the aesthetic oblique effect using the abstract art of Piet Mondrian. Latto et al. showed 30 observers 64 images of Mondrian's paintings taken from 1921 to 1944. There were eight initial paintings, four with horizontal and vertical formats and four with oblique (i.e., lozenge) formats (see Figure 1), which they rotated seven times at 45° intervals. Half of the rotations created oblique components or lines (45°, 135°, 225°, and 315°), and the other half created horizontal and vertical components or lines (original orientation, 90°, 180°, and 270°). They presented each image for 5 s and asked observers to rate each on a 7-point scale of aesthetic pleasingness. They found that observers rated images with horizontal and vertical components as more aesthetically pleasing than images with oblique components. They also found that the original orientation was preferred over rotated versions, specifically over all rotations that produced oblique components. They concluded that there were two factors that reduced the appeal of Mondrian paintings; one was rotation per se and how that might have affected the overall balance of the painting, and the other was the introduction of obliquely oriented components (Latto et al., 2000, p. 984). They concluded that "we prefer horizontal and vertical lines because they are perceptually more powerful" and therefore more effectively processed by our visual system (Latto et al., 2000, p. 986). We look to extend Latto et al.'s (2000) research (a conscious measure of aesthetic preference) by correlating it with pupil size, often considered to be an unconscious measure.

Method

Participants

Thirty Wake Forest University undergraduate students (nine men and 21 women) with normal or corrected-to normal vision (but no eyeglasses because they disrupt picking up an observer's

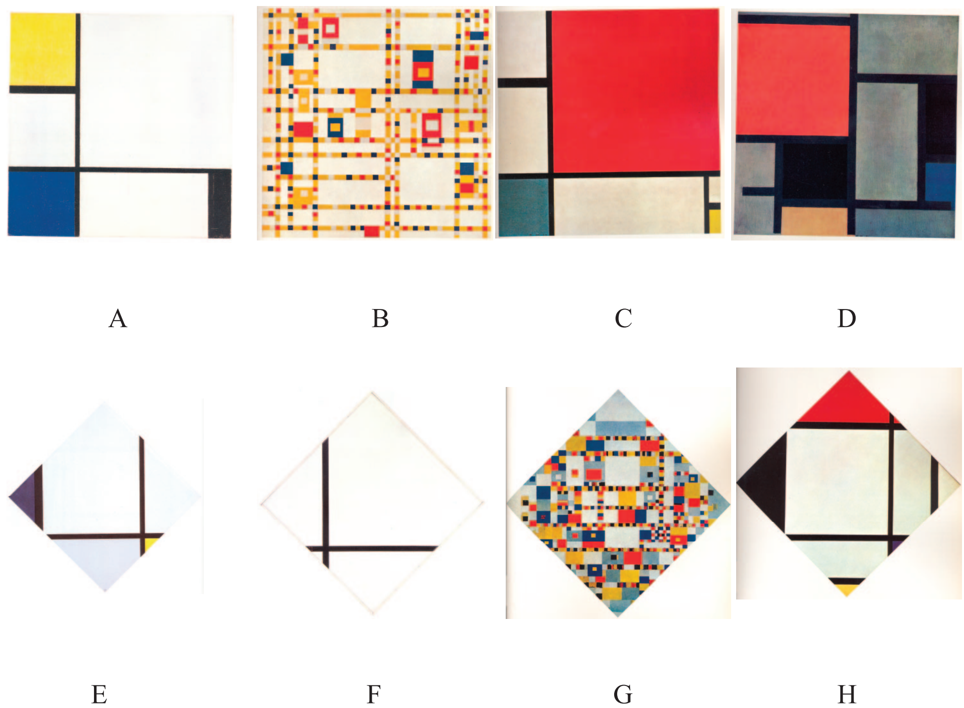

Figure 1. (A) *Composition in a Square* (1929); (B) *Broadway Boogie-Woogie* (1942–1943); (C) *Composition With Red, Blue, and Yellow* (1930); (D) *Composition With Red, Yellow, and Blue* (1927); (E) *Composition I With Blue and Yellow (Lozenge)* (1925); (F) *Composition With Two Lines* (1931); (G) *Victory Boogie-Woogie* (1943–1944, unfinished); (H) *Composition in a Lozenge* (1925).

corneal reflection by causing their own reflection) participated in the experiment in exchange for course credit. The study was performed in accordance with the ethical standards of the Declaration of Helsinki. Ages ranged from 18 to 24 years with a mean age of 19. After completing the experimental paradigm, six observers reported having been somewhat familiar with Mondrian's work and another five observers reported having been extremely familiar with Mondrian's work. However, none of the observers were art majors, nor had they taken a college art course. Their previous exposure to Mondrian's work reflects the prominence of his work in the visual arts, which is represented in a number of museums and art books.

Stimuli and Apparatus

We used eight color images of Mondrian paintings—all oil on canvas—adopted from Latto et al. (2000). We used colored images because they best reflect Mondrian's aesthetic intent even though we realize that color, like luminance, can affect pupil diameter (Kohn & Clynes, 1969; Miller, 1967). Each painting consisted of only horizontal and vertical lines and colored regions and had sides of equal length. As in Latto et al.'s study, to control for format orientation, four paintings had horizontal and vertical formats and four had oblique formats (see Figure 1). We could have obscured the format but not its orientation because some of the pictures formats were square and some were lozenges. Thus, there is no way to eliminate this issue. However, there were no differences between square formats and lozenges, thus the format per se should not have affected observer's responses. Each painting was rotated seven times at 45° intervals, creating eight different images, four with only horizontal–vertical components (original, 90°, 180°, and 270° rotations) and four with only oblique components (45°, 135°, 225°, and 315° rotations). Thus, a total of 64 images were presented to each observer.

Hess's (1965, 1972) experiments measured pupil size to appealing images (evoking dilation) and then measured pupil size to different unappealing images (evoking constriction). Thus, variations in pupil size may have been the result of different images having different luminances and contrast, instead of the appeal of the images per se. In contrast, we rotated the same image, keeping luminance and contrast constant. Thus, although luminances and contrast vary across pictures (there is no way to control for this), they are constant within the rotated versions of each picture.

The experiment was run in a 6 ft × 8 ft (1.8288 m × 2.4384 m) research lab that contained only the experimental apparatus necessary for collecting the pupil-size data. The room was dark except for the illumination coming from the computer screen that projected the images. The 64 images were presented to observers individually in a single random order in an automatically run PowerPoint slide show on a 21-in. (53.3 cm) CRT screen that was 36 in. (91.4 cm) from the observer's eyes. It was not the case that one picture and all of its rotations were presented before another picture. Observers used a chin rest to ensure a fixed distance between themselves and the screen. This fixed distance retains a constant depth of field across the images (Simms, 1967). The images were standardized in visual angle size (i.e., horizontal and vertical formats [16.3° × 16.3°] and oblique formats [22.6° × 22.6°]).

We fit an Applied Science Laboratories (Bedford, MA) Model 501 eye-tracking device (series 6000; with a temporal resolution of 60 Hz) onto each observer's head and calibrated it to his or her gaze. Only the left-eye pupil size was measured because pupil size is believed to be conjugate across the two eyes (Loewenfeld, 1999). Pupil diameter was measured automatically and continuously every 17 ms for the entire 20 s observers viewed each image because pupil size can vary over a 20-s viewing period. The 20 s of viewing was then averaged to give a mean pupil size for each image.

Procedure

Unlike the original Latto et al. (2000) study (which presented each image for only 5 s), we presented each image for 20 s on the basis of three previous findings. First, researchers found that art viewers examined paintings in the Metropolitan Museum of Art for a median time of 17 s (J. K. Smith & Smith, 2001). Second, prior studies have shown a rapid decrease in pupil size on presentation of images, which then recover to either baseline or above-baseline levels (Aboyoun & Dabbs, 1998). Consequently, it is important to record pupil size for at least several seconds to overcome this initial fluctuation. Last, Richer, Silverman, and Beatty (1983) found that pupillary dilation peaked around 1 s after presentation. As a result, observers were given more time than needed to generate an entire response to an image. However, it is noteworthy that when viewed for 1 min or less, the perception of several significant works of art, including a Mondrian, did not differ as measured by the semantic differential (L. F. Smith, Bousquet, Chang, & Smith, 2006).

Each observer verbally rated each image on a 7-point scale of pleasingness on which 1 represented *not at all pleasing*, 4 represented *neutral*, and 7 represented *extremely pleasing*. We chose this scale because it positively correlates with scales of likability and preferability (Russell & George, 1990). Observers were encouraged to use the whole range of the scale. They were told in advance that the images would be shown in several rotations.

A visual calibration was done by showing observers an initial slide on the CRT screen with the numbers 1–9 dispersed across three rows. They were instructed to focus on each number, one at a time, while we calibrated their gaze. Observers then focused on a subsequent fixation cross in the middle of the CRT screen. After 5 s, an image was shown for 20 s during which time we recorded observers' pupil size. After the picture-viewing period, there was a 5-s interstimulus interval during which the observers refixated on the middle cross of the screen while they verbally rated the prior image on the 7-point scale of aesthetic pleasingness. This process continued until all 64 images were viewed and rated. The entire experiment took approximately 30 min.

Results

We ran a one-way within-subjects analysis of variance (ANOVA) that compared the pleasingness rating of each original image to each of the seven rotated versions (see Figure 2). That is, the data were collapsed across all eight pictures but were kept separate by rotation. This allowed the ANOVA to reflect any main effect of line orientation. In agreement with Latto et al. (2000), we found that observers rated pictures composed of horizontal and vertical lines as more aesthetically pleasing than pictures composed of oblique lines ($M = 4.34$, $SEM = 0.287$, vs. $M = 3.91$, $SEM = 0.281$, respectively), $F(1) = 12.548$, $p < .001$, effect size $r = .782$. A series of t tests revealed that the original orientation ($M = 4.64$, $SEM = 0.106$) was significantly greater than all of the oblique orientations (45°: $M = 3.96$, $SEM = 0.102$, $t[29] = 6.595$, $p < .001$, effect size $r = .775$; 135°: $M = 3.91$, $SEM = 0.109$, $t[29] = 7.496$, $p < .001$, effect size $r = .812$; 225°: $M = 3.94$, $SEM = 0.107$, $t[29] = 7.159$, $p < .001$, effect size $r = .799$; and 315°: $M = 3.85$, $SEM = 0.103$, $t[29] = 7.785$, $p < .001$, effect size $r = .822$; all one-tailed). However, the original orientation was statistically insignificantly different from all of the images with horizontal and vertical lines ($p < .05$). Because we did seven post hoc t tests, a Bonferroni adjustment of $p < .0071$ is statistically

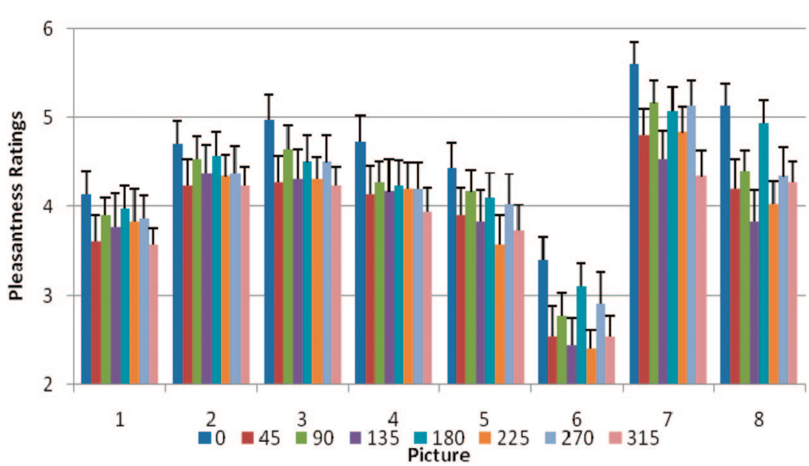

Figure 2. Average pleasingness ratings for eight pictures as a function of eight picture orientations. Degrees of image rotation are color coded in legend. (Error bars equal *SEM* for $N = 30$).

significant. Given our degree of freedom of 29 and that we compared seven groups, Tukey's post hoc test (Honestly Significant Difference) stipulates needing a critical value greater than 5.40 to be statistically significant ($p < .01$). This was the case for all oblique orientations, but not for any of the images with horizontal and vertical lines. These findings confirm Latto et al.'s (2000) main finding, thereby demonstrating an aesthetic oblique effect. Note that although some pictures were markedly preferred over others (e.g., compare Picture 7 and Picture 6), for which neither we nor Latto et al. (2000) have any hypotheses, the pattern of preferences for the original over the rotated images and for horizontal and vertical orientations versus oblique orientations was consistent across pictures.

Overall, pupil diameters were well within the normal range (Schmitz, Krummenauer, & Henn, 2003), where the picture viewed affected pupil size (Figure 3; range = 5.48 mm–6.78 mm). Thus, some pictures produced significantly greater pupil diameter than others. This is because different pictures had different luminance and contrast levels. This is expected but unrelated to our main hypotheses, except to show that we were correct in using rotated versions, so as to not repeat Hess's (1965, 1972) fatal confound of comparing pupil size across different pictures.

Consequently, we ran a one-way within-subjects ANOVA that compared the average pupil diameter of each original image with each of the seven rotated versions (see Figure 3). That is, the data were collapsed across all eight pictures but were kept separate by rotation. Thus, the ANOVA was able to discern a main effect of line orientation. We found that observers' pupil size was larger when viewing pictures composed of horizontal and vertical lines than pictures composed of oblique lines ($M = 61.84$, $SEM = 1.882$, vs. $M = 56.44$, $SEM = 2.137$, respectively), $F(1) = 6.432$, $p < .001$, effect size $r = .916$.

A series of t tests revealed that the original orientation ($M = 66.29$, $SEM = 0.605$) was significantly greater than all of the other orientations (45°: $M = 56.57$, $SEM = 0.718$, $t[29] = 19.534$, $p < .001$, effect size $r = .964$; 90°: $M = 60.87$, $SEM = 0.657$, $t[29] = 14.585$, $p < .001$, effect size $r = .938$; 135°: $M = 57.26$, $SEM = 0.736$, $t[29] = 20.070$, $p < .001$, effect size $r = .966$; 180°: $M = 60.64$, $SEM = 0.692$, $t[29] = 13.375$, $p < .001$, effect size $r = .928$; 225°: $M = 55.53$, $SEM = 0.791$, $t[29] = 19.528$, $p < .001$, effect size $r = .964$; 270°: $M = 59.56$, $SEM = 0.703$, $t[29] = 15.021$, $p < .001$, effect size $r = .941$; and 315°: $M = 56.40$, $SEM = 0.746$, $t[29] = 19.149$, $p < .001$, effect size $r = .963$; all one-tailed). Again, these results remained significant after a Bonferroni adjustment and with a Tukey Honestly Significant Difference test.

We also ran a paired samples t test for each observer, comparing their pleasingness ratings on each of the eight pictures for each of the eight rotations and their pupil diameter on each of the eight pictures for each of the eight rotations. We then took those 30 correlations and ran a one-sample t test obtaining a statistically significant correlation of $R^2 = 0.347$, $t(29) = 14.358$, $p < .001$, effect size $r = .936$ (Figure 4, where $y = 3.6x + 4.43$).

Because six observers reported having been somewhat familiar with Mondrian's work and five reported having been extremely familiar with his work, we reanalyzed the data set without these 11 observers. This did not alter the significance or direction of any of our findings.

Discussion

The pleasingness data from our experiment support an aesthetic oblique effect (Latto et al., 2000). Haun, Hansen, and Essock (2006) also showed that observers preferred horizontally and vertically oriented Mondrians to those presented on the oblique (which they call a horizontal effect). However, they obtained their results using a different method than Latto et al. (2000). They presented all eight versions of each picture (i.e., the original and its seven rotations) simultaneously and had observers rank-order the images, with 1 indicating the best image and 8 indicating the worst image. Given that we were interested in pupil size obtained while viewing (and mentally evaluating) each image, we were not able to present all images simultaneously.

As Stern and Strock (1987) noted, "One drawback to the use of pupillometry for investigating psychological variables is that changes associated with such variables are considerably smaller than those associated with illumination effects" (p. 251). Our new methodology reflects this artifact (e.g., compare Picture 2 with

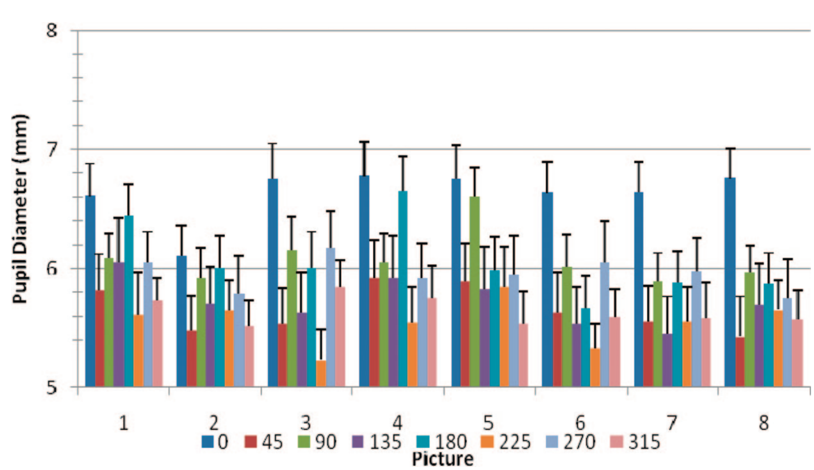

Figure 3. Average pupil diameter (millimeters) for eight pictures as a function of eight picture orientations. Degrees of image rotation are color coded in legend. (Error bars equal SEM for $N = 30$).

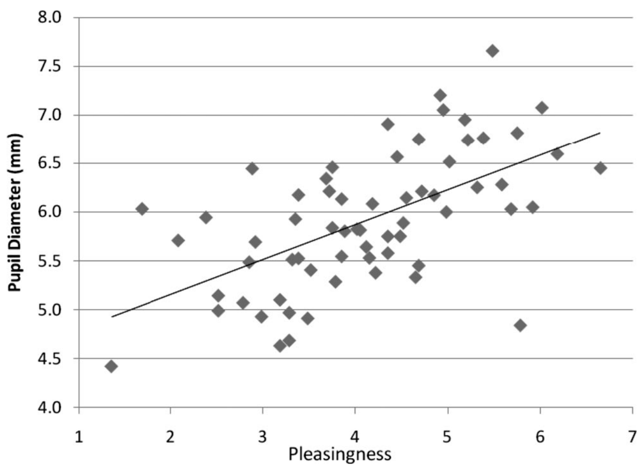

Figure 4. Average pupil diameter as a function of average pleasingness ratings for eight pictures in eight picture orientations ($N = 30$).

Picture 5 in Figure 3) while eliminating Hess's (1965, 1972) confound of fluctuations in luminance and contrast across images. Our design allowed us to observe how an unconscious measure, pupil size, varies as a function of the differences in conscious verbal reports of pleasant and less pleasant images. Thus, our findings support Hess's (1965, 1972) predictions of both dilation and constriction; pleasant images are associated with a larger pupil diameter, which systematically decreases as images become less pleasant.

Locher et al. (2005) have shown that altering the locations of the primary colors of specific Mondrians alters the perceived heaviness of a primary color. This may have altered the pictures' balance. Similarly, by rotating Mondrians, we may have altered their balance, which may have resulted in obtaining the oblique effect. This was determined via a conscious verbal report of pleasingness. However, we surmise that finding differences in pupil size goes beyond the oblique effect. If not, there would have been differences in conscious verbal reports and pupil dilation between the original orientation and all other orientations rather than only the oblique orientations. This notion agrees with the work of Nodine and McGinnis (1983), who added an extra rectangle of color to an original Mondrian to shift its pictorial balance, and the work of Wolach and McHale (2005), which suggests that observers prefer the way Mondrian spaced his lines compared with computer-generated images (but see Noll, 1966, and McManus, Cheema, & Stoker, 1993). However, we did not measure interest or balance, only aesthetic preferences. This was because we wanted to emulate Hess's (1965, 1972) initial work involving pupil size and preference and Latto et al.'s (2000) work related to pleasingness. However, in the future it may prove efficacious to measure interest or balance to determine whether these factors directly affect pupil size.

Further studies are also required to determine how the oblique effects affect aesthetic judgments and how pupil response relates to other types of artistic compositions. For example, the works of several abstract artists contain lines or edges at orientations other than vertical or horizontal—Kandinsky and Malevich come to mind. Yet these pictures appear both balanced and pleasing. Thus, it would be quite interesting to know what rotating such images would elicit. If rotating such images produced both less pleasing images and smaller pupil size, we would know that pleasingness is not driven by the component of the oblique effect as proposed by Latto et al. (2000) per se that is related to obliquely related components, but may involve a more complex formula for balance, which would consider line orientation but also color, open space, arrangement, and so forth.

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