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RESEARCH ARTICLE

Emotive hemispheric differences measured in real-life portraits using pupil diameter and subjective aesthetic preferences

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Abstract The biased positioning of faces exposed to viewers of Western portraiture has suggested there may be fundamental differences in the lateralized expression and perception of emotion. The present study investigates whether there are differences in the perception of the left and right sides of the face in real-life photographs of individuals. The study paired conscious aesthetic ratings of pleasantness with measurements of pupil size, which are thought to be a reliable unconscious measure of interest first tested by Hess. Images of 10 men and 10 women were taken from the left and right sides of the face. These images were also mirror-reversed. As expected, we found a strong preference for left-sided portraits (regardless of original or mirror-reversed orientation), such that left hemifaces elicited higher ratings and greater pupil dilation. Interestingly, this effect was true of both sexes. A positive linear relationship was also found between pupil size and aesthetic ratings such that pupil size increased with pleasantness ratings. These findings provide support for the notions of lateralized emotion, right-hemispheric dominance, pupillary dilation to pleasant images, and constriction to unpleasant images.

Keywords Emotional hemispheric laterality · Valence hypothesis · Aesthetic pleasantness · Pupil dilation/constriction · Face perception

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Introduction

The social-communicative aspects of human emotions are thought to be derived primarily from facial expressions since highly specialized facial muscles are capable of differentiating between many unique emotions. Recent research has shifted towards more detailed descriptions of neural mechanisms showing that specific facial muscles respond to different emotions. For example, the lower face (including the cheeks, lower nose, mouth, and chin) shows a significant amount of "lateral independence of action", meaning that individuals can unilaterally manipulate one corner of the mouth to curve upward while keeping the other relatively stationary (Rinn 1984).

Theories of facial asymmetries during emotional expression

Charles Darwin (1872) was the first of many to detect asymmetrical facial differences, observing that the canine tooth tended to be uncovered on only one side of the mouth when a person sneered. Facial asymmetry is defined as the "expression intensity of muscular movement on one side of the face (hemiface) relative to the other side of the face". It is a particularly useful behavioural indicator of cerebral hemispheric specialization of emotional expressions. For example, the facial muscles on one side of the lower face are innervated by neural circuits from the contralateral cerebral hemisphere (such that the left hemisphere of the brain manipulates the right side of the lower face and vice versa) (Rinn 1984; Borod et al. 1997). This bilateral independence of facial muscles may allow humans to simultaneously display qualitatively different emotions on either side of the face.

The possibility of divergent left- and right-hemiface emotional expressions has shown that hemifacial expressions differ not only anatomically, but also differentially impact those who observe them. Kowner (1995) provides an overview of the two main neuropsychological theories of brain specialization for emotion: the valence hypothesis, which postulates that the left brain hemisphere (right hemiface) is specialized for positive emotions and the right hemisphere (left hemiface) for negative emotions, and the right-hemisphere hypothesis that states that the right hemisphere dominates overall in the perception and expression of emotions regardless of their valence. The latter hypothesis has gained a great deal of support. This has been evidenced by findings that the right hemisphere has greater control over voluntary (posed) emotional expressions, accounting for the lower two-thirds of the contralateral facial musculature (Borod and Caron 1980; Brodal 1965; Kowner 1995). Likewise, several reports posit that the left side of the face is more intense and active during voluntary emotional expression (Sackheim et al. 1978; Borod et al. 1997).

Biased positioning of faces and sex differences in artistic portraits

A significant number of portraits skew the position of the facial profile, establishing a clear artistic preference for presenting the left cheek in portraits (McManus 2005). One examination of 1,474 Western European portraits found that the majority of posers (~64 %) exposed their left cheeks while only ~33 % exposed their right cheeks. More importantly, this leftward bias occurred more often in portraits of women than in portraits of men (McManus and Humphrey 1973). Although this sex difference has yet to be sufficiently explained, Powell and Schirillo (2009, 2011) provide two possible interpretations—first, males may prefer to *not* reveal their emotive left hemiface as much as females and second, it may be the artist's intention to portray women as being more emotive than men by displaying their more expressive left cheeks. Another leftward bias explanation suggests there may be asymmetrical differences in the portrait viewer's perception of emotional expression. Research has shown that the right cerebral hemisphere is superior in the perception of emotional stimuli that may ultimately cause a left visual-field advantage for the processing of emotional content (Gilbert and Bakan 1973).

Conscious aesthetic preferences versus unconscious pupil size

Although many theories have attempted to account for the historically pervasive artistic bias in portraiture, none so far have linked this phenomenon to lateralized emotional expression. Thus, research efforts have shifted to examine observers' aesthetic preferences of differentially oriented images to find evidence that emotional laterality results in perceptual differences in portraiture. A number of studies have since concluded that observers generally attend to the poser's actual facial characteristics when assessing portrait attractiveness (Schirillo 2000; Powell and Schirillo 2009, 2011). Thus, hemispheric emotive asymmetries may to some degree influence the perception of beauty.

Many popular methodologies link aesthetics to hemispheric specialization by examining an observer's subjective impressions of the emotional content in visual stimuli. However, observers may use a number of different visual elements (e.g. image contrast or specific facial features) to derive aesthetic judgments. To overcome this limitation, Powell and Schirillo (2011) simultaneously acquired aesthetic judgments of original and mirror-reversed images along with pupil diameter measurements that have previously been used as reliable unconscious physiological indicators of emotional arousal (Bradley et al. 2008).

Hess and Polt (1960) were the first to report an effect of emotional valence on pupil size. They revealed that pupils constricted when viewing unpleasant images but dilated when viewing pleasant images. Unfortunately, these results were confounded because luminance varied across images that caused considerable variation in pupil size (Hess et al. 1975; Lowenfeld 1999; Bradley et al. 2008).

Bradley et al. (2008) and Powell and Schirillo (2011) specifically re-examined Hess' proposal by testing the effects of picture emotionality on pupil diameter across paired original and mirror-reversed grey-scale images (thereby controlling the effects of luminance variance on pupil size). Both studies concluded that pupillary changes during picture viewing were due to sympathetic activation (emotional arousal) as they covaried with skin conductance changes and the perception of emotional content regardless of valence. In other words, pupil size was related to the emotional *intensity* of images rather than specific positive and negative emotive connotations.

Current experimental design and predictions

The current study tests whether one side of the face is more aesthetically pleasant than the other by pairing conscious aesthetic ratings of pleasantness with the unconscious physiological measure of pupil size. It is of particular interest to relate these two measures to facial asymmetries caused by brain specialization of emotions and/or right-hemisphere dominance. This will prove useful in constructing a more definitive neuropsychological explanation for the perceptive biases in artistic portraiture noted throughout history.

Grey-scale photographs were taken simultaneously from both sides of 20 (men and women) individuals' faces and presented to 37 observers for an aesthetic judgment task. Observers rated their perception of each image's "pleasantness" while their pupil size was simultaneously measured. It was expected that as image pleasantness increased so would pupil size. Also, higher ratings of pleasantness were expected to be assigned to women's left hemifaces, but no hemiface preference was expected for males. Likewise, a leftward female bias was also expected to occur with pupil size measurements such that significantly greater pupil dilation would be elicited while viewing female left hemifaces, but not while viewing either hemiface in male images.

Methods

Participants

All procedures were approved by the Institutional Review Board of Wake Forest University and were performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki. Twenty volunteer participants (10 men and 10 women; age, 35–65) from the Wake Forest University Psychology Department and a local insurance company (ACS Benefit Services) posed for portraits (Fig. 1). An older-age portrait group was chosen because their more mature faces allowed for easier assessments of their emotive qualities. To determine which final sets of pictures to use, ten volunteer from Wake Forest undergraduates rated the images (in addition to an eleventh rater who was a tiebreaker for one particular set of pictures). An additional 37 observers (23 women and 14 men; age, 18–22) with normal or corrected-to-normal (20/20) vision (but no glasses) from undergraduate Introductory Psychology courses at Wake Forest University participated in the picture-viewing task for course credit.

Stimuli

To acquire the pictures, two digital cameras on tripods were positioned at a 37.15° visual angle to either sides of the poser's face. This slightly less than 45° angle allowed the cameras to capture both of the poser's eyes and right- and left-facial features while still maintaining a hemiface bias. Figure 1 shows six representative posers reflecting the fact that the posers were looking straight ahead so that the cameras captured equal amounts of right- and left-facial features while also showing that their heads were not canted to avoid potentially biasing a given pair of images. This fact was verified by three naïve raters who used a 1–5 rating scale where "1" indicated looking straight ahead and "5" indicated turned significantly towards one side, and a separate 1–5 rating scale where "1" indicated no head cant and "5" indicated significant head cant. Straight ahead indices equalled 1.3 while cant indices equalled 1.1, and inter-rater reliability was calculated using Kendall's coefficient of concordance ($W = 0.78$ for sidedness and $W = 0.84$ for cant, respectively). Collecting left- and right-cheeked paired images minimized pupil size differences due to variation in image contrast or luminance. Pictures included the poser's face, hair, neck, and shoulder/neck area, along with any accessories that posers chose to wear (with the exception of hats and glasses). Light intensity was kept relatively constant across both sides of the face by using only overhead lighting.

Posers were instructed to "smile as naturally as possible" and to focus on a fixation point, positioned approximately 61 cm in front of and level with the posers' face to ensure that the poser was not looking directly at either camera. Posers pressed a button on a manual dual-timer remote to make both cameras fire simultaneously. They took 5–6 simultaneous sets of images of themselves. They were

Fig. 1 *Six* representative posers indicating that equal proportions of *right* and *left sides* of the face were captured

allowed to pause and readjust their posture (and pose) between successive pictures.

Adobe Photoshop was used to crop pictures so that the left- and right-cheek images were proportionate to each other. Because the pupil responds differentially to various colours, all 40 images were also converted to grey scale to minimize variance (Bradley et al. 2008). The images were further modified using a Gaussian blur function (with a standard deviation of 100 pixels radius of images that were, on average, 1,600 pixels squared) to create 40 blurred images that served as a baseline prior to the appearance of their corresponding original (non-blurred) image. All images were also mirror-reversed so that an original right-cheek image appeared to be a left-cheek image and vice versa. This led to a total of 8 pictures per poser—1 original right cheek, 1 original left cheek, 1 mirror-reversed right cheek, 1 mirror-reversed left cheek, and 4 blurred images corresponding to each of the latter pictures. To avoid confusion, we always labelled the poser's anatomical side from which the image was taken as the "true" left/right side versus their "perceived" left/right side. This takes care of when we mirror-reversed images. Each set of simultaneous left- and right-cheek images was printed on a single sheet of paper so that ten raters could use an ordinal scale to evaluate and rank the sets of pictures to determine the final set of images to be used in the picture-viewing task in terms of how natural/genuine the poser's smile appeared. This scale ranged from 1 to 5, with a "1" meaning the least natural/genuine looking smile and a "5" meaning the most natural/genuine looking smile. Each rater's scores for all 100+ pictures were summed to obtain the pictures deemed to have the most natural posed smile by consensus of all 10 raters. Inter-rater reliability was calculated using Kendall's coefficient of concordance ($W = 0.363$ for male images and $W = 0.491$ for female images).

For the picture-viewing task, the final sets of images were presented using MediaLab on an IBM CRT computer monitor using a randomized block design without replacement so that each of the four types of images would be presented only once within a block (making it impossible to see two images of the same poser in succession). A head-mounted ASL (Applied Science Laboratories) eye tracker recorded observer's left-eye pupil diameter every 17 ms. Since pupil size is believed to be constant across eyes, it was necessary only to take measurements of one eye (Lowenfeld 1999; Powell and Schirillo 2011). The device stopped recording when the observer's eyes were closed more than 50 % (due to blinks or partial closure of the eyes); therefore, these data were eliminated automatically. A chin rest was used to maintain a viewing distance of 24″ between the observer and the computer screen (Duchowski 2007). This distance was previously determined to limit eye movements "off-screen" to approximately 3 % of the overall viewing time (Powell and Schirillo 2011).

Design and procedure

Each picture was presented for 15 s during which time observers were instructed to consider how aesthetically "pleasing" they found the image, with a "1" meaning most displeasing, a "5" meaning neutral, and "9" meaning most pleasing. Pleasantness was chosen as an appropriate evaluative measure in that Russell and George (1990) established that pleasantness was highly correlated with likeability and preferability and was the highest of 5 different evaluative scales in intersubject agreement.

Blurred versions of the original 40 images were presented prior to each original (non-blurred) image for 10 s. Pupil diameter was recorded only during the presentation of the original image. The purpose for presenting blurred images was to cause observer's pupil size to adjust to the overall luminance level of each subsequent clear image. After the presentation of a clear image, observers recorded their rating for the previous (clear) image using the aesthetics judgment scale aforementioned, after which they viewed the next blurry image for 10 s followed by a clear image for 15 s. This procedure was repeated for the remaining images.

It is known that pupil size decreases rapidly after presenting a new image; therefore, the pupil required enough time to stabilize and recover to or above baseline levels (Aboyoun and Dabbs 1998). To overcome this initial depression, observers were given 6 s following the image presentation for their pupils to stabilize after which an additional 9 s were allotted to record pupil size measurements at the new stabilized level. This limited viewing time to 15 s since periods longer than 15 s may cause excessive fatigue.

Results

Verbal ratings of pleasantness

Verbal ratings of aesthetic pleasantness were recorded for each of the 80 images that ranged almost continuously from ~3.5 to ~6.5, with a grand average near neutral (~5.1). The ratings were averaged for each sex, and a paired-samples t test $(1{,}479) = -0.916$, $p = .360$ revealed no main effect of sex (of the poser) on observer's ratings (Fig. 2).

After this analysis, the raw ratings were normalized to z-scores (given that different observers used different parts of the range of possible ratings). Z-scores were subsequently converted to difference scores by subtracting each portrait's true left-image rating by the same portrait's true right-image rating and by subtracting perceived right-image ratings from perceived left-image ratings of the same portrait.

Average difference scores were calculated separately for male and female images and also separately for the two

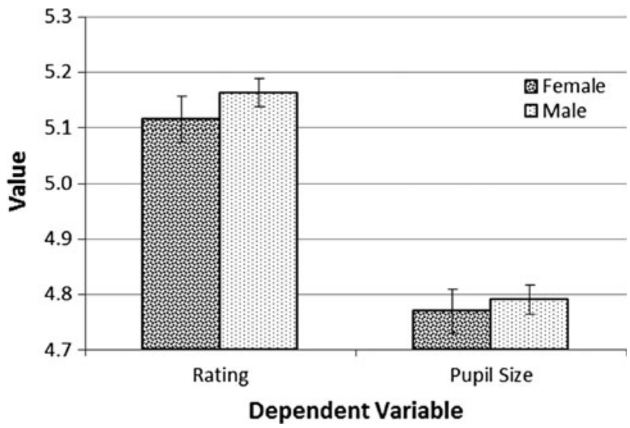

Fig. 2 Average pleasantness ratings (on a 1–9 scale) and average pupil diameter (units of mm^2) for male and female images

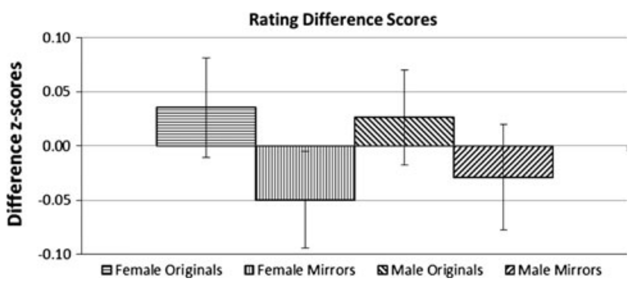

Fig. 3 Pleasingness rating difference z-scores for each portrait type

different orientations of the portraits (original or mirror-reversed; i.e. true or perceived). Thus, there were 4 different scores—female originals (i.e. true left or right), female mirror-reversed (i.e. perceived left or right), male originals (i.e. true left or right), and male mirror-reversed (i.e. perceived left or right). These different scores were then submitted to a 2 (side of face: original vs. mirror-reversed; i.e. true or perceived) X 2 (sex of poser: male vs. female) repeated measures ANOVA. This analysis indicated a marginal main effect for the side of face (F (1, 369) = 2.858, p = .092), but not for sex of poser (F (1, 369) = 0.014, p = .907). There was no significant interaction (F (1, 369) = 0.130, p = .719) (Fig. 3).

Pupil diameter

Average pupil size for male and female portraits was calculated from the raw measurements of pupil size recorded for each of the 80 images. The average pupil size elicited while viewing one sex was not significantly different than that recorded while viewing the other, by a paired-samples t test (1,479) = −0.976, p = .329 (Fig. 2).

Pupil measurements were then normalized to z-scores and converted to the above aforementioned 4 types of different scores (i.e. orientation and poser's sex). These different scores were again calculated by subtracting true right-image data from true left-image data of the same

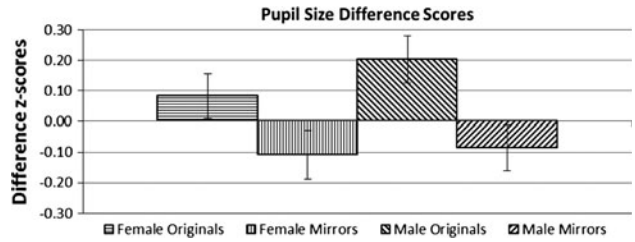

Fig. 4 Pupil size difference z-scores for each portrait type

portrait and by subtracting perceived right-image data from perceived left-image data of the same portrait and submitted to a 2 (side of face: original vs. mirror-reversed; i.e. true or perceived) X 2 (sex: male vs. female) repeated measures ANOVA. There was a highly significant main effect of side of face (F (1, 369) = 9.192, p = .003), but not of sex (F (1, 369) = 1.014, p = .314). There were no significant interactions (F (1, 369) = 0.382, p = .537) (Fig. 4).

Relationship between pleasantness ratings and pupil diameter

There was a positive correlation between ratings and pupil size across all 80 images ($R^2 = 0.242$, $r = 0.492$) (Fig. 5). Parsing the correlational data by sex and orientation determined the strength of each correlation (female original $R^2 = 0.147$, $r = 0.383$; male original $R^2 = 0.216$, $r = 0.465$; female mirror-reversed $R^2 = 0.121$, $r = 0.348$; male mirror-reversed $R^2 = 0.096$, $r = 0.310$) (Fig. 6).

Plotting average pupil size across the order of 80 trials revealed a standard U-shaped function using a second-order polynomial (Fig. 7). That is, hippus occurred. This is when the pupil diameter fluctuates by initially decreasing and then increasing as a function of time. It indicates that the pupil is returning to an enlarged size indicative of inhibition of the parasympathetic system. This was compared with a second-order polynomial function of ratings across order of trials (Fig. 8) to see whether the two variables followed the same pattern over time. This was not the case, indicating a valid relationship between pupil size and ratings that was independent of the order of image presentation.

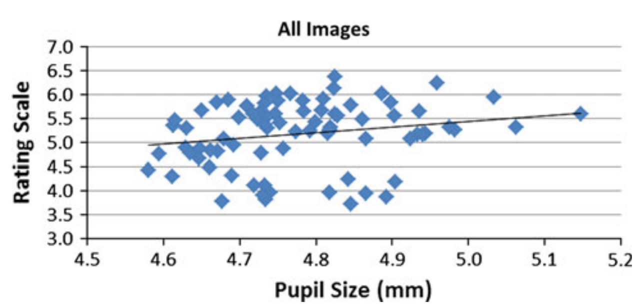

Fig. 5 Positive correlation between pupil size and ratings across all 80 images

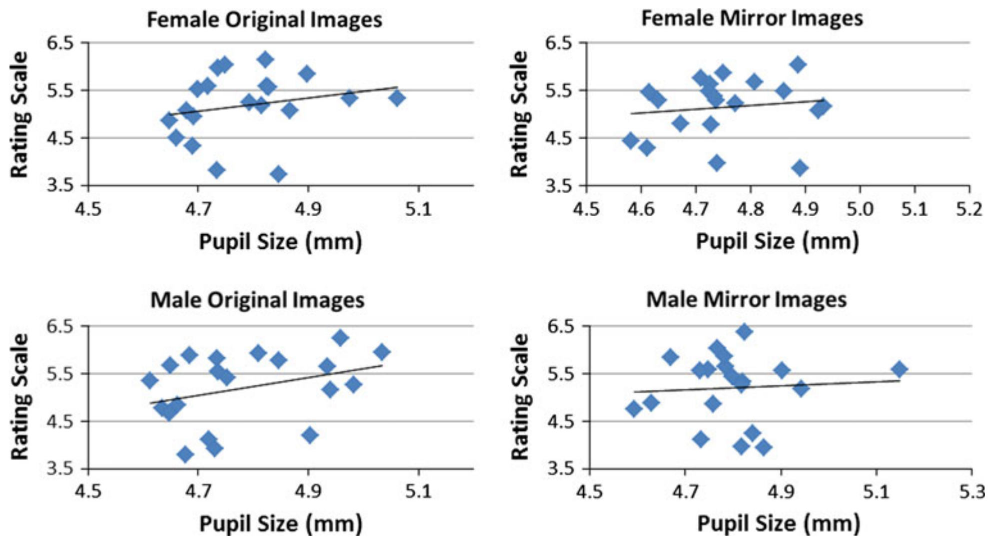

Fig. 6 Correlation between pupil size and ratings, parsed by sex (male and female) and picture orientation (original and mirror-reversed). Stronger correlations were obtained for original images than for mirror-reversed images

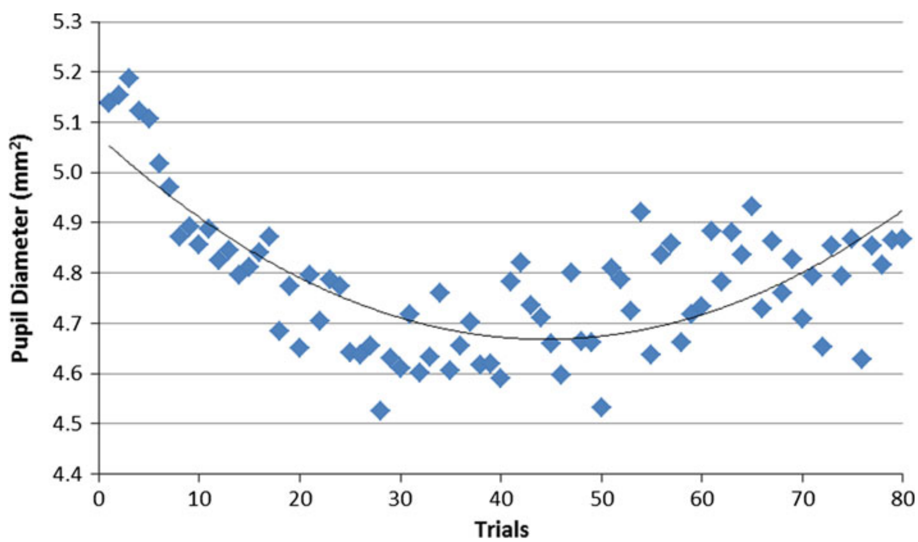

Fig. 7 Average pupil size over the course of the 80 experimental trials revealing hippus

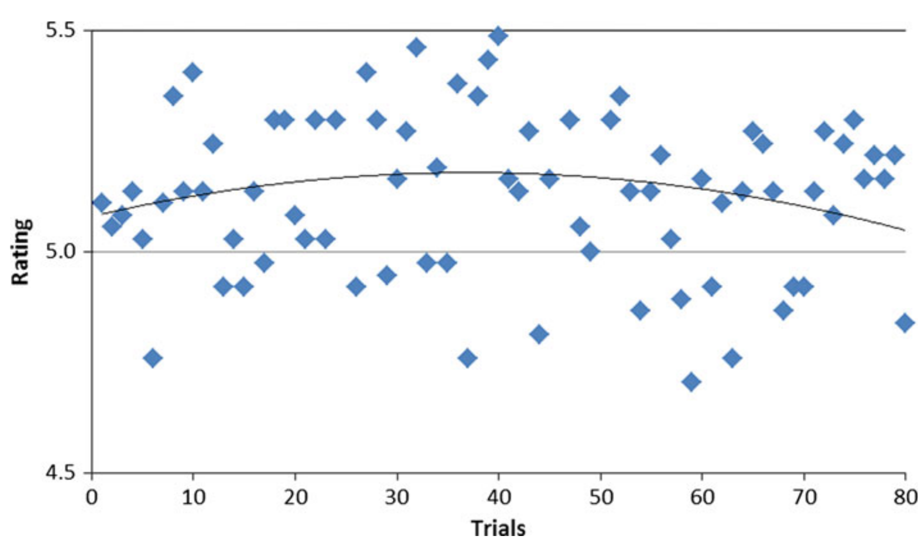

Fig. 8 Average ratings over the course of the 80 experimental trials

Fatigue over time

Fatigue effects over time were determined by plotting both the pupil size variability and blink rate over trials. Measured as pupil size standard deviation (mm^2), pupil size variability increased considerably over time ($y = -0.0005x^2 + 0.0041x + 0.822$; $R^2 = 0.621$, $r = 0.788$). Blink rate averaged ~11 % of the total task time, which increased slightly over trials ($y = -0.0002x^2 + 0.0042x + 9.675$; $R^2 = 0.135$, $r = 0.367$). Increases in both of these parameters are indicative of slight fatigue.

Photograph bias indicates conscious pleasantness for both sexes

Throughout six centuries of Western art, women have been painted primarily with their left cheek exposed, while men typically exposed their right cheek (Grüsser et al. 1988). Rembrandt's biased portrait positioning concurs with this finding, and it may have been his intention to display the dominant sides of men and the emotive sides of women (Powell and Schirillo 2011). Likewise, Schirillo and Fox (2006) found that left-cheeked female portraits were judged most often as "approachable", whereas left-cheeked male portraits were judged most often as "avoidable". The present study examined whether similar perceptions of sex produced preferential differences for side of the face in real-life.

Discussion

Perceived dominance in men has often been attributed to both positive *and* negative affective states (Demaree et al. 2005). However, the valence hypothesis claims that the expression of positive and negative emotions is divided more or less equally between the two hemifaces. Thus, it seemed unlikely to find significant differences between ratings of left- and right-faced male images. Conversely, several studies found greater lateralization (i.e. more facial muscle activity) of emotions in women, which predict distinctive differences in ratings of either side of the face in female images (Fridlund and Izard 1983). As expected, we found evidence for the hemispheric lateralization of the perception and expressions of emotions. Interestingly, however, evidence for lateralization occurred in images of *both* men and women.

Our results further strengthen the notion of right-hemispheric dominance (Sackheim and Gur 1983; Borod et al. 1997), in that higher ratings of pleasantness were assigned to left-faced images. Importantly, this occurred regardless of whether the left hemiface was viewed in their original or mirror-reversed orientation.

Portrait bias indicates Hess' unconscious dilation/constriction is valid for both sexes

To test whether conscious measures of pleasantness would also be present unconsciously, Hess' attraction-dilation and aversion-constriction hypotheses (Hess and Polt 1960) was elicited by presenting original and mirror-reversed images. Hess' hypotheses have received a large amount of criticism for his lack of control for intrastimulus brightness variation (Hess et al. 1975). Thus, the majority of the literature following Hess and Polt's discovery has suggested that it is not the valence towards a stimulus than matters, but rather it is the *intensity* of the emotion that is evoked from the stimulus (Janisse 1973). Thus, many researchers have concluded that regardless of valence, emotions tend to elicit predominantly sympathetic activity (i.e. pupillary dilation) (Goldwater 1972).

We found that pupil size was linearly related to pleasantness of an image, such that pupils dilated more when an image was rated as more "pleasant", but tended to constrict when images were rated as "unpleasant". This was true for both female and male images regardless of whether the images were in their original or mirror-reversed orientations. These findings suggest that posers' left hemifaces tend to exhibit a greater intensity of emotion, and this is, therefore, related to being more aesthetically pleasing to the observer. A number of other research findings have consistently shown that the left side of the face is more active than the right side during emotional expression, regardless of the methodology used to measure facial asymmetries (Borod et al. 1997).

Conscious aesthetic rating and unconscious pupil diameter correlation is not spurious

While only moderate, there was a linear relationship between pupil size and aesthetic pleasantness for both men and women in both original and mirror-reversed orientations. To validate this relationship, average pupil size was plotted across the order of experimental trials and compared to the pattern of average ratings across the same order of trials. This showed a standard pattern of response of pupil size across trials such that the pupil initially dilated, after which it shrunk in size (accommodation) and subsequently recovered (i.e. hippus). This pattern is typical of pupillary behaviour while exposed to steady illumination (Lowenfeld 1999). These findings can be explained in terms of the relative novelty of the images to the viewer since stimulus novelty is positively related to pupillary dilation (Janisse 1973). Thus, the first few images appeared novel to the observers eliciting an initial pupil dilation. As the novelty of the images subsided, pupil size decreased after which there was a gradual recovery.

Ratings across order of trials did not follow the same U-shaped pattern as did pupil size. Instead, ratings followed a slight inverse parabolic function over time signifying that observers assigned lower ratings to the first few images, increased their ratings slightly halfway through the experiment and lowered their ratings again towards the conclusion of the study. Thus, we were able to conclude that pupil size and ratings of pleasantness were independent of any effects of trial order.

Average blink rate of observers across the order of trials increased as a function of time, confirming the expected pattern of slightly increased fatigue over time (Doughty 2002; Powell and Schirillo 2011). Other studies have shown increased pupillary oscillations as a result of tiredness in otherwise healthy adult individuals (Lowenfeld 1999). We found this to be true of our study, along with findings of increased pupil variability over trials. Thus, these findings affirm the importance of limiting picture-viewing time to 15 s and randomizing the order of the faces such that pupil size was a function of the face being looked at rather than the order in which those faces were presented.

Conclusions

In summary, we found a main effect of sidedness of the face on aesthetic judgments of pleasingness with the left hemiface being the most preferable for both male and female posers, rather than just females as originally predicted. More importantly, the left side of the face was preferred *regardless* of how it was presented (i.e. original orientation or mirror-reversed). Consequently, the presented side of the face had no influence on preference. This suggests that the perceived emotional expressions are being rated on their facial musculature, and thus hemispheric specificity rather than the viewer's preference for a given perceived hemiface. We also found a positive linear relationship, albeit modest, between pupil size and aesthetic ratings of images as was expected. These findings reinforce the tenets of the right-hemisphere hypothesis and add to the growing amount of evidence supporting the lateralization of emotional perception and control (Davidson 1995). They also posit that sex is not a significant determinant of how the brain is lateralized for emotional functionality. Previously recorded sex differences in emotional expression may have been the result of different experimental demands made on men and women (Fridlund and Izard 1983). For example, women may have gained more practice in (and thus more control over) emotional expression than have men. One study found that between 10 and 20 years of age, girls spend twice as much time in front of the mirror as do boys (Grüsser et al. 1988). Thus, asymmetries as a result of experience may be of greater importance than genetically derived brain asymmetries.

Interestingly, our findings also agree with Hess' original conception of pupil dilation to pleasant images and constriction to unpleasant images. However, since the age discrepancies between posers (35–65) and observers (18–22) may have constricted the range of aesthetic pleasantness ratings ($\sim$3.5 to $\sim$6.5), these findings should be regarded as tentative. Even so, the relationship found between pupil size and ratings was independent of trial order, thus establishing that their correlation was not spurious.

The only outcome that differed with our original hypotheses was that a left-side aesthetic bias was present for all images, regardless of the poser's sex. This is likely because the posers used in this study were average-looking individuals (e.g. average ratings of 5.1). These results may differ from Powell and Schirillo's (2011) previous findings of a prominent female leftward bias in Rembrandt's portraits because it is hard to determine how "average" the people in Rembrandt's portraits tended to be since these individuals ranged from peasants to patrons. Thus, Rembrandt may have been biased his portraits to some degree to fit his particular aesthetic interests.

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