Following the masters: Portrait viewing and appreciation is guided by selective detail

Steve DiPaola[1], Caitlin Riebe[2], James T Enns[2] §
[1] School of Interactive Arts and Technology (SIAT), Simon Fraser University Surrey, Surrey, BC V3T 0A3, Canada; [2] Department of Psychology, University of British Columbia, Vancouver, BC V6T 1Z4, Canada; e-mail: jenns@psych.ubc.ca
Received 4 February 2013, in revised form 13 June 2013

Abstract. A painted portrait differs from a photo in that selected regions are often rendered in much sharper detail than other regions. Artists believe these choices guide viewer gaze and influence their appreciation of the portrait, but these claims are difficult to test because increased portrait detail is typically associated with greater meaning, stronger lighting, and a more central location in the composition. In three experiments we monitored viewer gaze and recorded viewer preferences for portraits rendered with a parameterised non-photorealistic technique to mimic the style of Rembrandt (DiPaola, 2009 *International Journal of Art and Technology* **2** 82–93). Results showed that viewer gaze was attracted to and held longer by regions of relatively finer detail (experiment 1), and also by textural highlighting (experiment 2), and that artistic appreciation increased when portraits strongly biased gaze (experiment 3). These findings have implications for understanding both human vision science and visual art.

Keywords: gaze, portraits, selective detail, detail-gaze hypothesis, Rembrandt, computer modeling

1 Introduction

Visual artists and photographers have long believed that a viewer's gaze can be guided by the selective use of image clarity. Regions that hold greater detail than the rest of an image are believed to attract the eye, whether this occurs in a photograph because of differential focus (Langford 1973), or in a painting because of finer brush strokes, heightened luminance, and colour contrast (Brown 2001; Sanden 2004). Conversely, regions of reduced clarity that derive from an out-of-focus lens or from coarser brush strokes are thought to repel the eye. But, until recently, there was little systematic research on this topic. In this paper we explore this question in the realm of portraiture.

The background research for this question includes the distinguished tradition of eye-tracking viewers while they inspect a work of art, beginning with Buswell (1935) and Yarbus (1967), and extending to the present time (Heidenreich and Turano 2011; Kapoula et al 2009; Leder et al 2004; Locher et al 2007; Miall and Tchalenko 2001; Molnar 1981; Zangemeister et al 1995). However, this work does not address whether the gaze of viewers is directed to regions of relatively greater detail. This is because relative detail in an artwork is entangled with many other factors, such as lighting, composition, and content. This entanglement is understandable when considered from the perspective of the artist, who selects a region of the canvas for increased detail in association with choices about meaningful content (the region is usually also of central interest), depicted lighting (detail is typically increased for surfaces falling in direct light), and spatial layout (the region is often near the centre of a composition). Strong correlations among semantic, lighting, composition, and detail likely all conspire to guide the gaze of the viewer to specific regions. However, for the purpose of the present question—does relative detail guide the viewer's eye?—these correlated factors in original artwork confound the question of whether the eyes are guided by relative detail alone.

§ Corresponding author.

Enns and MacDonald (2012) recently addressed this question for viewing of naturalistic scenes. These authors tracked the eye gaze of participants in several different tasks, in order to test the *detail-gaze hypothesis*, using photos commonly found on social media sites (eg vacation photos, photos of friends). These authors selectively altered one region in each photo, on either the left or the right side, with the alteration involving either a sharpening (a slight reduction in blur from the background) or blurring (a slight increase in blur from the background). These manipulations were all made without regard for the content of the photos in those locations. When participants viewed these photos in preparation for a new–old recognition test, the first fixations made to selectively sharp regions occurred sooner than first fixations made to selectively blurred regions. Subsequent fixations to selectively sharp regions were also more frequent, with the result that the total viewing time was substantially increased for a selectively sharp versus blurred image regions. Additional data in Enns and MacDonald (2012) indicated that this relationship between image clarity and gaze held even when participants were strongly motivated to look equally at the two sides of a photo. It also held regardless of whether the altered region in the photo depicted objects that were of high versus low interest to the viewer.

In the present study we ask whether similar rules apply when viewers look at portraits as works of art, and whether this has an influence on the subjective appeal of the artwork. A recent paper (DiPaola et al 2010) suggests that Rembrandt van Rijn (1606–1669) was one of the first portrait artists to exploit the detail-gaze relationship in his artwork, and some initial eye-tracking data were presented in support of this hypothesis. Here we put several more specific variants of the detail-gaze hypothesis to the test, including to what extent did Rembrandt's original portraits guide the viewers' eyes with the use of selective sharpening (experiment 1), whether the use of textural highlights in a painting have an influence on viewer gaze over and above selective sharpening (experiment 2), and how gaze to selective detail in a portrait is linked to judgments of artistic merit (experiment 3).

In each of these experiments that follow we tested the detail-gaze hypothesis by tracking the eye movements of viewers while they examined portraits in which the relative level of detail in the portrait was decoupled from other factors, such as meaningful content, lighting, and spatial layout. This was done through a five-step process. In the first step, illustrated in figure 1a, we used four of Rembrandt's most famous late portraits: *Self Portrait with Beret and Turned-Up* Collar 1659 (hereafter *Beret*); *Man with a Magnifying Glass* 1661 (hereafter *Man*); *Hendrickje Stoffels* 1660 (hereafter *Hendrickje*); and *Large Self-Portrait* 1652 (hereafter *Large*), as inspiration to create our own mimics of these paintings. The original sizes of these portraits and their home museum locations are indicated in table 1. The original Rembrandt images we used were downloaded in high-resolution form from the research tool ArtStor (http://www.artstor.org).

In a second step, shown in figure 1b, a professional photographer took pictures of modern models, using the original Rembrandt images as a guide, displayed full-screen on a laptop computer, while he arranged the composition and lighting to mimic the originals. The specific photographic goal was to mimic Rembrandt's depiction of lighting across the face and upper torso with as large a depth of focus as possible. We did not try to mimic period clothing, as the clothing was not in strong light in any case, but our goal was to capture the general look and feel with regard to lighting, age, sex, and hair length. So-called Rembrandt lighting (Jacobs 1993) was accomplished by lighting one side of the face with a key light high and above to one side, and a diffuse reflector on the other side of the face. The signature of this lighting scheme is an illuminated triangle on the cheek of the model that falls on the less illuminated side of the face.

Figure 1. [In colour online, see http://dx.doi.org/10.1068/p7463] (a) Four of Rembrandt's most famous late portraits, from left to right: *Self Portrait with Beret and Turned-Up Collar* 1659; *Man with a Magnifying Glass* 1661; *Hendrickje Stoffels* 1660; and *Large Self-Portrait* 1652. (b) Photos of human models, posed, dressed, and lit in a similar way to the original artworks.

Table 1. Later-life paintings of Rembrandt van Rijn (1606–1669) used in this study. All are oil on canvas.

| Name	Date, title, size, museum location, URL
Beret	1659, *Self Portrait with Beret and Turned-Up Collar* 84.4 cm × 66 cm National Gallery of Art, Washington, DC http://www.rembrandtpainting.net s–1lf_prtrts/turnedup_collar.htm
Man	1661, *Man with a Magnifying Glass* 91.4 cm × 74.3 cm Metropolitan Museum of Art, New York http://www.rembrandtpainting.net/complete_catalogue/portraits/bj.html
Hendrickje	1660, *Hendrickje Stoffels* 78.4 cm × 68.9 cm Metropolitan Museum of Art, New York http://www.rembrandtpainting.net/complete_catalogue/family_portraits/stoffels.htm
Large	1652, *Large Self-Portrait* 112.1 cm × 81 cm Kunsthistorisches Museum, Vienna http://www.khm.at/en/visit/collections/picture-gallery/selected-masterpieces/
ElderlyMan	1667, *Portrait of an Elderly Man* 81.9 cm × 67.7 cm Royal Picture Gallery, Mauritshuis, The Hague http://www.maurithuis.nl/

The third step, illustrated for one of the four models in figure 2, involved rendering the photos of our models in the style of Rembrandt using a knowledge-based computer painterly rendering system (DiPaola 2007, 2009). This system employs over 50 parameters of brush detail, colour palette, and other painterly attributes to match the resulting painterly images as close as possible to the original Rembrandt portraits. The parametric knowledge rules were gained from interviews with oil portrait painters and data from the portrait painter process described in art technique books (DiPaola 2009). These rules have been implemented in an

XML-based system that maps the low-level parameters into successively higher-level algorithms, including (i) *parameter constants* involving brush size and colour weighting, (ii) *method parameters* equations such as TonalColourPalette (tonally weighted colour palette choices) and BlobShapeStroking (find shapes and stroke fill them in early passes), and (iii) *thinker/painter* process method parameters, which guide the implementation of the lower level algorithms.

To create the Rembrandt base paintings shown in figure 2c, via the XML-script instructions, the system analysed the photo source image and set down passes of progressively smaller brush strokes until completion. Each artistic, knowledge-based pass correlates the blob or stroke size with a Gaussian blurred source image, which allows the system to analyse and paint at progressively detailed levels, much like artists do, but in a highly controlled and repeatable way. Thus, in the first stages, only the largest blobs are painted (ie using the blob algorithm), and these blobs gradually decrease in size until the final detailed strokes paths are determined (ie bi-cubic individual stroke renderer). The final passes use an image-specific salience map to paint in the eye regions for our experiments. When a stroke is applied its colour is calculated via a tone-first-then-colour approach, which limits the colour choice to the current semantic region of the source image (ie background, clothes, hair, light skin, dark skin, taken from the source Rembrandt paintings).

In the fourth step, shown in figure 2c, we selected two regions in each rendered portrait for a manipulation of painted detail. We selected the eye regions because previous research indicates that human viewers look disproportionately at the eyes versus all other regions of the face (Birmingham et al 2008a, 2008b). What has not been tested previously is whether the two eyes in a face will be examined differentially, depending on their relative level of detail.

In our implementation, either a circular region centred about the left eye was rendered in greater detail (with the right eye remaining rendered in coarser detail), or the region centred about the right eye was rendered in greater detail (with the left eye remaining coarser). We varied the detail of each eye using the painterly system's method parameters. This meant using additional passes of progressively smaller brush strokes to increase the level of detail and fewer passes of brush strokes to decrease the level of detail. In order to anchor the magnitude of these differences to our previous work with photographs (Enns and MacDonald 2012) we compared the width of the brushstrokes in the final pass to the degree of Gaussian blur needed to create the same effect on a fully rendered painterly image. Brush strokes in the coarse eye region corresponded to a Gaussian blur kernel of 6 pixel units, and brush strokes in the sharp eye region corresponded to a kernel of 2 pixel units (given an original image of 1000×1000 pixels).

(a)   (b)   (c)   (d)
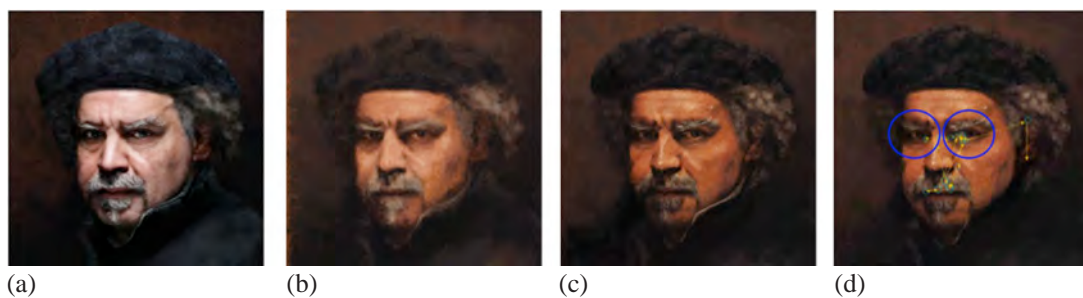
Figure 2. [In colour online.] Illustration of the method for one of the painterly renderings in the experiments. (a) Photograph of a human model, posed, lit, and dressed similarly to an original Rembrandt. (b) Computer rendering of the photograph in the Rembrandt style, at an intermediate stage of resolution, and prior to the application of any selective detail. (c) The same rendering at the final stage and after allowing the program to add greater detail to the left eye, following Rembrandt. (d) An example of the fixations (circles) and saccades (lines) made by one participant viewing the rendering for a 5 s period. The blue circles indicate the two regions of interest surrounding the eyes and are shown only for purposes of illustration; they were not shown to study participants.

In the fifth step we tracked the gaze of participants viewing these portraits in the context of a larger set of portraits taken from an assortment of fine art books covering noted artists from different periods and styles. Figure 2d illustrates the eye movements made by a typical participant while viewing this portrait for the first time. Of critical interest for the detail-gaze hypothesis was whether the gaze of the participants would be drawn sooner to the eye rendered in sharp versus coarse detail, and whether the sharp eye would also draw more return fixations. These two critical regions are illustrated in figure 2d with the blue circles, which the participants did not see.

2 Overview of experiments

In our previous work with these images (DiPaola et al 2010), we tracked the gaze of viewers examining the photos and the painterly renderings that were inspired by the four Rembrandt originals (*Beret*, *Man*, *Hendrickje*, *Large*). In that study we manipulated the degree of detail in four regions in each image, corresponding to the two eye regions and two collar regions (a similar size region to the eyes, centred on where the neck meets the face below each eye). We also presented some participants with the images in their original orientations and other participants with the same images mirror reversed. Participants viewed each portrait in a random order for a 5 s period on a first occasion (phase 1), with the participant instructed to inspect the images without making any overt responses or decisions. Then, on a second viewing of the same images in a new random order (phase 2), participants rated the artistic merit of each image on an 8-point scale. However, in that study we did not track the gaze of viewers examining the original Rembrandts themselves. Thus, in experiment 1 here we made this direct comparison, in order for us to evaluate whether our differential treatment of the eyes regions in the painterly renderings had a similar effect on viewer gaze as the original artworks. To anticipate, the results showed that eye gaze for the original Rembrandts was differentially sensitive to the relative degree of clarity in each eye, and about to the same extent as our painterly renderings altered to mimic the originals.

In experiment 2 we explored an additional feature of portraiture that artists used to guide the viewer's gaze: textural highlights. We focused on highlights because these light-valued brushstrokes are usually applied last in the painting of a portrait and are interpreted as indicating the conditions of illumination in the depicted setting (as opposed to the sitter's shape, which is conveyed by surface edges, tone, and shading). As such, highlights have the potential to convey much about the artist's intent to the viewer, even if lighting effects caused by highlights and shadows are not consciously perceived by the viewer (Cavanagh 2005; Fleming et al 2003). The results showed that viewers' gaze was indeed influenced by highlighting techniques designed to differentially emphasize the two eyes in a portrait.

Finally, in experiment 3 we tested whether the differential gaze patterns induced by the selective application of detail had consequences for their evaluation as works of art. We examined this question in four ways. In experiment 3a we first tested the hypothesis that, when the pattern of relative detail in a portrait matched that of the Rembrandt original, participants would also select it as the best portrait from an artistic point of view. This is a version of the visual rightness theory (Locher 2003) for the late portraits of Rembrandt, meaning that there is a certain composition or layout of elements that will have maximum impact on the naive viewer. The results established a causal link between portrait composition and participants' preferences.

In order to test the direct link from selective gaze to preference, experiment 3b examined the correlation between differential looking at the two eyes in the Rembrandt-like portraits and their subsequent evaluation in the rating phase of the DiPaola et al (2010) experiment. At the time of that publication we had not investigated the data for this possibility. Then, in experiment 3c we examined the same question for the present experiment 2, where we found that gaze could also be manipulated using textural highlights overlaid on a finished painting.

Finally, experiment 3d asked whether the correlation we found between differential gaze bias and artistic ratings in the Rembrandt paintings held more generally for portraits of many artists and styles. In each case the results indicated a significant correlation, suggesting that a differential eye-gaze bias can be generally associated with artistic merit in portraits.

Before presenting our results in detail, it is worth noting that the participants in this study were naive viewers of art, in that they were undergraduates in first and second psychology courses with little or no formal art training. As such, this study concerns the gaze patterns and preferences of viewers who are inspecting artworks, but who are not aesthetically fluent (Smith and Smith 2006). This literature suggests that naive participants are more likely to examine the paintings for realism and semantic content, rather than for compositional style, genre, and layout (Nodine et al 1993).

3 Experiment 1: Rembrandt's original portraits bias viewer gaze

This experiment addressed two questions left unanswered by the preliminary study of the gaze-detail hypothesis in DiPaola et al (2010). First, the design and interpretation of the gaze data in that study were premised on the untested assumption that the Rembrandt-like renderings of the modern-day photos were similar to original Rembrandt portraits in the way they guided the viewer's eyes. Therefore, in this study we included the original Rembrandt portraits for direct comparison with the painterly renderings.

A second change was to vary the origin of the participant's eye position at the beginning of each trial. In DiPaola et al (2010) each portrait was preceded by fixation at the centre of the image, which may have contributed to the disproportionate number of fixations made to the eye regions, which were also generally near the centre. To counteract this tendency, we therefore began each trial with fixation in either the lower right or left corner of the image viewing area. This forced the eye to move over much of the painting before arriving at the eye regions, increasing the latency with which the eye regions in the portraits are first fixated, when compared to most studies of face perception. This also more closely simulates the typical gallery experience of first encountering a portrait from one side or the other as one enters a room or moves from one frame to the next.

We restricted our displays in this experiment to the image orientations used in the original Rembrandt portraits. Although we had presented both original and mirror-imaged portraits to the participants in DiPaola et al (2010), this had no measurable influence on gaze, over and above the tendency for participants' eyes to fixate earlier and more often on the sharper of the two eye regions. In addition, two of the originals do have the detailed eye on the left side, and the other two have the detailed eye on the right side, as shown in figure 1, controlling for an overall bias with regard to side. We also restricted our main analyses of participants' gaze to the two eye regions, since both in this study, and in our previous study (DiPaola et al 2010), very few direct fixations were ever made to the collar regions.

3.1 *Method*

3.1.1 *Participants.* Twenty-two undergraduate students (five male, seventeen female) participated in return for extra-course credit in a testing session of about 1 h. The eye-tracking data from two participants were unavailable because of our inability to calibrate the eye tracker for them.

3.1.2 *Apparatus.* An EyeLink II tracker sampled eye position every 2 ms. Saccades (eye movements) and fixations (periods of stable gaze) were assessed using the default settings, namely a fixation was defined as the period of stable gaze between saccades. Saccades were defined as a spatial displacement greater than 0.5 deg, with a velocity of at least 30 deg s^{-1}, and accompanied by acceleration of at least 8000 deg s^{-2}. Images were shown on a Samsung 19-in LCD screen with a resolution of 1024×768 pixels and 24 bits per pixel.

3.1.3 *Images.* The images shown to participants consisted of 36 portraits in all, each at a resolution of 1 Mpx. These included the four original Rembrandt portraits (4), the four photos of the modern models (4), two of the critical portraits for each of the four models (8), and ten filler portraits each viewed twice (20). Viewing the filler portraits twice was an attempt to balance the fact that each critical portrait was viewed with two different detail manipulations. The two critical portraits for each model included the one with a detailed eye and collar on the same side (ie corresponding to the original Rembrandt, referred to as pro-Rembrandt, figure 3 upper right) and a variant with the more detailed eye and collar region on the opposite side from how Rembrandt had painted it (referred to as the anti-Rembrandt, figure 3 lower left). The filler portraits were selected from an assortment of fine art books covering noted artists from different periods and styles, intended to create a diverse context of portraiture in which the critical portraits could be judged. They were shown twice in each series in order to balance the presentation of each critical portrait, which were also shown in two subtly different versions (pro- and anti-Rembrandt).

Figure 3. [In colour online.] Four possible variants of the *Beret* rendering, as displayed on one screen in experiment 3a. Variation in the detail of the two eyes is crossed with variation in the detail of the two collar regions below each eye. The variant in the upper right is a pro-Rembrandt, that in the lower left is the anti-Rembrandt, which were used for the eye-tracking phase in experiment 1.

3.1.4 *Procedure.* Following a brief period of eye-tracking calibration, each participant viewed the 36 images, each for 5 s, and in a random order. Each trial began with a fixation cross either in the lower left hand corner of the screen (for half of participants) or in the lower right-hand corner of the screen (for the other half). Fixating this symbol for a period of 500 ms initiated

the presentation of the next portrait in the series. Participants were instructed to inspect each portrait in any way they saw fit, but not to make any overt responses or decisions. They were also told that they would be given the opportunity at a later time to indicate how much each image appealed to them as a work of art. The eye tracking of these initial inspections of each of the portraits are the data we report in the results.

In a second phase of the experiment, participants were seated in front of a 24-in eMac computer, so that they could make forced-choice preferences among four variants of the critical portraits for each model. Figure 3 shows an example of one of these screens, for the *Beret* renderings. Each participant was shown 16 screens, in a random order, each screen containing the 4 portraits for a given model (one portrait in each quadrant to fill the screen, also randomly determined). Thus each participant was given the opportunity to select "the best" variant 4 times for each of the 4 models. Participants made their selections by pressing one of 4 keys, spatially mapped to the 4 quadrants of the screen. Eye gaze was not recorded during these selections. These forced-choice preferences are presented in experiment 3a.

3.1.5 *Data analyses.* The total number of fixations and their average durations were recorded for the two eye regions, as well as for each image as a whole, on the first inspection of an image by each participant. The two main eye-tracking measures included a measure of attention *attraction*, defined as the mean time to make a first fixation to each of the two eye regions in a portrait, and a measure of attention holding, defined as the mean number of total fixations made to the two eye regions during the 5 s viewing period. Each eye region of interest was defined as a circular region, 145 pixels in diameter, centred on each eye, as illustrated in figure 2d.

3.2 *Results*

The eye tracking record of each participant was analysed with regard to three questions. (i) Is the bias to examine the eye regions of the portraits reduced by beginning fixation below the portrait (this experiment) rather than in the centre (DiPaola et al 2010)? (ii) What is the latency of the first fixation to each of the two eye regions in the various classes of portrait? Differences in this measure are an indication of the differential attention-attraction of a sharp versus a coarse eye region in an image. (iii) What is the total number of fixations landing in each of the two eye regions? This is a measure of the attention-holding function of sharp versus coarse eye regions. The detailed results that follow are presented as answers to these three questions.

(i) *Eye regions of portraits attract the greatest number of fixations.* Despite the initial fixation beginning below and to one side of the portrait, the two eye regions still received 45.1% of all fixations (compared to 52.1% in DiPaola et al 2010), the two collar regions received only 5.0% of fixations (compared to 4.3% in DiPaola et al 2010), with the remaining 49.1% of fixations being made outside the selected regions of interest (compared to 43.6%). These differences between experiments were not significant ($p > 0.10$), and so this finding confirms that the strong bias to fixate the eye regions and the very weak tendency to fixate the collar regions immediately below the eyes is not a function of an initial central fixation position.

(ii) *An eye with greater detail attracts the first fixation in less time.* Figure 4a shows the average time taken to make a first fixation to each of the two eye regions in the various portraits. In comparison to the more than 1000 ms taken to fixate one of the two eye regions in a photo, and the relatively small difference in fixation latency between the two eyes in the photos, the sharper eye was fixated more than 300 ms earlier in the original Rembrandts and the coarser eye was fixated more than 1000 ms later. The Rembrandt-like renderings that were in the same style as the originals (pro-Rembrandts) were similar in their first fixation pattern to the originals. Renderings done in the opposite style (anti-Rembrandts) were more similar to the photos in their first fixation pattern. ANOVA examining the factors of eye detail
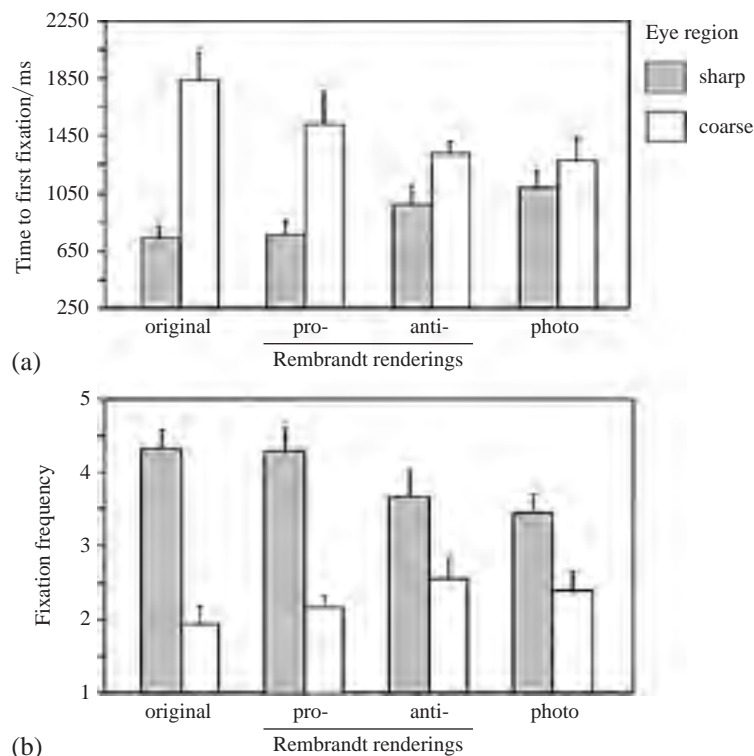
Figure 4. Experiment 1. (a) Attention attraction is measured by the mean time to make a first fixation to each of the two eye regions in the various portraits. (b) Attention holding is measured by the mean number of total fixations made to the two eye regions in the various types of portrait. Error bars are ± 1 SE.

(sharp, coarse) and portrait type (original, pro-, anti-, photo) indicated significant effects of both detail ($F_{1,19} = 36.07$, $p < 0.01$) and a detail $\times$ type interaction ($F_{3,57} = 5.13$, $p < 0.01$). Simple effects tests using Fisher's LSD procedure on the differences between sharp and coarse eye regions indicated a significant difference between the originals and the pro-Rembrandts versus the anti-Rembrandts and the photos ($F_{1,57} = 13.28$, $p < 0.01$) with no statistical differences between the two image types within each of these categories ($p > 0.20$).

It should be noted that these mean first fixations to the eye regions were longer, in absolute terms, than those reported in DiPaola et al (2010). We attribute this to our requirement here to begin each trial with fixation in one of the lower corners of the viewing area. However, beyond this difference in absolute latencies, the fixation patterns were very similar to those reported in many previous studies of face perception, generally showing a triangular pattern of fixations involving the two eye regions and the nose and mouth regions, as illustrated for the one participant in figure 2e.

(iii) *An eye with greater detail attracts more repeat fixations.* Figure 4b shows the average number of fixations made overall to the two eye regions in the various types of portrait. Following DiPaola et al (2010), an eye region with greater detail attracted more fixations than the eye with reduced detail over the entire 5 s viewing period ($F_{1,19} = 98.77$, $p < 0.001$), and this difference varied with portrait type ($F_{3,57} = 7.28$, $p < 0.001$). Examining this tendency with respect to the various portrait types indicated that this effect was greatest for the original Rembrandts and pro-Rembrandt renderings than for the anti-Rembrandt renderings and the photos ($F_{1,57} = 21.22$, $p < 0.001$), with no statistical differences between the two image types within each of these categories ($p > 0.20$).

3.3 *Discussion*

This experiment addressed two questions left unanswered by our previous report on eye tracking in portraits (DiPaola et al 2010). First, the results showed that viewer gaze was influenced in a similar way by the Rembrandt renderings designed to mimic Rembrandt's originals (pro-Rembrandt renderings) and the Rembrandt originals. This was seen in the differential time to first fixation, which was much sooner for the sharp than the coarse eye, and in the number of repeated fixations, which were more frequent to the sharp than the coarse eye. The renderings designed to oppose Rembrandt's originals (anti-Rembrandt renderings) yielded gaze patterns that were more similar to the untouched photographs of the modern models.

Second, having viewers begin their inspection of each portrait in a lower corner of the image, rather than at the centre as in DiPaola et al (2010), had a minor influence on overall pattern of results. The eye regions in a portrait still received close to 50% of all fixations made by viewers, and the two collar regions received only about 5% of all fixations. Moreover, the gaze-detail hypothesis received the same level of support in this experiment as in DiPaola et al (2010), with both first fixation latency and fixation frequency showing a strong bias toward the sharper of the two eyes in a portrait.

4 Experiment 2: Textural highlights guide the eyes over and above selective detail

In the previous experiment and in DiPaola et al (2010) progressively finer brush strokes were used to painted detail in selected regions and thicker brush strokes were used to decrease detail. But this is not the only tool artists can wield to guide the eyes of the viewer. Another very effective technique is to manipulate the textural highlights of a painting, those light-valued brushstrokes that are interpreted by the viewer as specular highlights (ie shiny regions indicating maximum light being reflected from the viewed surfaces). Since specular highlights in natural images are primarily an indication of the location of the light source relative to object surfaces, rather than a function of the relations among surfaces, art instructors teach that painted highlights can be an effective way to convey the artist's agency to the viewer. Art instructors also speak of highlights as finishing a portrait, and since they are usually applied last, the artist is given one last opportunity to alter the composition and thereby its possible effects on the viewer.

Our inspiration for studying the influence of highlights came from Rembrandt's own portrait, *Portrait of an Elderly Man* 1667 (hereafter *ElderlyMan*), as illustrated in close-up in figure 5a. This portrait has been responsible for a lively debate among art historians, who have wondered about the purpose behind Rembrandt's use of the unusually scattered highlighted strokes in this painting (Graham-Dixon 2007). Did Rembrandt purposefully scatter the highlights using a palette knife or butt of the brush to create a feeling of a man who was drunk, "unflattering" or in "disarray"? Graham-Dixon (2007) describes the figure in the *ElderlyMan* as someone who has "no idea of who he is, or of where he might be going". Because of these scattered highlights and other techniques, this portrait was once thought unfinished. But Graham-Dixon counters that "in fact the face, blurred though it appears, was painted by the artist with an immense degree of care … in places, teased with palette knife or the butt end of the brush into forms that indicate the precise contours … emphasizing his subject's apparently frail hold on reality". While this debate may never be resolved, the elderly man portrait and the critical discourse that surrounds it point to the possibly powerful influence that highlights can have in the viewing and appreciation of a portrait.

In experiment 2 we explored the influence of highlights on viewer gaze, using two of the portraits from the previous experiment (ie *Beret*, *Hendrickje*) and manipulating their textural highlights. Importantly, we made no additional changes to the relative detail of the eye regions in those portraits, holding them constant as in the pro-Rembrandt renderings of

the previous experiment. What we did vary systematically was the relationship between the textural highlights applied to these portraits and the two eye regions.

As shown for *Beret* in figures 5b–5e, textural highlights were applied to the same base-rendered portrait by a computer artist instructed to paint them digitally so that they were either absent as in figure 5b (ie "reduced below the level of highlighting in previous experiments"), gaze-supporting as in figure 5c (ie "to encourage inspection of the more detailed eye"), scattered as in figure 5d (ie "to divert emphasis from both eyes"), or gaze-opposing as in figure 5e (ie "to encourage focus on the less detailed eye"). Our research question was

(a)

(b)

(c)

(d)

(e)
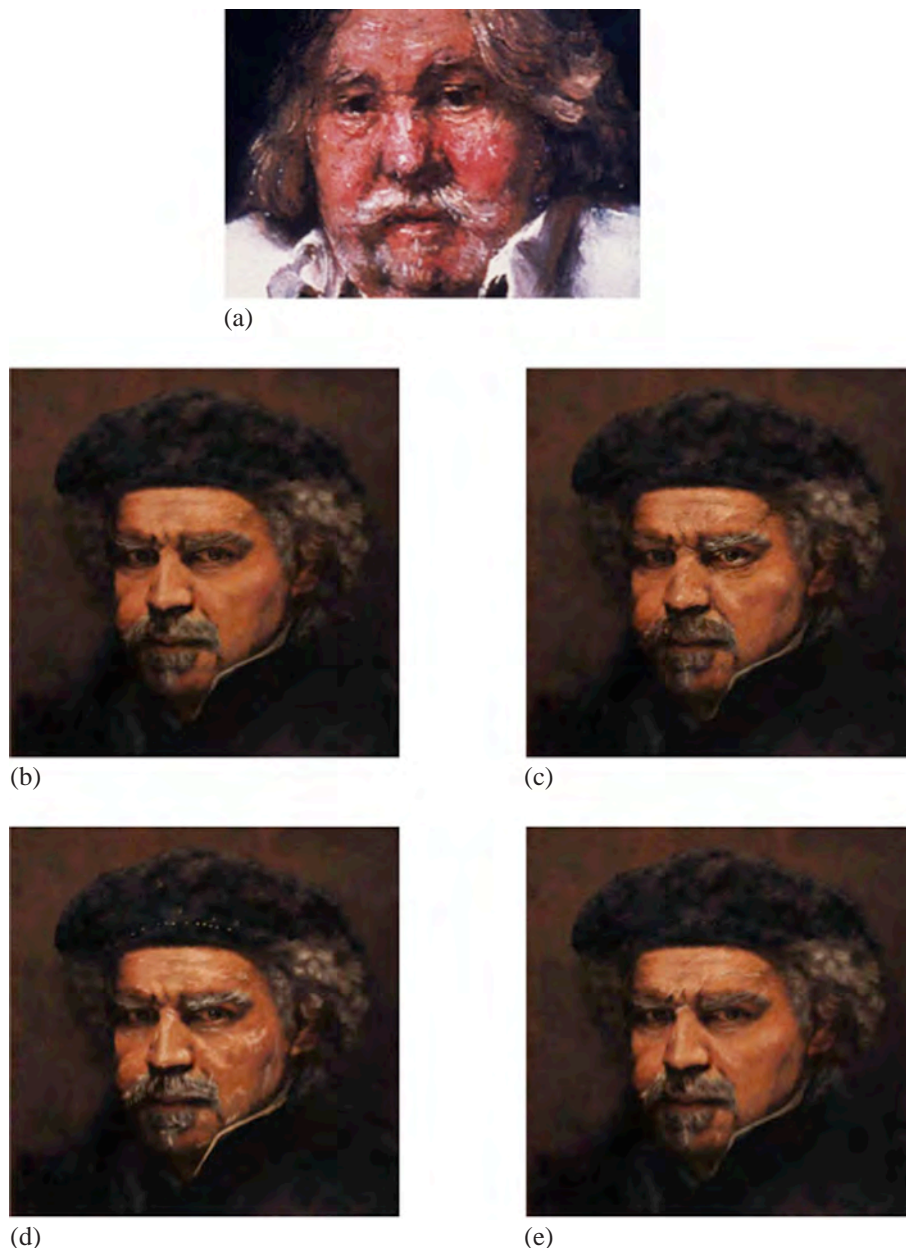
Figure 5. [In colour online.] (a) A crop of Rembrandt's *Portrait of an Elderly Man*, which served as inspiration for our exploration of textural highlights. Textural highlights were applied to the same base portrait by a computer artist instructed to add highlights that were either (b) reduced below the level of highlighting in experiment 1, (c) to support inspection of the more detailed eye, (d) to divert attention from both eyes, (e) to support inspection of the less detailed eye.

whether the intuitions of the computer artist would be matched by the gaze patterns of our viewers, who were blind to the detail-gaze hypothesis.

Otherwise, the procedures were similar to experiment 1, so that we were able to examine the influence of textural highlighting on both gaze patterns and artistic ratings. The eye-tracking record of each portrait viewed for the first time was then analysed to answer the question: "Do textural highlights influence looking patterns in portraits over and above the already established influences of relative detail?"

4.1 Method

4.1.1 *Participants.* Twenty-four undergraduate students (six male, eighteen female) participated in return for extra-course credit in a 1 h testing session.

4.1.2 *Apparatus, images, and procedure.* The painterly rendering system (DiPaola 2007, 2009) has parameters that affect how straight or curved a stroke is, its direction and length, as well as the colour palette model used. These parameters were controlled to mimic the typically thin, straight, bright textural highlights that Rembrandt used in his original work. The created strokes mimicked the magnitude, size, length, and brightness from Rembrandt's original. The rendered portrait shown in figure 5b was generated by first deleting the "highlight strokes commands" from the base images used in experiment 1, and then the digital computer artist added highlight paint strokes using Adobe Photoshop to create the remaining three image types in figure 5c (gaze-supporting), 5d (scattered), and 5e (gaze-opposing).

Methods in the eye-tracking and art-rating phases of the experiment were identical to experiment 1, with the following exceptions. The image types included (i) two original Rembrandts (*Beret*, *Hendrickje*), (ii) eight renderings generated by the combination of two models, and four variants of textural highlighting (support, scatter, absent, opposing), and the ten filler portraits used in experiment 1, each viewed twice, for a total of 30 images.

Following the initial 5 s viewing of each of the 30 images in a random order, participants were given the opportunity to view the images again, in a new random order, in order to provide ratings of artistic merit on an 8-point scale. These data are presented in experiment 3c below.

4.2 Results

4.2.1 *Textural highlights influence looking patterns.* Figure 6a shows the mean time that elapsed before a first fixation was made to each of the two-eye regions. In addition to the general tendency for the first fixation being made earlier to the sharper of the two eyes ($F_{1,23} = 31.17$, $p < 0.01$), this effect interacted with the portrait type ($F_{4,92} = 2.90$, $p < 0.01$). Simple effects indicated that the difference in first fixation time to the sharp versus coarse eye was similar for the original Rembrandt (mean difference = 1075 ms), and the rendering with supporting highlights (mean difference = 1210 ms), ($F_{1,92} < 1$), but that each of these differences was larger than when the highlights were absent (mean difference = 520 ms) or opposing (mean difference = 382 ms), ($p < 0.03$).

Figure 6b shows the mean total number of fixations made during the 5 s viewing period to the same two eye regions. As in experiment 1, more fixations were generally made to the sharp than to the coarse eye across all portraits ($F_{1,23} = 61.64$, $p < 0.01$). However, this bias also interacted with portrait type ($F_{4,92} = 5.98$, $p < 0.01$). Simple effects indicated that the difference in fixations to the two eye regions was similar for the original Rembrandt (mean difference = 3.8), the rendering with supporting highlights (mean difference = 3.6), and the rendering with scattered highlights (mean difference = 3.0), ($F_{2,92} = 1.14$), but that the difference in looking for renderings with scattered highlights was significantly greater than for rendering with no highlights (mean difference = 2.2 fixations) and for rendering with highlights emphasising the coarse eye (mean difference = 1.2 fixations), ($p < 0.05$).

(a)

(b)
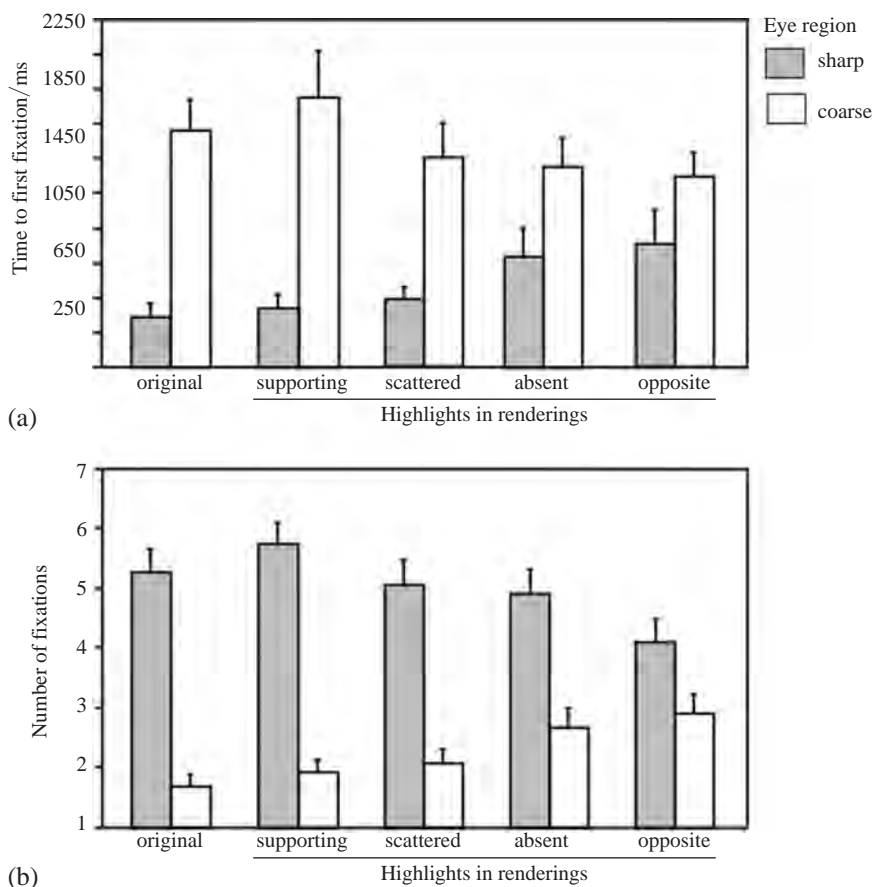
Figure 6. Experiment 2. (a) Mean time of first fixation to each of the two eye regions. (b) Mean number of total fixations made in each eye region. Error bars are ±1 SE.

4.3 Discussion

Experiment 2 asked whether viewer gaze patterns were affected by the relations between the textural highlights of a painting, which are typically applied last in the composition of a painted artwork, and the regions of relative detail that exist in the work prior to the application of highlights. Specifically, we began with two Rembrandt-like renderings that each had a more detailed eye and a sharper collar edge on the same side of the portrait and then had an artist paint light-coloured highlighting strokes to either support or oppose the influence of relative detail in the underlying image. The results showed that highlights placed by an artist to support of inspection of the more detailed eye resulted in a greater frequency looking toward the more detailed eye than highlights placed in support of the less detailed eye, or even than when no highlights were added at all.

5 Experiment 3: Affective consequences of selective detail

In this experiment we tested the hypothesis that the gaze patterns induced by the selective use of detail had consequences for their evaluation as works of art. We tested this hypothesis in four different ways. Experiment 3a tested for a correlation between preference judgments of the portraits and the pattern of selective detail implemented in the Rembrandt renderings used in DiPaola et al (2010) and in the present experiment 1. Note that this is a version of the visual rightness theory (Locher 2003) for selective detail in the late portraits of Rembrandt. Experiment 3b looked for the related link from gaze behaviour to subjective merit, by examining the correlation between differential looking at the two eyes in the portraits and

the portrait's subsequent evaluation in the rating phase of the DiPaola et al (2010) study. At the time of that publication we had not investigated the data for this possibility. Third, experiment 3c examined the same correlation for experiment 2 in the present paper, where gaze was influenced by textural highlights. Finally, experiment 3d examined the correlation between differential gaze bias and artistic ratings in the filler portraits we had used in previous experiments, comprising many different artists and styles, and tested on a new group of participants. This tested whether the detail-gaze hypothesis extended to the appreciation of portraits beyond those painted in the Rembrandt style.
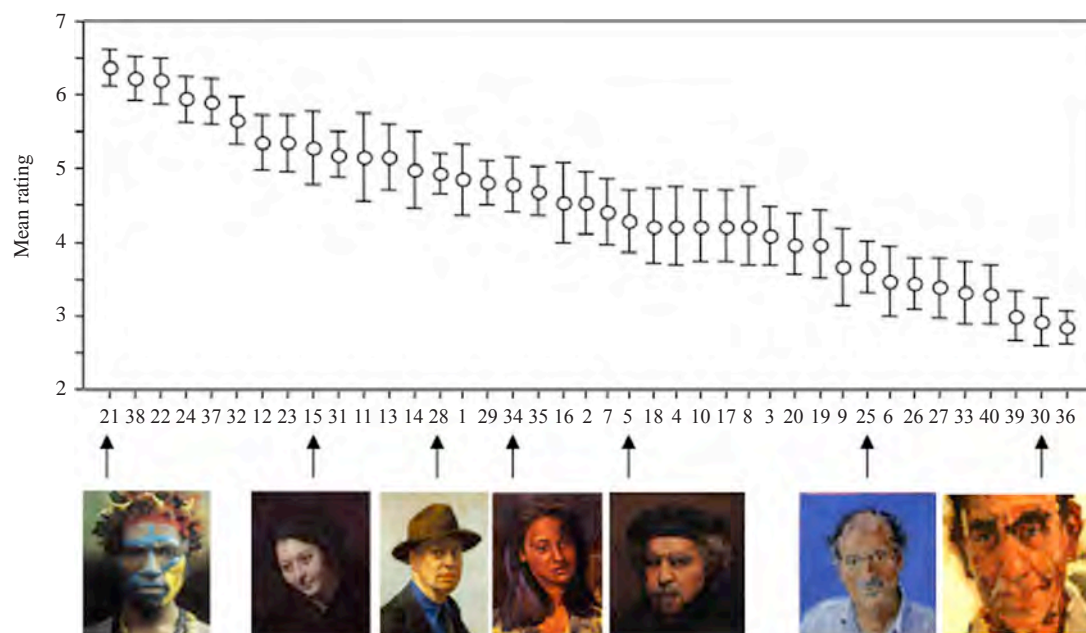
5.1 Experiment 3a
We examined the four-alternative forced-choice data of participants in the second phase of experiment 1, where they were given the opportunity to select the very best portrait from the four possible versions for each sitter (see figure 3). Since participants could choose one of four portraits on every screen, having no systematic preference would result in any particular variant being selected 25% of the time. Across all four models, participants preferred the most Rembrandt-like rendering 40% of the time (141 of 352 selections), which was significantly greater than the chance level ($\chi_1^2 = 41.76$, $p < 0.01$). Broken down for each model, the portrait mimicking *Beret* showed the strongest Rembrandt preference of 52.3% ($\chi_1^2 = 33.47$, $p < 0.01$), the portrait mimicking *Hendrickje* was 42.0% ($\chi_1^2 = 12.75$, $p < 0.01$), the portrait mimicking *Large* was 37.5% ($\chi_1^2 = 6.68$, $p < 0.01$), and the portrait mimicking *Man* was 28.4% ($\chi_1^2 = 1.71$, $p < 0.20$). Interestingly, when asked at the end of the forced-choice test, none of the participants was able to articulate a reason for their choices that referred specifically to our portrait manipulations, namely to the fact that the eye and collar region depicted most directly in the light were also the eye and collar regions that were rendered in greatest detail in the portraits that were selected most often.

5.2 Experiment 3b
After participants in the DiPaola et al (2010) study had freely inspected the artworks while their eyes were tracked, they were invited to view the same images in a new random order and to rate the artistic merit of each one on an 8-point scale. Participants were encouraged to use the entire range of the scale, applying a rating of 1 for the "worst" image in the set and a rating of 8 for the "best" image.

Figure 7 shows a rank ordering of mean artistic ratings for all 40 portraits in the DiPaola et al (2010) study, along with some thumbnail examples of the portraits, along the continuum from most to least artistic. The relatively small SE bars, when compared to the overall difference between mean ratings, indicates that there was much agreement among participants. On average, the modern studio photos fell in the low to moderate range (mean for photos a–d = 3.5 to 5.2) among all portraits, while the modern renderings designed to mimic Rembrandt were in the moderate range (mean for a–d = 4.1 to 5.3). However, it is also clear that there was considerable variation in the mean ratings within the set of modern renderings, ranging from a low of 3.7 to a high of 5.4.

To test whether these mean ratings, made on the second viewing of each portrait, could be predicted on the basis of the eye-gaze data from the first viewing, we chose as our predictor the difference in fixation frequency for the two eye regions. For example, if one eye region attracted 4 discrete fixations by a participant and the other eye region attracted only 1 fixation during the first 5 s viewing period, then that participant had a fixation frequency difference of 3; equal fixations to the two eye regions yielded a difference of 0. Thus, the bigger the different score, the more disproportionate the number of fixations to only one eye in the portrait. This measure was then averaged over the eight participants that viewed each of portraits and a correlation was computed over the 40 portraits and photos used in

Figure 7. [In colour online.] Mean artistic ratings for the 40 portraits in DiPaola et al (2010), ranked from highest to lowest. Selected sample portraits are shown below in thumbnail form. Error bars are ±1 SE of the mean.

the experiment. This analysis resulted in a significant correlation ($r_{38} = 0.381$, $p < 0.02$), suggesting that factors that lead to one eye in a portrait being repeatedly fixated over another can also be associated with the greater subjective appeal of a portrait to the viewer.
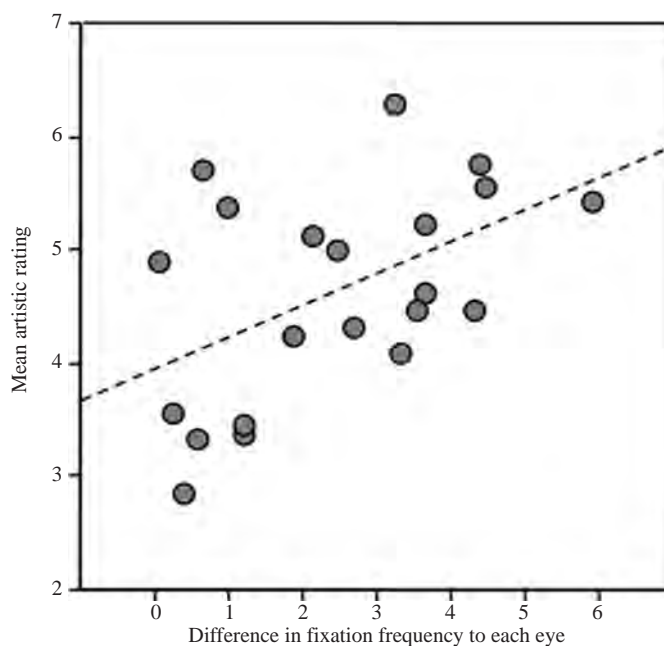
5.3 *Experiment 3c*

In experiment 2 of the present paper we had differential looking data for 10 critical portraits (the two models for *Beret* and *Hendrickje* combined with five levels of textural highlighting) and so we examined the correlation between mean artistic rating and the difference in fixation frequency for these 10 portraits. A preliminary analysis of all 10 data points showed no significant correlation overall ($p > 0.10$), but an examination of the scatterplot also revealed there was a significant overall difference in ratings given to portraits based on *Beret* (mean rating = 4.4) versus those based on *Hendrickje* (mean rating = 3.8) ($F_{1,23} = 5.77$, $p < 0.01$). When we examined the correlations separately for each of these portrait types, we found strong positive correlations between the difference in fixation frequency to the two eyes and a portrait's mean artistic rating (*Beret* $r_3 = 0.92$, $p < 0.01$; *Hendrickje* $r_3 = 0.80$, $p < 0.01$).

5.4 *Experiment 3d*

In a final test of the detail-gaze hypothesis, we asked whether the positive correlations we had found between artistic ratings and the bias to look disproportionately to one eye held only for our Rembrandt-like portraits, or whether this correlation held more generally for portraits of many artists and styles. To test this hypothesis, free from any possible bias that might occur from participants viewing the Rembrandt-style portraits, or from viewing portraits that had been artificially manipulated through the introduction of selective detail, we tested a new, naive, group of participants. They were asked to view and rate all of the 21 different filler portraits we had used in previous experiments. If the correlation held under these conditions, it would be strong support for the hypothesis that there is a more general association between disproportionate gaze toward one of the two eyes in a portrait and the subjective appeal of the artwork.

5.4.1 *Methods.* Twenty-one undergraduate students (seven male, fourteen female) participated in return for extra-course credit in a 1 h testing session. The methods were the same as described in experiment 1, with the following exceptions. Each of the participants viewed the same 21 filler portraits in a different random order. We defined two selected regions of interest in advance for the filler portraits, 145 pixels in diameter centred on each eye, allowing us to see whether the correlation we had observed between artistic ratings and differences in fixation frequency for the Rembrandt renderings also held for this assortment of portraits representing many different styles and artists.

Figure 8 shows the scatterplot of mean artistic ratings for the 21 portraits and the difference in fixation frequency to the two eye regions in each portrait. The correlation was significant ($r_{19} = 0.529$, $p < 0.02$), indicating that a stronger bias in looking disproportionately to one eye was associated with increased artistic ratings. This result clearly shows that the positive correlation observed in the previous experiments—between differential eye-gaze patterns and judged artistic merit—not only applies to the realm of Rembrandt-like portraits, but applies at least as well to the viewing and appreciation of an eclectic set of portraits painted in many different styles.

Figure 8. Scatterplot of the mean artistic rating of each filler portrait in experiment 3d, as a function of the difference in fixation frequency to the two eyes.

6 General discussion

A recent study of photograph viewing confirmed what artists have long believed, namely that a viewer's gaze can be influenced by the selective use of image clarity and blur, even though the viewer may not be aware of this influence (Enns and MacDonald 2012). The first fixation to a region is made sooner when the region is selectively sharper than when it is selectively blurred. Subsequent fixations to the same regions are also more frequent when it is selectively sharp versus blurred. In the present study we asked whether similar rules apply when viewers examine portraits as works of art, and whether these implicit viewing biases have an influence on the subjective appeal of the artwork.

Adult participants in this study first simply viewed and then later selected for preference or rated their artistic appreciation for a variety of portraits. The eye-tracking data from each participant's first viewing of portrait indicated that viewers on average looked first to the

more detailed of the two eyes, and then with their subsequent fixations returned more often to look at the more detailed eye region than to the one that was rendered more coarsely. The first of these findings implies that the selective use of detail has an attention attraction quality. The eye rendered in greater detail draws the gaze of the viewer and thus their first impression of the artwork. The second finding points to an additional attention holding quality. Namely, regions of selective detail invite repeated glances over a sustained period of time.

In experiment 2 we documented that textural highlights in a portrait can also have an influence on viewer gaze, over and above the influence of relative detail. The results showed that painted highlights can serve to either support the tendency for a more detailed eye to attract looking, or they can work against it. Art instructors have often suggested that highlights have great importance, both for directing the attention of the viewer and for establishing the narrative intended by the portraitist. They are most often the "finishing touches" on a piece and can therefore help to either consolidate themes that have been established by other techniques (eg use of colour and edge) or to work against them to create intentional discord. Our findings are evidence that there is a measurable influence on viewer gaze when highlights are used in this way, such that the viewer's gaze pattern is reinforced when added textural highlights support the direction given by the use of relative detail, and that it is disrupted when the highlights are at odds with the layout of relative detail

The most important contribution of this study, however, is that the selective use of detail can influence the viewer's appreciation of a portrait. This was shown in the forced-choice preferences of participants, asked to select among four different variants of a Rembrandt rendering in experiment 3a, and it was shown in the correlation between differential looking to the two eyes of a portrait and a portraits rated appeal in experiments 3b to 3d. This result can be summarised succinctly: when viewers spent a disproportionate amount of time looking at only one of the two sitter's eyes in a portrait, they tended to judge it as a better work of art. To put this correlation between differential gaze and appreciation into perspective, it is important to be reminded of the many potential influences that play a role in whether a viewer finds a portrait to be appealing. These include factors relating to the viewer's experience, training, and past exposure to art, factors involving cultural norms and deemed societal approval, and factors involving the artist's skill in conveying aspects of the multilayered narrative of the portrait experience to the viewer. These would include the sitter's character, intent, and expression, along with the artist's skill and choices. It is against this backdrop that finding any correlation at all between how strongly one of the two eyes in a portrait receives repeated looks and how highly the portrait is rated as a work of art is, simply put, remarkable.

Indeed, our initial finding of a relationship between differential gaze and portrait appreciation in the data from the DiPaola et al (2010) study came as a surprise. In contrast to our a priori hypothesis that detailed regions of a portrait might attract greater looking than less detailed regions, and that participants might prefer a pro-Rembrandt composition over an anti-Rembrandt (experiment 3a), the discovery of a correlation between differential looking and a portrait's judged merit was post hoc (experiment 3b). As such, it was important to replicate this finding with independent groups of viewers and to check its robustness, which we did in subsequent experiments. Experiment 3c showed that the relationship held when viewer gaze was manipulated through the use of textural highlights rather than only through relative detail, and the new group of participants tested in experiment 3d on filler portraits showed that the relationship held even when viewer's rated a collection of portraits that were originally outside the scope of our interest in the study and were not originally intended to test for this effect.

These considerations prompt us to speculate that the differential gaze-appreciation effect involves a causal link. Simply stated, a portrait that guides the viewer's gaze disproportionately to one of the two eyes will be considered by viewers, all else being equal, to be a better work

of art than a portrait that results in a more equal distribution of gaze. We are sufficiently confident of these initial results to state this as a working hypothesis for future research, although at the same time we acknowledge that it is technically still a statistical correlation. This means the direction of causality may yet be found to run in the reverse direction (ie when a portrait is judged to be especially good, the viewer's gaze will tend to look disproportionately on the more detailed of the two eyes in the image for reasons unrelated to textural detail and highlights) or that a third unknown variable is involved. Whatever the outcome, the discovery of this correlation is worth pursuing because it suggests a heretofore-unknown link between looking and liking.

6.1 Implications for vision science

The perception of pictures is possible because pictures evoke many of the same perceptual processes that are evoked by a real scene. However, picture and natural perception also have important differences, including the inherent dual reality of pictures (Haber 1980), the reduced dynamic range of pictorial luminance (Hochberg 1980), and the fixed image resolution of pictures, which differs from natural perception where image resolution changes dynamically with every eye movement.

In natural perception there is a tight coupling between image clarity and the viewer's spatial attention. One reason is the non-uniform sensitivity of the human retina. Only those portions of a scene that are registered on the fovea are signaled with high resolution; objects in the periphery are less clear. A second reason is lens accommodation, which causes image clarity to be correlated with image acuity. Objects at depth planes other than ones currently being accommodated are seen with lower resolution (Campbell et al 1958; Fisher and Ciuffreda 1988), making image clarity coincidental with the objects at the spatial centre of attention. Third, there is vergence, or the angular relation between the two eyes. Objects at the point of convergence will be represented with clearer images than objects not at that point, making image clarity again coincidental with objects that are currently attended.

These visual mechanisms all conspire during natural perception to have the viewer's interest coincide with image clarity. Picture viewing, in contrast, offers the opportunity for the normal direction of causality in this relationship to be reversed. By rendering some regions of a picture in greater detail, the artist implicitly invites the viewer to interpret the gaze-clarity correlations that occur using the default assumptions of natural perception.

The present finding of a link between selective looking and the subjective evaluation of an artwork (ie the differential gaze-appreciation correlation) takes this implicit guidance by the artist one step beyond simply providing a roadmap for viewing the artwork. The finding suggests that, at least in the realm of portraiture, there is a direct connection between how one looks and whether what one is looking at will be evaluated subjectively as positive or negative. The specific finding is that looking longer and more often at an eye in a portrait that has been selectively highlighted by the artist leads to a more positive evaluation than looking more equally at both eyes. We offer as a tentative hypothesis for this finding the proposal that viewers are sensitive to the implicit cues offered by the artist about where to look, and when these cues are highly consistent with one another the artist is credited by the viewer (again implicitly) for offering a clear roadmap to viewing the work. This is support for the visual rightness theory (Locher 2003) extended to relative detail in portraits. This sensitivity to the clarity of the goals of the artist may well operate to enhance the appraisal of the artwork, in much the same way that perceptual clarity has a positive influence on the evaluation of an otherwise neutral stimulus (Reber et al 1998) and that attentional neglect of a stimulus has a negative influence on its evaluative appraisal (Fenske and Raymond 2006).

6.2 *Implications for visual art and science*

Artists and scientists have historically taken different approaches to knowledge acquisition and dissemination. This research project is one attempt to build a bridge across these fields, by transferring knowledge from one domain to another, and by testing and validating claims in a way that is not usually considered conventional within a field. In support of the idea that knowledge can flow both ways, we note first that our study began with a case where artistic knowledge clearly anticipated scientific knowledge. In particular, the collective wisdom of artists held that regions of increased detail in a portrait would generally attract more frequent and longer looking. This has now been verified empirically, through the collection of objective data on where viewers look when first considering a portrait. The data show that viewer's gaze was not only attracted to regions of greater detail, as previous studies of eye tracking of artworks has shown (Miall and Tchalenko 2001; Molnar 1981; Yarbus 1967), but that this attraction could be influenced by manipulating the degree of detail present in a region, relative to other regions, while holding all other aspects of the artwork constant. This is the truly novel contribution of these experiments.

Moving in the other direction, the present data help build the art historical case that during the Renaissance period Rembrandt was one of the first artists to begin exploring the consequences of varying relative textural detail in his artwork (see the full development of this art historical argument in DiPaola et al 2010). This argument for precedence had been made previously by art historians, including Berger (1998, 2000) and Martin (1988), in the context of a much wider discussion of how the Renaissance application of science to art went well beyond the contribution of mathematics, perspective, and geometry in the construction of a painted image. Specifically, these authors propose that the emerging understanding of science during the Renaissance included an understanding, implicit or explicit, of the perceptual-motor dynamics that occur when a human eye with limited spatial resolution is confronted with a large scene or image. Yet, prior to the present study, this argument had to rely on authors and readers sharing intuitive assumptions about how the gaze of an observer actually behaved when viewing works of art. Here we report data that bear directly on the issue. Looking to the future, it is possible that a similar approach to the one developed here may be used to test other assumptions concerning the art historical record.

Another contribution to the interdisciplinary exchange made by this study concerns the specific experimental design and eye tracking employed to track the gaze of naive viewers in an objective way. When an argument is made about the relations between composition and eye gaze, based on a single, finished work of art, the argument depends on the untested assumption that gaze would be different if the painting was altered. In other words, a control or comparison condition is rarely possible when studying gaze and appreciation of specific artworks. Here we were able to test such comparisons for the first time, because we were able to use a knowledge-based computer painterly rendering system (DiPaola 2007, 2009) to construct images that varied in systematic ways from one another, yet that were judged by our participants to be plausible works of art in the same category as Rembrandt and other portraitists. The results using these images showed that looking and liking are indeed linked, and that one of the ways they are linked is through the *detail-gaze hypothesis*. Viewers tend to look first to regions of increased detail in an image and their gaze tends to return to these regions more often (experiments 1 and 2). When their return fixations are such that one eye region in a portrait is examined in much greater detail than the other eye, then they also judge that portrait to be a better work of art (experiment 3). These experiments and their initial findings therefore move the debate about eye paths in viewing art away from the art critic's introspective reports of where they looked when viewing an artwork and place it squarely into the realm of empirical research.

6.3 *Limitations and future directions*

At the same time we must acknowledge limitations of the present study, since they can guide future research. One important limitation concerns the art-naive participant sample; a second limitation concerns the very brief period for which the portraits were displayed while participants' eyes were tracked. One of the lessons of past research examining the role of expertise, often referred to as aesthetic fluency in this literature (Smith and Smith 2006), is that naive viewers are more likely to inspect an artwork for its realism and semantic content, rather than for compositional style, genre, and layout (Winston and Cupchik 1992). At the level of eye-gaze behaviour, this is manifest by a tradeoff between viewing specific objects (defined by longer fixations, leaving less opportunity for saccades to new regions) versus diversive scanning (defined by shorter fixations and thus a greater number of saccades to new regions), with naive participants biased to engage in more specific exploration and art-fluent participants engaging in more diversive exploration (Nodine et al 1993; Zangemeister et al 1995). Clearly, finding out how art expertise interacts with the present findings will be an important avenue for further research.

The brief viewing time of the present study limits our conclusions to the first-impression phase of the aesthetic experience. A number of recent studies have been directed at how gaze changes over the time that elapses from the onset of an art display. All of these studies tested art-naive participants, as in the present study, but none of them has focused specifically on portraits. For example, Kapoula et al (2009) compared the first and last 5 s of viewing while viewers explored three nonrealistic cubist paintings by Ferdnand Léger over a 30–40 s period. They reported that fixations were distributed both more centrally in the image, and on a select few regions during the first 5 s than they were during the last 5 s. This overall pattern was influenced by the content of the image and by the goals of the participant, with more realistic content (faces) restricting the range of gaze exploration, and a participant's active attempt to understand the title of the painting increasing the range of exploration.

Locher et al (2007) looked specifically at how much of an image is covered with fixations as a function of time since onset for renowned art works spanning a wide range of genres. They used a talk-aloud protocol simultaneously with eye tracking and reported that within 2 s of viewing participants reported holistic, relational aspects of the artworks, consistent with the extraction of gist and layout in the first few glances at a piece. This was true even though direct fixations did not extend very widely from the centre (less than 27% of total area). Moreover, even though verbal descriptions became more elaborate with viewing time, the total area covered with fixations increased by only 11% more. Clearly, direct fixation to all regions is not required to extract most of the critical aspects of an artwork.

Heidenreich and Turano (2011) tracked the gaze of a four participants viewing artwork in a museum, in order to address questions of how gaze might vary with genre, time of exploration, and aesthetic appreciation. They reported that fixation durations increased with time spent viewing some pieces, but this small trend was overwhelmed by the individual differences between the four participants. With this sample size, they were also unable to establish any relations between fixation duration, overall viewing time, and aesthetic judgments of the paintings.

Findings such as these have been the focus of a lively debate about whether the acquisition of information from an artwork proceeds in sequential stages, beginning with sensory, then perceptual, and ultimately cognitive analyses (Leder et al 2004), or whether the evaluation of an artwork proceeds with numerous analyses in parallel (Locher et al 2007). According to Locher et al (2007), the first glance at an artwork initiates a rapid global analysis to extract spatial, semantic, and emotional gist, followed by an exploration phase in which specific scrutiny of various pictorial features will occur in order to test predictions formed in these

global analyses. The exploration phases is where cognitive curiosity can be satisfied and a deeper aesthetic appreciation can be developed.

From the perspective of this debate, the present eye-tracking results from the first 5 s of viewing are limited to the early sensory and perceptual extraction phases of Leder et al's (2004) model and the gist extraction phases of Locher et al's (2007) model. It is therefore notable that the subjective evaluation of these artworks can be linked to the compositional details picked up in these first impressions (experiment 3a) and that the implicit guidance about where to look, given by the regions of greater clarity in an artwork, can have a direct influence on how much an artwork is valued relative to others (experiments 3b–3d). Because the present findings are restricted to gaze and appreciation of portraits, future research will have to pursue the questions of how gaze patterns when viewing other genres (eg landscapes, still life, abstract) can be linked to their subjective evaluation.

7 Conclusion

The history of visual cognition is filled with examples of large gaps between meta-awareness (ie what participants think they are doing) and what they are actually doing (ie measured performance). This has been documented in the realms of reasoning (Wilson 2009), memory (Dunlosky and Bjork 2008), visual perception (Levin and Beck 2004), and the perception of visual art (Cavanagh 2005). Yet, nowhere is this gap larger than in the areas of visual attention and eye gaze when viewing scenes, as attested to by the well-known effects of change blindness (Simons and Rensink 2005), inattentional blindness (Mack 2003; Mack and Rock 1998), the attentional blink (Shapiro et al 1997), and the work of entertaining magicians over hundreds of years (Kuhn et al 2008). Aside from the historical observation that vision scientists and artists have not been communicating with each other very much, there is no reason we can think of why our modern understanding of the art experience should be lagging so far behind our more general understanding of human image and scene perception. Although these two disciplines may at times use special language and tools, it is undeniable that they share an interest in many of the same questions about the human experience. The present study is offered as a small step toward improving this dialogue.

References

Berger H Jr, 1998 "The system of early modern painting" *Representations* **62** 31–57

Berger H Jr, 2000 *Fictions of the Pose: Rembrandt Against the Italian Renaissance* (Palo Alto, CA: Stanford University Press)

Birmingham E, Bischof W F, Kingstone A, 2008a "Gaze selection in complex social scenes" *Visual Cognition* **15** 341–355

Birmingham E, Bischof W F, Kingstone A, 2008b "Social attention and real-world scenes: The roles of action, competition and social content" *Quarterly Journal of Experimental Psychology* **61** 986–998

Brown H, 2001 *Harley Brown's Eternal Truths for Every Artist* (Cincinnati, OH: North Light Books)

Buswell G T, 1935 *How People Look at Pictures: A Study of the Psychology and Perception in Art* (Chicago, IL: University of Chicago Press)

Campbell F W, Westheimer G, Robson J G, 1958 "Significance of fluctuations of accommodation" *Journal of the Optical Society of America* **48** 669, doi:10.1364/JOSA.48.000669

Cavanagh P, 2005 "The artist as neuroscientist" *Nature* **434** 301–307

DiPaola S, 2007 "Painterly rendered portraits from photographs using a knowledge-based approach", in *Proceedings of SPIE Human Vision and Electronic Imaging XII* International Society for Optical Engineering, **6492** 33–43, doi:10.1117/12.706594

DiPaola S, 2009 "Exploring a parameterized portrait painting space" *International Journal of Art and Technology* **2** 82–93

DiPaola S, Riebe C, Enns J T, 2010 "Rembrandt's textural agency: A shared perspective in visual art and science" *Leonardo* **43** 145–151

Dunlosky J, Bjork R A, 2008 *Handbook of Memory and Metamemory* (New York: Psychology Press)

Enns J T, MacDonald S C, 2012 "The role of clarity and blur in guiding visual attention in photographs" *Journal of experimental Psychology: Human Perception and Performance* Advance Online Publication September 17, doi:10.1037/a0029877

Fenske M J, Raymond J E, 2006 "Affective influences of selected attention" *Current Directions in Psychological Science* **15** 312–316

Fisher S K, Ciuffreda K J, 1988 "Accommodation and apparent distance" *Perception* **17** 609–621, doi:10.1068/p170609

Fleming R W, Dror R O, Adelson E H, 2003 "Real-world illumination and the perception of surface reflectance properties" *Journal of Vision* **3** 347–368

Graham-Dixon A, 2007 "Dutch portraits: The age of Rembrandt and Frans Hals" *Sunday Telegraph Reviews* 7 January

Haber R N, 1980 "How we perceive depth from flat pictures" *American Scientist* **68** 370–380

Heidenreich S M, Turano K A, 2011 "Where does one look when viewing artwork in a museum?" *Empirical Studies of the Arts* **29** 51–72

Hochberg J, 1980 "Pictorial functions and perceptual structures", in *The Perception of Pictures* Ed. M A Hagen (New York: Academic Press) volume 2, pp 47–93

Jacobs L, 1993 "Belasco, DeMille and the development of Lasky lighting" *Film History* **5** 405–418

Kapoula Z, Daunys G, Herbez O, Yang Q, 2009 "Effect of title on eye-movement exploration of cubist paintings by Fernand Léger" *Perception* **38** 479–491

Kuhn G, Amlani A A, Rensink R A, 2008 "Towards a science of magic" *Trends in Cognitive Sciences* **12** 349–354

Langford M J, 1973 *Basic Photography* 3rd edition (Garden City, NY: Amphoto)

Leder H, Belke B, Oeberst A, Augustin D, 2004 "A model of aesthetic appreciation and aesthetic judgments" *British Journal of Psychology* **95** 489–508

Levin D T, Beck M R, 2004 "Thinking about seeing: Spanning the difference between metacognitive failure and success", in *Thinking and Seeing: Visual Metacognition in Adults and Children* Ed. D T Levin (Cambridge, MA: MIT Press) pp 121–143

Locher P J, 2003 "An empirical investigation of the visual rightness theory of picture perception" *Acta Psychologica* **114** 147–164

Locher P, Krupinski E A, Mello-Thoms C, Nodine C F, 2007 "Visual interest in pictorial art during an aesthetic experience" *Spatial Vision* **21** 55–77

Mack A, 2003 "Inattentional blindness: Looking without seeing" *Current Directions in Psychological Science* **12** 180–184

Mack A, Rock I, 1998 *Inattentional Blindness* (Cambridge, MA: MIT Press)

Martin J, 1988 "Scopic regimes of modernity", in *Vision and Visuality* Ed. H Foster (Seattle, WA: Bay Press) pp 3–23

Miall R C, Tchalenko J, 2001 "Painter's eye movements: A study of eye and hand movement during portrait drawing" *Leonardo* **34** 35–40

Molnar F, 1981 "About the role of visual exploration in aesthetics", in *Advances in Intrinsic Motivation and Aesthetics* Ed. H I Day (New York: Plenum Press) pp 385–413

Nodine C F, Locher P J, Krupinski E A, 1993 "The role of formal art training on perception and aesthetic judgment of art compositions" *Leonardo* **26** 219–227

Reber R, Winkielman P, Schwarz N, 1998 "Effects of perceptual fluency on affective judgments" *Psychological Science* **9** 45–48

Sanden J H, 2004 *Portraits from Life* (Cincinnati, OH: North Light Books)

Shapiro K L, Arnell K A, Raymond J E, 1997 "The attentional blink: A view on attention and a glimpse on consciousness" *Trends in Cognitive Sciences* **1** 291–296

Simons D J, Rensink R A, 2005 "Change blindness: past, present, and future" *Trends in Cognitive Science* **9** 16–25

Smith L F, Smith J K, 2006 "The nature and growth of aesthetic fluency", in *New Directions in Aesthetics, Creativity and the Arts: Foundations and Frontiers in Aesthetics* Eds P Locher, C Martindale, L Dorfman (Amityville, NY: Baywood) pp 47–58

Wilson T D, 2009 "Know thyself" *Perspectives on Psychological Science* **4** 384–389

Winston A S, Cupchik G C, 1992 "The evaluation of high art and popular art by naive and experienced viewers" *Visual Arts Research* **18** 1–14

Yarbus A L, 1967 *Eye Movements and Vision* translated by B Haigh (New York: Plenum Press)

Zangemeister W H, Sherman K, Stark L, 1995 "Evidence for a global scanpath strategy in viewing abstract compared with realistic images" *Neuropsychologia* **33** 1009–1025