Expertise in pictorial perception: eye-movement patterns and visual memory in artists and laymen

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Abstract. In two sessions with free scanning and memory instructions, eye-movement patterns from nine artists were compared with those of nine artistically untrained participants viewing 16 pictures representing a selection of categories from ordinary scenes to abstraction: 12 pictures were made to accommodate an object-oriented viewing mode (selection of recognisable objects), and a pictorial viewing mode (selection of more structural features), and 4 were abstract. The artistically untrained participants showed preference for viewing human features and objects, while the artists spent more scanning time on structural/abstract features. A group by session interaction showed a change of viewing strategy in the artists, who viewed more objects and human features in the memory task session. A verbal test of recall memory showed no overall difference in the number of pictures remembered, but the number of correctly remembered pictorial features was significantly higher for artists than for the artistically untrained viewers, irrespective of picture type. No differences in fixation frequencies/durations were found between groups across sessions, but a significant task-dependent-group by session interaction of fixation frequency/duration showed that the artistically untrained participants demonstrated repetition effects in fewer, longer fixations with repeated viewing, while the opposite pattern obtained for the artists.

1 Introduction

Picture perception in artists and laymen has been compared in several studies on the assumption that artists view the world differently from others. While there is no question that the image projected on the retina initially is the same for most people, regardless of their experience, Putko (1989) found that artists employed different cognitive interpretations of 16 well-known paintings in the styles of impressionism, fauvism, expressionism, and cubism than do artistically untrained viewers: whereas a group of artists assessing 16 well-known paintings used terms such as “contrast versus fusion of colour”, “contour versus fluid form”, “dominance of color versus dominance of form”, artistically untrained participants used terms such as “joy versus sadness”, “gay versus gloomy”, “expressive versus unexpressive”. In one 12-s recording session, Nodine et al (1993) found that artistically untrained viewers tended to spend more time viewing individual objects than relationships among elements in paintings. These authors present descriptive eye-movement data but no statistical analyses of their findings, and, furthermore, they used famous paintings that were well-known to the group of artists but not to the control group (each group comprising seven participants). Other authors have reported different eye-fixation patterns in artists and non-artists viewing pictures. Antes and Kristjanson (1991) found that eye-movement parameters alone could differentiate artists from non-artists by fixation densities on less important aspects of paintings, with ‘important’ being defined a priori by one professional artist (rather than by the experimenters according to hypotheses). Zangemeister et al (1995) found that artists and sophisticated viewers used a more global scanning strategy than artistically untrained participants when viewing abstract pictures. This study used only 5 more or less well-known pictures with different levels of abstraction, few participants—only four were professional artists with unspecified types of experience—and the authors did not advance ideas why such differences were found.
To our knowledge, few attempts have been made to differentiate the types of practice familiar to artists studied for their perceptual information-processing strategies. It seems apposite to relate the differences found in pictorial viewing and assessment between artists and laymen to more specific experiences involved in the production of artwork. Although it may be difficult to separate the effects of production of artwork from eg experience in viewing artwork, there is some evidence that learning to draw from life, ie producing figurative work, affects the way we see. Figurative rendition is one of the few activities that require a very exact apprehension of the physical properties of real objects and scenes, and in which categorical knowledge of objects and scenes is not immediately useful. Preconceptions of what a model ‘is’ has been shown to influence renditions in participants (eg Reith and Liu 1995). The art teacher Betty Edwards (1999) found that her previously untrained students tended to overemphasise informative features of human models in portraiture: the face was drawn large while the rest of the head was drawn much too small. In time, however, the students learned to perceive and draw proportions more accurately in models. We propose that in figurative rendition, the ability to apprehend exact physical properties of objects and scenes must of necessity take priority over preconceptions if the model is to be accurately rendered. Subsequent abstractions and manipulations are not subject to this constraint, in that abstractions do not have direct physical references to real scenes and models. Thus, in that the production of figurative artwork involves an enhanced attention to exact physical properties that are not normally crucial for the visual apprehension of the environment, this activity can be thought to involve training effects. A somewhat more focused assessment of specific activity involved in producing figurative artwork is represented in a study by Solso (2001), who used fMRI technology to record the brain activity of one skilled artist and one artistically untrained participant while they each drew a series of portraits. Differences were found in cerebral blood flow in an area of the brain involved in facial processing, with the artist showing lower activation, suggesting a more efficient processing of facial information. The author offers no more specific ideas about the nature of such efficiency.

As mentioned, Antes and Kristjanson (1991) had one professional artist determine which areas of a painting are ‘important’. A more precise way of defining areas of a painting (or a scene) as being more critical than others may be derived from the eye-movement recordings made by Alfred Yarbus (1967). He found that the most powerful attractors of eye movements are features that have meaning for the viewer. He found the single most meaningful objects for artistically knowledgeable, untrained participants to be human features. When participants were allowed to view pictures freely, fixations were mostly associated with human heads and faces, and to a somewhat lesser extent with the human body. He found this preference to override all other features, such as colour and brightness contrast, amount of detail, etc. On the basis of this finding, and using a group of artists with similar backgrounds in terms of artistic experience in which figurative work with both human models and still lifes was a criterion for inclusion, Vogt (1999) in a preliminary study found that eye-movement patterns of painters differed from those of laymen. Whereas the fixations of the group of artistically untrained participants clustered mostly on human features and other recognisable objects, the fixations of the group of painters were significantly more associated with structural/abstract, non-object related features, ie there were fewer fixations on human features and other recognisable objects. This would indicate that artists acquire different viewing strategies as a function of expertise in the apprehension of exact physical properties of scenes and objects, rather than general conceptual associations, and that this may be associated with the figurative rendition of three-dimensional scenes on canvas or paper, ie that structural features have acquired meaningfulness (eg as cues for accurate rendition).
In further study of the effects of artistic training in relation to figurative versus abstract artwork (Vogt and Magnussen 2005), recognition memory and hemispheric specialisation were assessed for abstract colour pictures and black-and-white pictures of sport situations (in which the actors appeared in similar postures as human models in art-education situations) in painters with a similar career background as the group mentioned above, and artistically untrained participants, by a forced-choice yes/no tachistoscopic procedure. Reaction times showed a significant three-way interaction of picture type, expertise, and visual field, indicating that painters processed the abstract pictures in the right hemisphere and sport pictures to the left, relative to the artistically untrained group. The different gradients for the two picture types in the painters (as opposed to the consistent left-visual-field/right-hemisphere advantage in the untrained group) indicate a preferential change of processing strategy by which descriptive systems appear to have developed for figurative, but not abstract pictures. These studies suggest that artistic experience can be studied according to specific criteria derived from the activity of portraying models.

Here, we extend the study of pictorial scanning in artists and artistically untrained participants (Vogt 1999), comparing abstract and realistic pictures in two different viewing sessions, one involving free scanning and one involving efforts to memorise the same pictures, and adding a test of verbal recall to evaluate the possible effect of scanning strategy on subsequent pictorial-memory performance.

2 Methods
2.1 Participants
Nine artists were recruited from the National College of Arts and Crafts and the National Academy of Fine Art, both in Oslo. Ages varied from 25 to 50 years, with most in their late twenties, early thirties. These are the two most prestigious art education institutions in Norway, and most students have additional preliminary training from other art schools. Thus, the participants had between 5 and 11 years of art education behind them, and all were trained in working with models. The artistically untrained group comprised nine participants of the graduate program and staff at the Department of Psychology of the University of Oslo, also an institution with strict screening and a very low rate of admittance. Ages were between 22 to 37 years. Thus, both groups had been through rigorous selection procedures in their respective fields, and any differences in visual behaviour and memory found between the groups should not be due to differences in general abilities or age. Participants had normal or corrected-to-normal vision, and reported no colour blindness.

2.2 Stimuli
16 pictures were compiled with the use of photographs edited in Adobe Photoshop into four increasingly abstract groups. One group of pictures, called 'mundane', consisted of uncomposed snapshots of very ordinary scenes and included human features and recognisable objects (eg car, bicycle, shovel, architectural features, etc; objects that can be assumed to be familiar to anyone); a second group comprised aesthetically pleasing photographs culled from magazines, called 'good', also with human features and recognisable objects; a third group of pictures was made to contain human features and more or less abstract surroundings, ie uniform surroundings without focal, object-related features (eg water surface), called 'edited'; pictures in the fourth group were abstract, with no human features or recognisable objects. Thus, the pictures comprised a selection of categories from everyday scenes to pure abstraction, which to some extent enabled us to assess whether changes in viewing modes were general or applied only to works of art. None of the pictures was familiar to the participants.
In the pictures with recognisable features, the areas thought to attract an object-oriented viewing mode (ie more fixations on recognisable features) were defined in the eye-tracker software, which allows the editing of ‘regions of interest’, henceforth called ROIs, in this case areas with identifiable human or other object features, yielding the percentage of total scanning time within these areas. ROIs were subjectively defined in relatively small areas (figure 3).

2.3 Apparatus
The eye-tracking equipment was from SensoMotoric Instruments (Teltow, Germany), consisting of an infrared camera located on the table directly in front of a 17-inch Eizo-Flexscan T960 monitor showing the 16 pictures successively at a screen resolution of $1024 \times 768$ pixels. The camera recorded from the participant’s left eye. Participants were placed at a distance of 57 cm from the screen in a chin-rest, with pictures subtending visual angles of 23.2 deg vertical, 30.8 deg horizontal. Spatial and temporal resolutions were 0.25 deg and 50 Hz respectively. Fixation time was set at a minimum of 150 ms, which is sufficient for the processing of complex scenes (Thorpe et al 1996). All presentations were made with the software SuperLab Pro from Cedrus (San Pedro, CA), which ensured that the pictures were shown in random order for each participant. Data output provides vertical and horizontal eye movements, fixation duration, and percentage of viewing time within areas defined in advance of recording. Saccade magnitude was computed from the data files.

2.4 Procedure
Recordings of eye movements were done in two separate sessions: one in which participants viewed the pictures freely, and one in which they were requested to concentrate in order to remember them. The sessions were not counterbalanced (free scanning was always first) to ensure that task instruction did not influence spontaneous viewing preferences. Viewing time was 40 s for each picture, with 20 s intervals in which the participants had their eyes closed in order to minimise eye strain. On entering the laboratory, participants were seated comfortably in front of the monitor and positioned in a chin-rest. To distract participants from the real objective of the study, all were told that they would be measured on a variety of physiological parameters, such as pupil size, with a short explanation of how pupil size yields information about how we respond physiologically to pictures. A calibration procedure was conducted with a nine-point grid stimulus provided by SensoMotoric Instruments. In the first recording session, participants were told that they would see 16 different pictures to be viewed as they wished, and that there would be a pause between pictures in which they were to close their eyes. Following this sequence and a short rest, recordings resumed in the second session. A new calibration was made, and the participants viewed an instruction on the screen informing them that they would see the same pictures again, asking them to concentrate in order to remember them. Instructions were not further specified in order to accommodate spontaneous memory performance. Participants were not informed of the nature of the test of memory.

Following the second session, participants were taken to another room for the test of recall memory and asked to speak into a mini-disc recorder describing as much about the pictures they had seen as they could, in any order. They were left alone in the room during recording to minimise distraction. The material from the mini-disc was fully transcribed and scored on a schema for categories of responses. These were (i) configuration, referring to remarks concerning spatial properties and size, such as “to the left of”, “upper corner”, “up”, “down”, “small”, “large”, etc; (ii) form/colour, referring to all simple colour descriptions such as “blue”, “greenish”, “shiny”, etc as well as “round”, “oblong”, etc. Included were simple form descriptions such as “pattern”, “striped", etc; (iii) conceptual, which includes all references that are not strictly visual,
eg “man”, “shirt”, “bicycle”, since this is a category for a large group of visually extremely varied units. Four additional categories for aesthetical evaluation, associations, procedure (comments about how pictures were made), and false positives (memory for features not seen) were scored, but these were not included in the data analysis since the responses in these categories were too few to be of interest.

3 Results

3.1 Eye movements

Analyses of fixation frequency/duration or viewing time within ROIs (both groups) showed no differences between picture types, and no main effect was found between groups for the number of fixations or fixation durations across sessions. Figure 1a shows the average number of fixations per picture in the first and second sessions for artists and artistically untrained participants. The results show an unexpected group by session interaction of fixation frequency \( (F_{1,16} = 22.952, p < 0.001) \) and an inversely proportional interaction of fixation durations \( (F_{1,16} = 14.333, p < 0.01) \), with the artistically untrained group having more fixations of shorter durations in the first session and fewer, longer fixations in the second session, while the opposite obtained for the group of artists. The pattern for the artistically untrained participants corresponds with what is known as the Eye-Movement-Based Memory Effect (Althoff and Cohen 1999; Henderson et al 1999; Ryan et al 2000), ie in moving their eyes around a visual display and fixating various picture elements, participants make fewer fixations and sample fewer regions for previously viewed items than for novel ones, thus demonstrating a form of priming. Ryan et al (2000) used in their study 8 pictures and 5 s exposures for a repeated viewing condition. They observed a repetition effect, in that participants made fewer fixations in the second viewing of the pictures. In the present study, the artists demonstrated the opposite effect, with more fixations of shorter durations in the second viewing of the pictures. Although there are important differences between the procedures used by Ryan et al and those used in the present study, the similarity of the patterns of fixations of their participants and our artistically untrained participants was striking. In order to effect a cursory comparison with the part of the study by Ryan et al (2000) assessing the Eye-Movement-Based Memory Effect, the first 5 s of the present eye-movement data were sectioned and re-analysed. The results of this analysis, plotted in figure 1b, show a similar group by session interaction \( (F_{1,16} = 21.569, p < 0.001) \) for fixation frequency. An inverse \( (F_{1,16} = 7.81, p < 0.01) \) obtained for fixation duration. Subsequent analyses of ROIs were also carried out for the first 5 s as well as the remaining 35 s recordings for the purpose of consistency as well as to assess eventual time-related dynamics in viewing preference, ie whether the patterns would alter with viewing time.

![Figure 1. Mean number of fixations for the collapsed picture types for both groups (artistically untrained participants ◆, and artists ▲) in two sessions: (a) the entire recording, 40 s; (b) the first 5 s. Error bars show SEM.](image-url)
Figure 2 shows the percentage of scanning within areas with recognisable objects and human features, ROIs. Results for the entire 40 s recordings show that, across sessions, the untrained group spent more viewing time within ROIs than the artists \((F_{1,16} = 40.23, p < 0.001)\). Furthermore, the untrained group did not alter from the first to the second session in this respect, while the artists spent more time within ROIs in the second session. The difference in the pattern for the artists—the tendency towards more object-oriented viewing in the memory task—produced a significant group by session interaction \((F_{1,16} = 4.90, p < 0.04)\) in the analysis of the first 5 s of the recordings. The analysis of the remaining 35 s of the recordings also showed a group by session interaction for scanning of ROIs \((F_{1,16} = 4.4, p < 0.05)\) with a main effect of expertise \((F_{1,16} = 32.46, p < 0.001)\) and a main effect of session \((F_{1,16} = 5.45, p < 0.03)\). Analysis of the differences between the first, 5 s section and the remaining 35 s section showed a main effect of time \((F_{1,16} = 14.08, p < 0.002)\), with a difference in the free-scanning conditions \((F_{1,16} = 7.99, p < 0.01)\), and in the memory condition \((F_{1,16} = 14.08, p < 0.002)\). Figure 3 shows representative scanning patterns for the entire recordings for an artistically untrained (centre panel, top and bottom) and an artist (right-hand panel, top and bottom) viewing pictures from the categories ‘mundane’ (top) and ‘edited’ (bottom). No effect of picture type was found in the analyses above.

In the analysis of local versus global saccades, local saccades were defined at 1.6 deg (and global saccades beyond that value), as normal participants apply saccades and drifts of fixational eye movements during maintained fixation in the range between 0.08 deg and 0.8 deg (Stark and Choi 1996; Zangemeister et al 1995). This boundary could be greater, but in increasing the definition of regions defined as local, the global/local ratio would decrease, thus compromising discrimination capability (Zangemeister et al 1995). Figure 4 shows the global/local ratios for the artistically untrained participants and the artists.

All picture types were included in the first analysis of global/local saccades. In this analysis, no differences were found for the picture types ‘mundane’, ‘good’, and ‘edited’, but the abstract pictures differed with regard to global/local ratios. Hence, the first three picture types were collapsed (and called ‘realistic’) and compared with the abstract pictures in the subsequent analysis. In this, an effect of picture type was observed for artists viewing abstract pictures. The results show an overall group by session effect of global/local ratios \((F_{1,16} = 8.12, p < 0.001)\), reflecting an overall tendency for reduced global scanning from the first to the second session, with the exception of the global/local ratio for the artists increasing from the first to the second session for abstract pictures. When data for the picture types with objects and human features were collapsed and compared with data for the abstract pictures, a three-way interaction between viewer group, session, and picture type was found \((F_{1,16} = 6.17, p < 0.02)\).
3.2 Memory

There were no significant overall differences between the participant groups in the number of recalled pictures, except that the artists, somewhat surprisingly, remembered fewer abstract pictures than the untrained group ($t_{16} = 2.12, p < 0.05$). However, the artists showed a better memory for pictorial detail than the artistically untrained viewers for all picture types. Figure 5 shows the total number of correctly recalled pictorial items for each category and each type of picture for artistically untrained (upper histogram) and trained (lower histogram) participants.

The results further showed a main effect ($F_{3,218} = 9.50, p < 0.001$) of response frequency between groups for picture attributes. Results for responses within the individual categories of response types were as follows: conceptual $t_{16} = -2.30, p < 0.02$; configurational $t_{16} = -4.16, p < 0.001$; form/colour $t_{16} = -4.30, p < 0.001$. This analysis also yielded differences with regard to picture types. The overall difference between the ‘mundane’ and ‘good’ picture types was $t_{41} = 11.2, p < 0.001$. Otherwise, no significant differences were found for the picture types.

Figure 3. Examples of eye-movement patterns of individual participants viewing the pictures shown in the left panel with ROIs outlined; the top and bottom pictures are from the categories ‘mundane’ and ‘edited’, respectively. The scanpaths of an artistically untrained participant are shown in the upper and lower centre panels; those of an artist are shown in the right-hand upper and lower panels (both from session 2). The ROI outlines were not visible to any participants.

Figure 4. Mean ratios of global/local saccades for artistically untrained participants (left) and artists (right) viewing the same set of pictures in two sessions. Results for pictures with human features are collapsed, labelled ‘realistic’, and contrasted with results for abstract pictures.

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4 Discussion

The results of the present study confirm and extend earlier findings (Vogt 1999) in showing that artistically trained participants view familiar objects to a lesser extent than the laymen, with an increased preference for viewing more or less abstract, structural features instead. In extending the former study with an extra memory-related viewing session, we were able to observe that the eye-movement patterns of artists varied with both task and time, a finding that did not apply to artistically untrained participants. In the artists, viewing was more object-oriented when attempts were made to remember the pictures, as observed in more scanning time within ROIs in session 2. Furthermore, in comparing viewing preference for the first 5 s of viewing with the remaining recording, we observed that for both groups the tendency to scan within ROIs was more pronounced initially, with less object-focused viewing over time.

The increased global/local ratios for abstract pictures confirmed the results found by Zangemeister et al (1995). Although a significant difference between the groups was found, our results were less dramatic than those found by Zangemeister et al (1995) for artists viewing abstract pictures. This may suggest that the nature of the pictures themselves represents a strong influence. For example, in the present study, none of the four abstract pictures had striking focal areas, whereas the two abstract pictures used by Zangemeister et al (1995) had much greater brightness and colour contrasts.

The unexpected finding that artists do not demonstrate repetition effects in the form of fewer and longer fixations in a second viewing is difficult to account for. This type of effect has been used as an implicit measure of memory and obtains even for patients with severe memory impairment; its absence in the group of artists in the present study may indicate a somewhat radical deviation from normal viewing strategies.

Figure 5. Recall memory for the 16 pictures for artistically untrained participants (upper panel) and artists (lower panel). The mean number of correctly remembered pictorial details in response categories labelled conceptual, configurational, and form/colour.
Further work is needed to assess this finding, but one may tentatively propose that the strategy used by the artists affects encoding variability. In a study of the interactions of priming and explicit memory Wagner et al (2000) found an inverse proportion between high behavioural priming and subsequent explicit memory, suggesting that priming for past experiences may hinder new episodic encoding. Their proposed explanation for this finding is that priming may result in a reduction of encoding variability. The absence of repetition effects in the form of fewer and longer fixations in second viewings, together with superior memory for picture features found in artists in the present study may suggest a similar scenario, ie that artists become more skilled at extracting and remembering a greater variety of visual features because this is relevant to the production of pictures.

With regard to the superior memory for features demonstrated by the artists, it could be argued that performance reflects past experience and expectation and that artists are merely better at guessing the likely constituents of pictures. However, given the large range of such possible likely constituents together with the absence of any false positives in the responses indicates that it is unlikely that guessing is the reason for higher recall memory performance in the artists.

Why do artists scan pictures differently from laymen? We have suggested that the scanning behaviour of artists is related to training in figurative rendition, in which the ability to correctly apprehend the exact physical features of picture elements is necessary. One trend within cognitive psychology seems particularly apt for describing the effects of such training. As part of a general model of object recognition and visual imagery, Kosslyn et al (1989) proposed a distinction in the processing of spatial relations in terms of categorical and coordinate visual properties. In this view, categorical representations relate to general properties of the spatial structures of objects and scenes without defining physical proportions, while representations of coordinate spatial relations involve precise spatial locations of objects or parts in terms of metric units. This conceptualisation serves to describe an important aspect of the development of drawing and painting skills. When drawing or painting real models, as opposed to rendering abstract work that does not immediately depend on realistic portrayal, coordinate information acquires immediate importance: one needs to apprehend the exact physical properties of the scene, otherwise rendition is impossible. Anyone who has tried to draw or paint from models knows that this is difficult. Although it may not be apparent why this is so, it is likely that preconceptions of what the model ‘is’ interfere with the ability to see what is actually there. This idea has a long history. Gombrich (1960, page 10) observes that “the academic teacher bent on accuracy of representation found, as he still will find, that his pupils’ difficulties were due not only to an inability to copy nature but also to an inability to see it”. A variety of techniques have been devised in order to flout our natural tendency to extract meaning and invariance from scenes. For example, several woodcuts by Albrecht Dürer (1471 – 1528) depict ways and means of circumventing perceptual size constancy by portraying models viewed through transparent panes with grids. Thus, accurate rendition is achieved in the transcription of features piece by piece as guided by the confines of the individual cells of the grids. This method may have been inspired by Leonardo da Vinci’s (1452 – 1519) suggestion that perspective was nothing more than viewing a scene behind a pane of transparent glass on the surface of which the objects behind the glass can be drawn. This is referred to as a ‘da Vinci window’. In much more recent times, Reith and Liu (1995) used a da Vinci window to assess hindrances to accurate depiction of projective shape. They had adult participants draw the visual projection of two models, one a trapezoid and the other a tilted rectangle in the frontoparallel plane. They found that the projected shape of the trapezoid was drawn accurately, but the tilted rectangle was systematically distorted in the direction of its actual dimensions. Thus, even with the help of a
da Vinci window, the participant’s knowledge of the real shape of the model influenced performance, i.e. the categorical spatial relations view overrode the apprehension of the coordinate features. One may argue that the lack of training in the motor aspects of drawing may comprise difficulties in rendering natural scenes. This undoubtedly compounds the problem, but art students tend to demonstrate systematic mistakes implying that preconceptions of objects are the dominant hindrance. As mentioned, the art teacher Betty Edwards (1999) found that previously untrained students drawing portraits tended to draw the back of the head much too small, probably reflecting the tendency to emphasise the ‘important’ features of the face, i.e. the eyes, mouth, and nose. In effect, laymen tend to draw portraits in a way that mirrors the way artistically untrained participants scan faces, as observed by Yarbus (1967). If lack of training in the motor aspects of drawing were the cause of laymen’s difficulties in rendering scenes, then it is probable that misrepresentation would be more random.

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