https://doi.org/10.2352/ISSN.2470-1173.2017.14.HVEI-154

Imaging human vision: an artistic perspective

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Abstract

The purpose of artistic practice has frequently been to translate human visual experience into pictures. By viewing these pictures we can retrospectively share something of the world the artist saw, and the way he or she saw it. Over the centuries artists have evolved highly refined methods for depicting what they see, and the works they produce can provoke strong emotional, aesthetic, and perceptual responses. Looking at a painting by Vincent van Gogh of a vase of sunflowers, for example, can be more thrilling and memorable than seeing a real vase of sunflowers, or even a photograph of the same scene. Why do we respond so strongly to artistic depictions of everyday scenes? The hypothesis considered here is that artists do not attempt to faithfully record reality. Rather, they select and manipulate visual information in ways that are tuned to our subjective experience. I will discuss some of the techniques artists have used to achieve this, and consider how they might be relevant to those designing new forms of imaging technologies in order to improve how they represent visual experience.

1. Introduction

Artistic representations of reality are among the earliest human artifacts [16] and today images that depict the visual world are ubiquitous. For most of human history the sole methods of imaging what was seen were drawing and painting. Only relatively recently, with the invention of photographically fixed images in the early nineteenth century, have mechanical methods become established. Now there is a proliferation of imaging technologies able to capture and present the world in pictorial form. Such technologies include 'wet' film, digital stills and moving image photography, computer graphics, holography, 3D scanning, virtual, augmented and mixed reality, light field technology, and others now in development.

In this paper I will consider some of the techniques used by artists, specifically painters, to create images of visual reality, or what I will refer to as 'depictions'. I suggest this consideration is timely for two reasons. First, we are currently experiencing rapid and complex changes in imaging technologies that now threaten to disrupt traditional ideas about what it means to depict reality. It is possible that artists have already anticipated some of this disruption. Second, vision scientists and technologists are increasingly interested in what they can learn about human vision from analyzing art. How can this knowledge contribute to new and better imaging methods?

In order to achieve their aims artists have generally rejected what might be called the logic of photographic (literally 'drawn with light') depiction, which strives for optical fidelity [11]. Instead they have tended to address the subjective aspects of human perception, i.e. the phenomenal experience of seeing the world. As a result the artistic approach to depiction often departs quite fundamentally from the objective laws of optics and geometry around which current imaging technologies are designed. A painting of a vase of flowers by Vincent van Gogh has much greater monetary and cultural value than a photograph of the same subject, despite the latter being a much more faithful optical record of its visual properties.[1] This paper tries to help us understand why.

2. The ontology of depiction

I use 'depiction' to refer to the act of representing a visual experience of the world in a picture, either artistically or through some mechanical process [3; 7; 12]. Depictions, or pictures, are thereby distinguished from other kinds of images, such as symbols, diagrams, charts, abstractions, imaginative reconstructions, maps, patterns, etc., which may be representational (of things like ideas, data, terrains, hallucinations, and memories) but do not aim to portray what the depicter sees in the world. While the distinction between pictures and images is not precise, it is nevertheless useful to limit our discussion to cases in which a depicter intentionally converts the appearance of the three-dimensional world onto a (normally) two-dimensional surface. The act of depiction entails at least four ontological states:

State 1: The objective world, available to all observers.
State 2: The subjective experience of viewing the world, available only to the depicter.
State 3: The objective depiction, available to all observers.
State 4: The subjective experience of the person viewing the depiction, available only to the viewer.

Depiction, therefore, entails both objective and subjective states that relate in a certain sequence.[2] The nature of these ontological states is complex and beyond the scope of this paper to decompose in detail.[3] It is enough here to point to their existence in order to explain how artistic and technologically generated depictions function (see Figure 1).

3. The logic of photographic depiction

We can think of pictures as simulations of, or substitutions for, the patterns of light that arrive at a viewer's eyes from the world. According to most scientific accounts of depiction linear perspective provides the only method of achieving this accurately [6; 7; 18; 27; 29; 30; 31]. The principles of linear perspective, first formalised by Leon Battista Alberti [1] in 1435, determine how light rays projecting onto a plane lying parallel to the viewer create a pattern or image (illustrated in

[1] A painting of sunflowers by van Gogh sold for the then record sum of $39.9 million in New York in 1987 (New York Times, 4th April, 1987).
[2] Note that the ontological states described here do not imply a fundamental discontinuity between external reality and internal perception [24].
[3] There is a huge literature on the philosophy of depiction, too wide-ranging to summarise here. Of particular importance are [6; 26; 28].

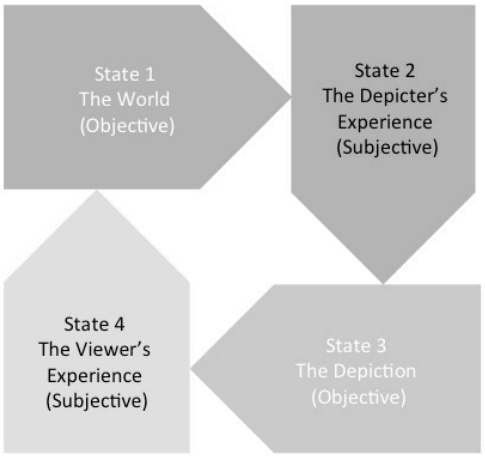

Figure 1. *A diagram of the four ontological states entailed by depiction. Note that they occur in sequence, and the loop is closed. The viewer's experience (State 4) relates to the world (State 1)*

Figure 2). When viewed from the correct position they will present the exact pattern of light that would have been seen emanating from the world. Assuming ideal conditions, the picture would be indistinguishable from the scene it represents [29]. Referring to the table of ontological states above, viewing the depiction (State 3) would be identical to viewing the world (State 1). This outlines the logic of 'photographic' depiction, underpinned by the laws of linear perspective.[4]

4. The limitations of photographic depiction

It was artists and architects who first decoded and applied the laws of linear perspective, later to be refined and extended by scientists, engineers and mathematicians.[5] But it was also artists who first realized their limitations. It soon became apparent to Leonardo da Vinci and Piero della Francesca among others that linear perspective was ineffective for rendering any scene with an angle of view wider than around 90 horizontal degrees [10]. As light rays fan out from their source towards the edges of the flat plane on which they are being rendered the angle at which they diverge from the perpendicular becomes ever greater, to the point where unacceptable levels of pictorial distortion occur in the margins of the picture [11; 17]. Moreover, the illusion of realism that would have resulted from adopting an ideal viewing position was rarely achieved in practice. Paintings were often installed in far from optimal locations, such as on

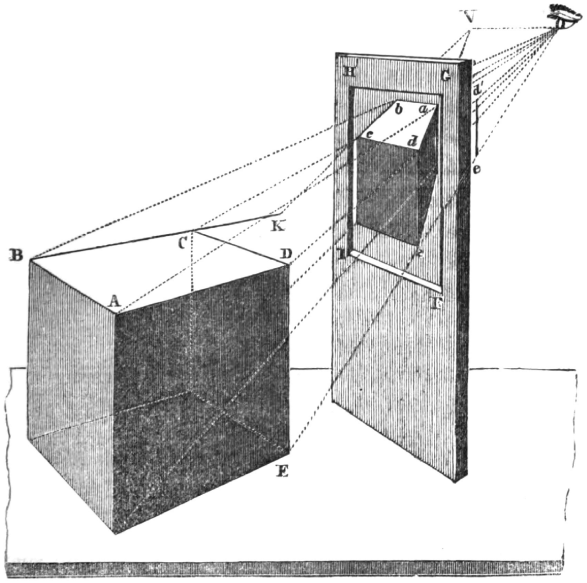

Figure 2. *An illustration from Brook Taylor's* Principles of Linear Perspective*, M. Taylor, London, 1835, page 9, showing how, according to those principles, an eye placed at the correct position will receive the same pattern of light from a picture as would be seen from the world.*

ceilings or high up on walls. For these and other reasons, providing a perfect simulation of the patterns of light from the world on a surface, while theoretically possible, proved impractical. Artists had to compromise on strict mathematical accuracy when depicting reality and find creative solutions that would overcome the limitations of the linear perspective method [15; 29].[6]

Today powerful computer graphics and high quality optics enable us to automatically render visual spaces with great linear perspectival precision. Second wave virtual reality and augmented reality systems come as close to providing the ideal simulation of light patterns as any method invented so far. Sensors on the head mounted display control the presentation of light patterns to the eyes in the headset in such a way that they mimic the patterns of light that would be seen from the world. The relatively narrow field of view in the headset is, to some extent, compensated for by the ability the viewer has to explore the virtual environment with head and body motion. But even with recent technological developments the ideal conditions required for completely accurate simulations are virtually impossible to achieve. A system would need to be able to project light paths at the full dynamic range of natural light to both eyes individually with very high resolution and with a very high refresh rate across the entire span of the binocular visual field (some 180 degrees horizontally and some 130 degrees vertically) regardless of the position of the eyes viewer's eyes, head or body. No existing system is able to achieve this.[7]

[4] I use the term 'photographic' to mean not only depictions made with cameras but also all those made with imaging technologies that capture and display patterns of light according to the laws of linear perspective. At the time of writing this includes almost all imaging technologies.

[5] Linear perspective is one the most successful technologies ever invented, and now underpins all lens-based and computer graphical imaging technology. The fact that it was first discovered and applied by artists and architects is worth pointing out to those (and there are still some) who question the utility of art & design education and research in comparison to science, technology, engineering and mathematics.

[6] Andrea Pozzo (1642-1709) was one of the few artists who went to the extent of prescribing the exact viewing location —marked by a circle on the floor — from which to see his ceiling decoration in Sant'Ignazio Chapel in Rome [18].

[7] It is also debatable as to whether such a system, were it to be built, would be displaying pictures at all. The viewer would be unaware of the picture surface, as is the case with conventional

5. Artistic approaches to depiction

Artists realized long ago that it was futile to aim for photographic realism in painting. In fact, such an aim was often disdained as the 'mere copying of appearances', lacking any original contribution from the artist.[8] Today, the genre of 'photorealism' in painting is not highly regarded by art critics or historians, and such works rarely fetch high prices at auction. Instead, it was discovered that forms of depiction that many people would think 'unrealistic', i.e. un-photographic, proved highly memorable and engaging for audiences. In what follows I will outline some of the techniques used by artists that eschew the logic of photographic depiction, and suggest why they seem to attract and hold our attention so effectively.

5.1 Depiction as approximation

In the absence of any method of fully and accurately simulating light patterns, whether in artistic or technological depictions, the general solution adopted by artists (and also by technologists) has been to approximately render the patterns of light from the world. Figure 3 shows a digital painting by the author that depicts a still life scene. Note how the objects are sparsely rendered and many of their outlines deformed. The dynamic range of the image is far narrower than would have been the case in reality, and the colours correspond only loosely to what was reflected by the scene. Fortunately for artists and technologists, humans are surprisingly tolerant of such approximations. We are able to decode pictures that deviate markedly from the appearance of the objects they depict, whether this is because the representation in the picture itself is non-veridical or because the picture is viewed from a non-optimal angle.[9]

Figure 4 shows a reproduction of another painting by the author. It deviates from its original source in several ways. As with Fig. 3, the objects in the scene have been rendered in distorted manner; most of the detailed texture has been filtered out; colours have not been reproduced faithfully; the dynamic range has been reduced. In addition, the picture itself has been distorted to simulate how it would appear when viewed from a skewed angle. Despite the discrepancies between what was originally seen and what is shown here the content of the picture is still quite readable.

In fact, all extant depictions are approximate or partial in that none of them fully simulate light patterns from the world. Consequently, we must classify existing photographs, movies, computer graphic images, holograms, and other mechanical

Figure 3. *A reproduction of a* Still life at a conference on human-inspired models of computer vision *by Robert Pepperell, 2016, digital painting. This depiction is an approximate rendering of the light patterns available to my eyes as I looked at the bowl of sweets in the centre of the table.*

depictions in this way. What tends to distinguish paintings from photographic depictions is that the former are generally far more approximate than the latter (see Figure 8).

Being free from the requirement to accurately record patterns of light gives artists great license to manipulate appearances in order to perceptually or emotionally affect their audiences.[10] They can apply infinite degrees of distortion, transformation, or exaggeration, they can leave areas blank or incomplete, as long as the pattern of light they record is sufficiently similar to what would have been presented by the scene that viewers can recognize what is being depicted. Jan Koenderink and colleagues have recently formalized the relationship between accurate and approximate depictions in terms of the 'fudicial' and the 'eidelon'; the latter they describe as a 'capricious local sign' [14].

5.2 The dichotomous nature of depiction

Once we accept that pictures are approximate and partial representations of the visual world another factor comes into play of great importance to the nature of depiction. Because a depiction is not identical in appearance to what it depicts the viewer is aware of the physical structure of the depiction at the same time as the contents being depicted. This is a fact all too easily overlooked, but one that artists are particularly conscious of.[11] In Figure 3 we are

pictures, which many authors have taken to be a requirement of picture perception [26].

[8] There is long tradition of anti-mimesis in Western thinking about representation, stretching back at least to Plato's theories of art.

[9] What has puzzled many who have studied pictures is how we are able to satisfactorily interpret the contents of a depiction even when we are not located in the ideal viewing position [18]. Indeed it is remarkable the extent to which we can do this from almost any viewing position, regardless of the 'distortions' to which the original image is subjected. A photographic subject looks no less real when viewed from an angle as when viewed straight on. This so-called 'robustness' of the perspectival illusion remains the subject of much debate and research [13; 15].

[10] As an example of a recent study on how artistic distortion can affect viewers, both perceptually and emotionally, see [32] where the figurative paintings of Francis Bacon are analysed.

[11] The famous remark by the painter Maurice Denis made in 1890 is often quoted in this context: "It is well to remember that a picture, before being a battle horse, a nude woman, or some anecdote, is essentially a flat surface covered with colours assembled in a certain order."

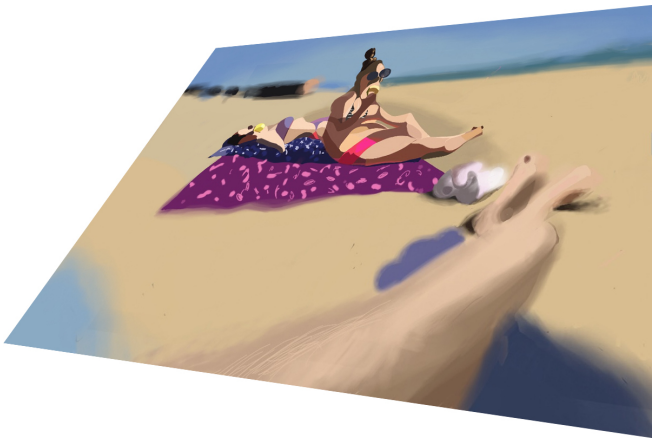

Figure 4. *Robert Pepperell,* Beach scene*, 2016, Digital painting. Despite the distortions in both the rendering of the scene and in the way the reproduction of the picture is viewed (a skewed angle has been simulated) the overall content of the picture remains quite readable.*

aware of seeing water bottles, a bowl of brightly wrapped sweets, etc. but are also aware of the image on the screen or page that occupies a distinct ontological state from things it depicts. This 'dual' or 'dichotomous' property of our awareness of pictures has often been noted but its significance is rarely appreciated [7; 13; 18; 22]. Referring again to the table of ontological states, the experience of viewing the depiction (State 4) consists in being aware of the contents of the world (State 1) and the physical properties of the depiction (State 3). Looking Figure 5, the artist, J M W Turner, has given great prominence to the physical texture of the material from which the scene is woven, and when viewing the painting we experience a perceptual conflict between what it depicts and what it is made from [22]. According to this account, pictures (with the possible exception of ones that accurately simulate light patterns, were such pictures to exist) are not *illusory* in the sense of being misleading, but objects in which we recognize the co-existence of multiple distinct states simultaneously, not least the physical surface and the depicted scene.[12]

5.3 Depiction of subjective experience

Alongside the accurate and approximate forms of depiction already described there exists a further kind of picture that has long been of interest to artists but is also becoming of increasing importance to image technologists. This is picture that not only approximates certain patterns of light from the world but also portrays something of the subjective experience of the depicter.

Figure 6 is a wide-angled photograph made from the same viewpoint as the painting in Figure 3. It is a far more accurate and complete depiction of the patterns of light emanating from the scene than Figure 3. However, it is actually less representative of the experience of seeing the scene. Why? Because, unlike the photograph, which records objective patterns of light in the world, my painting records how that scene appeared to me when looking at the bowl of sweets. Note how the peripheral areas of the painted visual field are less distinct and more spatially compressed than the central region in comparison to the photograph [19].

[12] Depiction has often been theorized as form of illusion. See [6].

Figure 5. *A reproduction of* Mercury Sent to Admonish Aeneas *(detail) by Joseph Mallord William Turner, Exhibited 1850, Tate Bequest, London. Photograph by the author.*

The painting is also a composite of two points of view, one from each of my eyes. Binocular fusion, differential clarity and peripheral compression are all features of subjective perception rather than properties of recorded light.[13] Referring again to the table of ontological states above, viewing the depiction (State 3) approximates to viewing a part of the world (State 1) but also portrays something of the depicter's visual experience (State 2).[14]

The distinction between depicting what is 'out there' in the form of light from the world and what is 'in here' in the mind was cast by the historian Ernst Gombrich in terms of the difference between *what* we see and *how* we see [8].[15] Until recently this distinction would have been of less interest to imaging technologists (those who design the devices we use to depict the world) than artists. The scope for portraying subjective experience has traditionally been much greater for painters with their freedom to manipulate appearances than for photographers and other users of imaging technology who have, until now, relied on devices that conform to the logic of linear perspective.[16] Giving prominence to the subjective aspects of vision has been one of the most important

[13] For further accounts of how a painting represents a first-person subjective viewpoint and how this differs from the standard picture created by a linear perspective device see [2].

[14] Paul Cézanne remarked: "To paint from nature is not to copy an object; it is to represent its sensations." [4].

[15] It is often taken for granted that the mind is located inside the head, specifically in the brain, or part thereof. I have long argued against this view [21], For the purposes of this paper I will say only that, for me at least, it is more helpful to regard the mind and world as integrated. In which case the mind is partly in the head and partly in the world. For a more thorough treatment of this view see [20].

[16] There are a few examples of photographers who have used the medium to portray subjective properties of vision. Peter Henry Emerson (1856-1936) was a British photographer who experimented with and argued passionately in favour of a form of 'naturalistic photography' based on the biology and phenomenology of human perception rather than, as he saw it, the mere mechanical recording of reality [5].

ways artists have engaged their audiences. The painter and writer Timothy Hyman talks in a recent book of the how Ludwig Kirchner's rapid style of sketching shifts "…the emphasis away from the object seen towards the presence of the artist" [9]. With many works of art, particularly great works of art, we are aware of both what is being depicted and the 'personality' of the artist, manifest in the stylistic character of the way the scene is rendered.[17]

Figure 6. *A reproduction of a wide-angle photograph taken by the author of the same scene depicted in Figure 3. Note the differences in how the space is represented, the photograph being a more 'objective' and accurate record of the light patterns than the painting, which depicts the 'subjective' experience of viewing the scene.*

Recently released technologies, such as Snapchat's Spectacles and the Povie are marketed as devices for recording and sharing the user's first person perspective. Compelling first person perspectives are a key selling point of many leading first person shooter games, such as Doom. Such products point to a growing trend for media that reflects and conveys subjective experience. Future developers of such systems may look to artists for solutions on how to make subjective media more engaging and personal, which to be fully effective may require abandoning adherence to the logic of photographic depiction.

5.4 Depiction as shared experience

Accurate simulation, as discussed in 3.1, provides the viewer of the depiction with an identical experience to that which would have arisen from looking at the world itself. State 2 in the ontological table is of no consequence. In subjective depiction, however, the experience of the depicter (State 2) is part of what is being depicted. Consequently the experience of the viewer (State 4) is, in part, composed of the depicter's experience (State 2). In this case, both subjective states (2 and 4) become more deeply integrated or shared. This raises questions about the exclusivity of subjective experience. If, as is generally agreed, the only person having access to a subjective experience is the person in whom that experience originates, then this is not so when depictions simulate and thereby convey subjective experience. In such circumstances it is meaningful to talk of 'shared experience',

[17] This idea is captured by Zola's dictum "…a work of art is a corner of creation seen through a temperament" [33].

Figure 7. *A reproduction of a painting by the author that depicts the visual experience of making a drawing. Try looking at the picture with one eye (you may need to enlarge it) and cast your 'mind's eye' through the picture surface into the imaginary world beyond. You may feel an odd sensation, as if you are seeing the world through somebody else's eyes.*

across or between individuals. The difference between this and what was described in 5.2 is the difference between *seeing a picture of what I saw* and *seeing what I saw*. In the latter case the dichotomous properties of the picture are less prominent, promoting a more vivid 'presence' of the depicted scene.

It turns out that artists are quite familiar with the idea of sharing experience through art. For many it is the whole point of doing it. The painter Sargy Mann (1937-2015) wrote an essay in which he explicitly identified the enabling of shared experience as the goal of art [25]. The consequences of thinking about depictions as a means of enabling shared experience are quite profound, not least for those involved in creating new forms of imaging technology. It changes the way we habitually think about what pictures are and what they do. Rather than a picture being a record of the visible world, or even a record of somebody's experience of the world, it becomes an experience of the world that can be distributed.

Figure 7 is a painting made by the author. As with Figure 3 it is an attempt to convey the entirety of my visual experience when looking at a given point in the space. But rather than looking at it, as you might be accustomed to do, as if it is a picture of *what* was in front of me look at it instead as if you were seeing *as* I saw. In other words, imagine you are seeing 'through me' into the world.[18] Once you are able to do this there is a tangible feeling or sensation that accompanies it, something like a perceptual shock that is exciting to experience. Pictures like this demand, as the philosopher David Chalmers pointed out to me, a different way of

[18] One way I have found to produce this effect is to take a viewing position quite close to the picture so that it fills as much of the visual field as possible (the optimal distance will depend on its physical size). Then close one eye, and focus the open eye on a feature somewhere in the centre of the picture. Now try to imagine you are seeing *through* the artist's eyes *into* the world that would have been before them. This may take some practice but once the skill is learnt it can be applied to almost any depictive painting. If you try this in museums you may well attract the attention of the guards, who are accustomed to visitors looking at the works in more conventional ways.

looking from that we conventionally bestow on pictures. Remarkably, the effect seems to work with very many painted and drawn depictions, almost irrespective of how realistic they are, i.e. how accurately they have simulated certain patterns of light.[19] Strangely, it seems far harder to achieve the same effect with conventional photographs.

New imaging technologies that aim to depict visual experience, rather than just vision, may involve not only different methods for capturing and displaying content, but of looking too.

6. Conclusion

The principles of linear perspective provide a logical framework for achieving depictions of the highest fidelity. Yet artists have largely sidestepped this framework, preferring instead to approximate visual appearances, or indeed grossly distort them. [20] Far from harming artistic prospects, however, this approach has resulted in the creation of some of the most revered and coveted objects in human culture. Looking at the two pictures in Figure 8, why is the (real) painting so much more interesting and engaging than the photograph? Both show very similar scenes. This paper has suggested there are at least two main reasons:

1. The painting is more approximate to the patterns of light from the world sand therefore highlights the dichotomy between the physical material from which the depiction is composed and what is depicted. This is even more apparent in the real painting, where the texture of the paint is prominently featured.

2. The painting conveys aspects of the artist's subjective experience, his personality, while the photograph does not. In the painting this is accentuated by the distinctiveness of van Gogh's depictive style, and features such as the prominent autograph on the vase.

The advent of digital image processing and artificial intelligence technologies opens the way for new methods of simulating subjective properties of visual experience not necessarily bound by previous constraints of photographic logic. Such technologies may be capable of creating depictions of the first person, or egocentric, perspective that are more intimate and compelling than can be achieved with current linear perspective-based devices [23]. This suggests important questions for designers of imaging technology: What is such technology designed to do? Is it to capture a scene from the world in the most accurate way, and convey this to a viewer with objectively measurable fidelity? Or is it to capture and share a certain kind of subjective experience that would otherwise occur only to a single person? Are we imaging *human vision* or *human visual experience*? Which is the more potent, powerful, engaging or meaningful? [21]

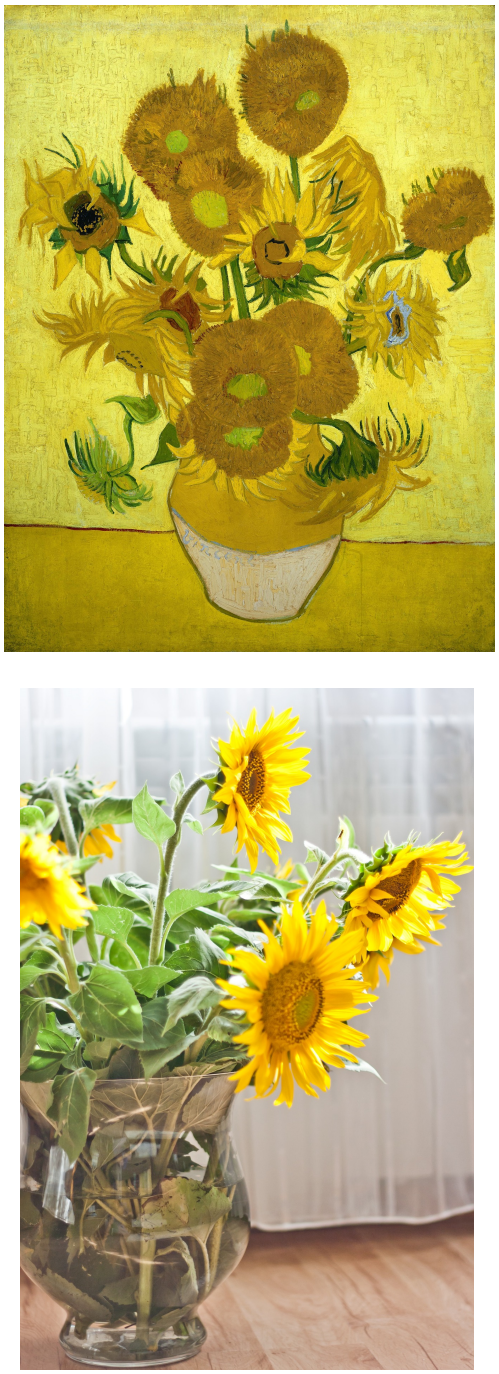

Figure 8. *Top is a reproduction of painting by Vincent van Gogh,* Still Life: Vase with Fourteen Sunflowers *of 1888 (Wikicommons). Below is a photograph that shows a similar scene. The painting is a more approximate representation of the patterns of light from the world than the photograph, and conveys more of the subjectivity of the artist.*

Acknowledgements

I thank colleagues in the Fovolab (www.fovography.com) for the stimulating discussions on the topics covered in this paper, in particular Alistair Burleigh, Nicole Ruta and Richard Vigars. I would also like to acknowledge the support of Cardiff Metropolitan University's Vice Chancellor's Board.

[19] I have had very powerful experiences of this kind when looking at portraits by Alberto Giacometti (1901-1966), which are by no means conventionally realistic.

[20] Interestingly, I am yet to find any examples of paintings in the history of art conforming *strictly* to linear perspective, despite generations of artists having been thoroughly schooled in its rules.

[21] I work with a research team at Fovolab (www.fovography.com) who are currently developing a new form of perceptually realistic imaging technology that doesn't rely on the logic of linear perspective.

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Author Biography

Robert Pepperell PhD studied at the Slade School of Art, UCL. He is Professor of Fine Art at Cardiff School of Art & Design and leader of Fovolab at Cardiff Metropolitan University. As an artist he has exhibited at Ars Electronica, the Barbican Gallery, Glasgow Gallery of Modern Art, the ICA, and the Millennium Dome. As an academic he has published books, articles, reviews, and papers in the fields of art history, philosophy of mind, artificial intelligence, neuroscience, and perceptual psychology.