



BRILL

Art & Perception 1 (2013) 19–47



From Perception to Paint: the Practical Use of the Camera Obscura in the Time of Vermeer

Jane Jelley*

Oxford, UK

Received 18 January 2013; accepted 10 April 2013

Abstract

This is a report of a studio experiment to explore how images from the camera obscura could have been used directly by artists of Vermeer's era. It has a pragmatic and practical approach, bringing a painter's eye and experience to the problems of transferring images from the lens to a canvas, using the primitive technology and unrefined materials available then. It addresses how an artist could use the condensed, flattened images from camera obscura projections in his painting process, when the subject could appear reversed and inverted on the screen or on the wall. It considers how the limitations of the materials that make transfers possible might affect studio practice, and ultimately the stylistic qualities of the work produced.

This paper outlines a simple printing method that would enable the seventeenth-century painter to transfer monochrome images, corrected in orientation, from the lens to a canvas with relative ease, for use as the painting progressed in the stages prescribed at the time. Prints made on the ground layer could form the basis of underpainting, while those on top layers could transfer highlights and optical effects, not seen with the naked eye. This technique would allow the painter to be in the light of his studio, facing his motif, when working in colour. Reference is made to art historical literature and contemporary workshop treatises, and all materials used are authentic. The results obtained using this process are consistent with the visual evidence of the way in which Vermeer applied his paint, and with recent scientific examination of his work. The findings suggest possible causes for some of the unusual qualities of Vermeer's work, in particular the strong tonal polarity in the underpainting with no evidence of drawing, his choice of material in the ground layers, and the qualities of variable focus.

Keywords

Vermeer, camera obscura, optical effects, underpainting, tracing and transfer, projection

* E-mail: printedlight@hotmail.co.uk; www.printedlight.co.uk

1. Preface

The arrival of the camera obscura in seventeenth-century Holland caused a sensation. The images projected through the lens seemed to show ‘life itself’ (Kemp, 1990).

At that time, the Dutch laid great store by the qualities of ‘houding’: the achievement of a harmonious realistic illusion in painting, which mimicked the real world (Taylor, 1992). But would it be possible or even desirable for images shown in an optical projection to be transposed into paint (Westermann, 2003)? Would painters fear that their abilities might be eclipsed by the magic of the lens and challenge its seeming supremacy; or might they try to harness the fleeting moment in their pictures?

There is very little documentation as to how a painter of the seventeenth century could actually have used a camera obscura in practice. Contemporary paintings betray evidence of the use of lenses by Dutch painters of the time, in particular by Vermeer (Steadman, 2001), but how could a projection have been traced and transferred to a canvas, using the primitive technology and unrefined materials of the time?

In order for images to be clearly seen from such an optical device, the subject has to be brightly lit, producing deep shadows (Hockney, 2012). The subjects appear smaller than life but have an unchanged clarity and depth of colour. The monocular lens makes the space recede, and ‘flattens’ the motif (Kemp, 1990; Wheelock, 1995). How could an artist respond to a moving, condensed, two dimensional ‘reality’ and use it directly to help in the painting process, especially if the subject could appear reversed and inverted on the screen or on the wall?

This paper outlines an experiment which brings a painter’s eye and experience to bear on these practical issues, and has a pragmatic approach. It looks at the equipment available to the seventeenth-century artist who wanted to use projections directly in his work. It questions whether there are any possible advantages in being presented with reversed images, and also considers how the limitations of the materials that make transfers possible might affect studio practice, and ultimately the outcome of any images made from a lens. A work of art made with paint on canvas, is first and foremost a painting, whatever its significance or iconography. It follows that an appreciation of the mechanics of its making could be important in explaining some of the stylistic qualities of the painter.

In trialling methods of transfer from a lens to a canvas, reference was made to scientific and art historical literature, and also to contemporary workshop treatises. It became clear that instructions from the latter were invaluable, and also that painters of the seventeenth century would have been at liberty to experiment with ways of working within the strictures of the time, and the

prescribed order of creating a painting. Exactly how individual artists used their materials may never be known. As David Hockney (2001) has shown, painters did not always want to broadcast their methods in the past and often kept their techniques secret (Fels, 2010).

The direct use of the camera obscura would have allowed painters to work in a different manner than hitherto. The difficulties of transposing effects from the lens would have conferred some limitations. However, the use of such an optical ‘aid’ would have provided new possibilities. In the particular case of Vermeer, some experts do not find this a challenge to his extraordinary ability. Alejandro Vergara (2003) sees the camera “not as a substitute for Vermeer but rather (as) an instrument at the service of his creativity”. Martin Kemp (1990) considers that the use of a camera ‘in no way prescribes’ artistic choice. However, others seem to fear that Vermeer’s stature might be diminished by the proximity of a lens. This anxiety is perhaps partly due to a belief that using a camera obscura is as easy as taking a picture on a mobile device today. This is very far from the case. The camera obscura bears limited comparison to a photographic camera. Although both project an image through a lens, the effort required to use these is very different. The photographic version provides a positive picture with film or digital technology, but the image from the camera obscura is merely a projection. The only way to transfer and fix the images of arrested movement that we see in Vermeer’s pictures would be by a slow, painstaking manual process.

In order to see the image from a camera obscura, the artist has to work in semi-darkness, possibly in a confined space. This experiment found that tracings could only be made in monochrome, as colour cannot be judged or traced in these conditions. This corresponds with some of the rare documentation we have of the contemporary use of such a device. Jean-François Nicéron, writing in 1652 says: “. . . if a painter imitates all the shapes that he sees, and if he applies the colours that appear so vividly, he will have a perspective as perfect as one could reasonably desire” (Steadman, 2001). It seems that Nicéron is suggesting that colour is a second step in the procedure, which also corresponds with the careful process of building up a painting in stages, as recommended at the time.

One of the compelling qualities of Vermeer’s pictures is the feeling of ‘reality’ they convey. Do we actually see detail or is it that we think we do? The way we understand the world visually is partly the result of our knowledge from previous experiences. The maps, furniture and framed paintings in Vermeer’s pictures are precise in scale but not in detail. Maybe this feels like verisimilitude because we do not expect to see everything sharply at once.

The qualities of variable focus in Vermeer’s paintings could possibly be the result of a recognition by the artist of the way we see, or the result of the use of a lens employed in an optical device (Fink, 1971). Practical experiments

in the studio led to the conclusion that the blurred look and underlying tonal polarity of Vermeer's images could also be a function of a number of variables in a transfer process from a projection to a canvas.

This experiment demonstrates that the camera obscura would be useful at particular times for the artist and not at others; and does not preclude the use of alternative techniques. This corresponds with the view of Vergara (2003), and also Robert Wald (2010). The camera can help at all stages of the painting, particularly with planning, underpainting and the transfer of optical effects; but most of the work can be done using direct observation in the full light of the studio. There is no reason why perspective cannot be used in conjunction with the camera, nor why images from the lens cannot be cropped, altered, or used as reference drawings. Information for painting is cumulative: it can be taken over a long period, at varying times of day, or from different viewpoints. Optical inconsistencies in Vermeer's paintings are therefore to be expected, but are not evidence that a lens was not employed at some point in the production of the painting.

The experiment below shows a simple method that would enable an artist of Vermeer's time to use the camera obscura and transfer information from projections directly to the canvas with relative ease. The results obtained using this conjectural process are consistent with the visual evidence of the way in which Vermeer applied his paint, and also with the recent scientific examination of his work.

There has been much recent research into the quality of lenses in the seventeenth century, which shows that images from a camera obscura would have been good enough for copying to be readily done (Cocquyt, 2007; Groen, 2007; Lefèvre, 2007; Molesini, 2007; Staubermann, 2007; Wald, 2010; Wirth, 2007). The assumption throughout this article is that this is the case.

It appears that no practical experimentation like this has been attempted before, and although the methods used in this hands-on approach are unproven and suppositional, they can be reliably repeated.

2. Introduction

The discussion of Vermeer's painting method is contentious. Scholars are deeply divided about the methods he used to achieve his luminous, highly constructed works. And in no place is there more vigorous argument than in the discussion about his possible use of the camera obscura (Pénot, 2010).

Vermeer's paintings have some unusual features, which have been examined in detail by many scholars. But despite much research, several questions remain. Scientific analysis of the *Girl with a Pearl Earring* has revealed that Vermeer appears to have applied his underpainting 'without correction' showing, as Lawrence Gowing (1952) comments, "an almost solitary indifference

to the whole linear convention”. As yet there has been no explanation as to why Vermeer would have begun his pictures in such a manner, or how he could have achieved monochrome underpainting of such sharply contrasting dark and light without outlines or guide marks, and with such assurance (Groen, 2007; Steadman, 2001; Wheelock, 2010). Vermeer’s paintings are also strangely blurred (Arasse, 1994). Quentin Williams (1995) describes his pictures as having a “particular, atmospheric, feathery quality. . . found hardly anywhere else in painting”, and Wadum (1998), and Groen (2007) both comment on Vermeer’s use of sfumato.

Vermeer’s paintings seem to share some characteristics of photography (Clark, 1961; Fink, 1971; Schwarz, 1949; Steadman, 2001): the focus seems to vary (Wheelock, 1995); and on the top layers, some of his paintings feature effects of light visible only through a lens, optical phenomena which are not seen with the naked eye (Hyatt Mayor, 1946; Kemp, 1990). These include ‘circles of confusion’ (Seymour, 1964); areas that are distorted or out of focus (Nash, 1991); and also specular highlights, as seen dancing on the water in the *View of Delft* (Wheelock, 1995; Wheelock and Kaldenbach, 1982).

There is no suggested solution as to how Vermeer could have transferred optical effects straight onto his canvas, and no agreement amongst scholars that he did so. There is some consensus that Vermeer would have been able to view his motif through a lens (Wheelock, 1995); but was he just influenced by such effects (Liedtke, 2001), or would he have worked on his painting using a camera obscura projection directly?

Philip Steadman (2001), who has done a great deal of research on Vermeer’s possible use of the camera obscura, puts forward some compelling evidence to suggest he did use such a device. He found that a great number of the objects depicted, such as the paintings, maps (Welu, 1975), and pieces of furniture, actually exist; and are rendered accurately and at their true sizes. When Steadman calculated the size of Vermeer’s studio and the viewpoint of his pictures (and hence the position of a lens), he found in a high number of cases that the size of the images that would have been projected on the back wall precisely matched the size of the corresponding canvases.

Steadman proposes that the apparatus that Vermeer is most likely to have used would project an image onto a wall in a curtained-off space at the back of the studio. However, the image given by this ‘room camera’ is not only upside-down but is also reversed left to right (Hammond, 1981; Wald, 2010). The disadvantage of this for the painter is that should he trace this directly onto a canvas, when the tracing is rotated and compared with the motif in front of him, it is still mirror-reversed (see Figs 1 and 2).

How can these projected images be transferred onto a canvas and corrected? One solution is that charcoal dust could have been pounced through holes made in a tracing on paper (Cennini, 1398; Kemp, 1990; Steadman, 2001),



Figure 1. Original view.



Figure 2. Image as seen in a room camera obscura.

but no physical trace of such a method has been found in Vermeer's pictures (Groen, 2007). Other theories suggest the use of a pantograph (Fink, 1971), or that multiple mirrors could have been cunningly employed (Wirth, 2007). Steadman (2002) also proposes that the projection could be viewed on a screen situated in a room beyond the studio, although he acknowledges a counter-argument that studies of the topography of Vermeer's house suggest that there would not have been enough space for an extra room to have existed.

In order to see the camera image properly, the painter has to work in near darkness (hence 'camera obscura', meaning darkened chamber). In these circumstances the light coming from the projection illuminates the palette, and so it is very difficult for the painter to mix paint to match the colour he perceives (Mollon, 1995).

Any colour apart from white applied on the work under the projection immediately upsets the tonal balance of the image, and is also coloured by the light falling on it (Stork, 2003). How can the painter judge what colour he is applying to the canvas, or know how it will look when it is removed from under the projection? Although Carsten Wirth (2007) has painted in colour inside his *Experimental Historical Camera Obscura*, he increased the ambient light level in order to do so.

It seems unlikely that Vermeer could have painted in colour straight onto his canvas under a projection. This concurs with the view of Jørgen Wadum (1998): "No painter would ever sit with his palette full of bright colours in a dark room painting an upside down-image".

The results of the practical experiment below address some of the problematic questions about Vermeer's technique, including that posed by Karin Groen (2007): "Is there something *extra* in Vermeer's underpainting that would make the use of the camera obscura feasible?".

3. Outline of Technique

The clue to the method used to transfer images from a camera obscura to a canvas, came from the orientation of the images themselves. The upside down/mirror reversed images of the room camera is actually a ‘printing reversal’ of the motif. What if a tracing is made not on the canvas, but first on some form of paper? Then the tracing could be turned the right way up and *printed* onto a canvas. After some experimentation, this offset method proved successful in the studio, and monochrome images from a projection were printed directly onto prepared canvases, using only manual pressure.

The ‘something *extra*’ needed to make these prints is paper saturated with oil. Oil paint tracings made on this surface can be transferred. The advantage of using oiled paper is that it is transparent, meaning that prints can be made on any layer of the painting, and can be lined up with previous ‘landmarks’ in the picture, using registration.

Using this method, the painter has no motivation to try to trace colour modulations from the camera obscura projection, not because it would be difficult, but because he does not need to do so. This simple method corrects the orientation of the image as it is printed onto the canvas, enabling the artist to do the majority of his painting conventionally in the light of his studio, directly facing his subject (Fink, 1971).

The first prints on the ground of the canvas can be used as the basis for the underpainting, and then subsequent transfers onto further layers of paint can be used as notations to mark figures, objects or highlights. The method allows for effects seen only through a lens to be directly transferred to the canvas onto top layers of paint. The only proviso is that the surface receiving the print has to be dry for the oiled paint tracing to transfer successfully.

A bonus of this technique is that once the tracing on transparent paper is turned over, and its image viewed from the correct side, it becomes a useful reference tool in its own right as a preparatory or reference drawing, which can be cut or cropped.

It has been argued that Vermeer used perspective rather than an optical device to compose his pictures (Wadum, 1995, 1996a, b), but it would be possible to trace a projection from the camera, and then correct this using perspective techniques (lines curve at the edges of an image seen through a lens) (Huerta, 2005; Wirth, 2007). The correction could be made either on the oiled paper, or on the canvas. An oiled paper tracing can be laid over a canvas and a pin can be inserted right through them both, to correspond with a vanishing point. In this manner tracings from a camera obscura projection can help provide the ‘composition machine’, that Philip Steadman (2001) imagines. Large images can be built up using registration, as the projection itself does not vary.

Looking at the lack of underdrawing in Vermeer's painting, Groen (2007) wonders if "a material was used that evades detection by the available examination techniques".

Should a tracing and transfer technique using oiled paper have been used by Vermeer, there would be no physical trace of its presence on the painting itself, apart from the effect it produces. There is another reason why there can be no tangible evidence that it was used: once oiled, paper degrades, and eventually becomes brittle and useless (Kühn, 1986). Any tracings would have a limited use and a limited lifespan (Cook and Dennin, 1994). Maybe this is why no drawings of Vermeer's have ever been found (Groen, 2007; Montias, 1989; Swillens, 1950).

4. Historical Feasibility

A painter of the seventeenth century worked in a predetermined order, and would have built his colour up in layers painstakingly, grinding his paint as needed. There were distinct stages in the painting process in Vermeer's time: the 'inventing', the 'dead colouring', and the 'working up' and 'finishing' layers (Costeras, 1998; van de Wetering, 1995; van Eikema Hommes, 2004; Wadum, 1998). It is likely his palettes were small: he would have been careful not to waste materials, putting out just enough paint for the day's work, and he would have kept his most expensive paints for the very top layers, laying down the dead layer in the cheaper pigments such as earths and indigo (Fels, 2010; van de Wetering, 2009; Wallert, 1999).

The technique described in this paper conforms to this order, and allows for the judging, mixing, and application of colours to be done in a conventional manner.

Oiled paper has long provided a material on which to trace, and in Vermeer's time it had many uses (Fahy, 2003–2004; Hicks, 2007; Martin, 1905), including as the material for the screen of the box camera obscura (Hammond, 1981; Seymour, 1964). Cennino Cennini (1398) gives a recipe for its preparation, and valued it for its transparency.

A number of tracing techniques would have been known to artists of the seventeenth century. Vermeer may have heard of Dürer's drawing machines, which the master used to transfer images in around 1525 (Hyatt Mayor, 1946). Pieter Jansz. Saenredam (1597–1665), living close by in Haarlem, routinely transferred information from drawing to painting surface, without reversals, by blackening the back of his drawing paper and using a hard stylus (Fels, 2010; Wadum, 1995).

It is clear that Vermeer would have been easily familiar with the technology of printing. The many maps he depicted in his paintings were produced by the use of up to four different printing methods, as Svetlana Alpers (1983) has

pointed out. Vermeer may have taken advantage of others' technical knowledge (Wadum, 1995); certainly he would have mingled with printers and booksellers at the Guild of St Luke where he was a member and also Headman (Montias, 1989).

The main bookseller and printer in Delft, 'The Golden ABC', was on the market square, a stone's throw from Vermeer's house, and was owned by the Dissius family, who were subsequently to inherit some of Vermeer's pictures (Montias, 1981, 1989). There was a weekly book market in the nearby town of Leiden (Levy-van Halm, 1998) and we know that Vermeer had a 'respectable little collection' of books, and 'three bundles with all sorts of prints' in his possession at the time of his death (Montias, 1989).

Also, to live in Delft was to live with reflections and reversals from the many watery surfaces around.

5. The Transfer Method

The successful transfer method illustrated below results from many attempts in the studio to find the best balance of materials. Tracings were made from projections of a number of Vermeer's paintings onto handmade oiled paper, and the images were transferred to dry canvases prepared with a variety of grounds. These grounds and all materials were matched as closely as possible to those used by Vermeer himself, as indicated in literature concerning the scientific examination of his paintings (Costeras, 1998; Gifford, 1998; Groen, 2007; Groen *et al.*, 1998; Kühn, 1968; Wadum, 1995; Wadum *et al.*, 1995). Reference was also made to workshop treatises available in Vermeer's time in order to use materials as authentically as possible. Very detailed scientific examination of all layers of paint has been done of Vermeer's *Girl with a Pearl Earring*, and this is the reason that this image was chosen above others for preliminary experimentation (Fig. 3).

The image was projected onto a non-absorbent board on an easel at actual size, and in the orientation it would be seen in the room camera obscura (Fig. 4).

The prepared oiled paper was cut and fixed onto the board. Using hand ground bone black paint, and a hand-bound brush, a tracing was made on the oiled paper (Figs 5 and 6). The tracing gave an indication of the tonal balance of the image, but because it was necessary to use a medium size brush in order to hold enough paint to transfer, the marks themselves were relatively crude and imprecise.

Once the tracing was complete, the oiled paper was immediately lifted from the projection board, turned over (Figs 7 and 8), and with the paint side



Figure 3. Johannes Vermeer, *Girl with a Pearl Earring*, c. 1665, Oil on Canvas 44.5 × 39 cm, Royal Cabinet of Paintings, Mauritshuis, The Hague.

downward, placed onto the slightly dusty canvas lying flat on the table. Using the back of a wooden spoon the tracing was rubbed down (Fig. 9), and when the paper was lifted (Fig. 10), a clear print was made on the canvas (Fig. 11).

The tracing on the oiled paper retained its image, even after three further proofs were printed onto separate canvases. The second printed proof was used for further work.

The image transferred particularly strongly where the spoon had been pressed down hard, and showed some brush marks from the tracing on the oiled paper (Fig. 11). The majority of the print surface appeared grainy and mottled rather than painterly, and lacked a feeling of line. The print was left to dry.



Figure 4. Measuring the projection.



Figure 5. Tracing on oiled paper under the projection.



Figure 6. The finished tracing on oiled paper.



Figure 7. Lifting the paper from the board and turning it over.



Figure 8. The turned tracing with the painted side down.



Figure 9. Tracing placed on canvas being rubbed with a spoon.

6. Working Up

Thin layers of paint and glaze were applied to the canvas one after the other, allowing the surface to dry between each application (Fig. 12).

First, using the same brush as had been used for the tracing, the print was corrected on the canvas using more bone black. Then some dark areas were strengthened with lamp black. Once dry, opaque blue (a mixture of lead white and lapis lazuli ground in linseed oil) was applied to the headdress of the girl. A thin layer of ochre was applied to some parts of the coat, and oil glazes of lapis lazuli and massicot (lead yellow) to the head-dress. The dark underpaint still showed through under the glazes and became an integral part of the picture.



Figure 10. Removing the tracing from the canvas after printing.



Figure 11. First printed proof on canvas.



Figure 12. Second studio proof with some added colour.

Where the print was too dark to be used with just a single glaze on top (for example on the nose of the girl), a lighter opaque layer (a mixture of ochre, bone black and white) was added before glazing. The face was then glazed with a very thin layer of ochre, white and red lake (cochineal) (Bailey, 2001; Butler Greenfield, 2005; Feller, 1986). A weld glaze (a yellow organic lake) was painted over an indigo layer in a small portion of the background (Groen *et al.*, 1998).

7. Transferring Highlights

The original tracing was put under the projection once more and highlights near the girl's mouth and on the earring were traced and transferred in thin white paint. These were then strengthened with thicker paint.

8. Transferring Information Using Registration

The method described above has many advantages for a painter wanting to make corrections. Not only is it possible to erase and change tracings as they are being made on the oiled paper, but also wet transfers can be rubbed off the canvas easily, either with oil, or with a thinner such as oil of spike lavender. Dry transfers can be removed with a pumice stone. New tracings can be made either in whole or in part from the same projection, onto a new piece of oiled paper, and then transferred to the dried area where the previous image has been erased. Registration marks can be made using stick charcoal, which will only transfer when rubbed, or using ink, which will not transfer at all once dry.

An example of registration is shown below. A print was made from a tracing of Vermeer's *Young Woman with a Water Jug* (Fig. 13). The image of the map had been very roughly traced and transferred, and so this was rubbed off the canvas (Fig. 14), and a new tracing was made of this area, on a smaller piece of oiled paper. This was then transferred (Fig. 15) using registration marks made with stick charcoal (Fig. 16).

9. Further Print Transfers

A further number of Vermeer's images were traced and transferred successfully, including a detail of *The Music Lesson* (Fig. 17) and *Woman with a Balance* (Fig. 23).

To establish that the texture and tone of the transfers achieved by printing tracings from oiled paper onto canvas was the result of the process itself, and



Figure 13. Print from *Young Girl with Water Jug*.



Figure 14. Print with the map rubbed off.



Figure 15. Print with new tracing in place showing registration marks.



Figure 16. Print with the new tracing transferred.



Figure 17. Print from a tracing of a detail of *The Music Lesson* at actual size. The tracing on the right is reversed with paint side on top. Note the imprecision of the brushstrokes on the tracing, and the softening of these when printed onto the abraded ground of the canvas on the left.



Figure 18. Photograph.



Figure 19. Print on canvas.



Figure 20. Detail of print.

was unaffected by the content of the images, other transfers were made using exactly the same method, from a projection of a modern, digital, medium resolution photograph (Figs 18–20) onto canvases with a chalk and lead white ground.

The print on canvas (Fig. 19) displays similar tonality and texture to the print made in the studio from a tracing of the *Girl with a Pearl Earring* (see Fig. 11).

10. Details of Materials and Techniques

10.1. *Canvas and Ground*

Fine linen canvas of weight 265 g/m² and with a thread count of 17/15.4 threads warp/weft was prepared on modern stretchers with one layer of glue size made with about one part rabbit skin glue to twenty parts water (Massey, 1968; Mayer, 1951; Seymour, 2003). The traditional test, to achieve the right proportions, is to make the glue up, and when it has cooled to a jelly, see if it just breaks apart in the hand. Different dilutions were tried until this was achieved.

Chalk was detected in the lower layers of Vermeer's canvases, although scientific analysis does not make it clear whether this was put into the glue layer or the ground layer (Groen, 2007). One very thin coat of gesso was applied over the glue layer allowing the canvas still to flex without cracking (Herringham (1930) in Cennini, 1938; van de Wetering, 2009; Saitzyk, 1987).

One trampoline canvas was rolled and threaded with linen string onto a wooden frame (see Fig. 17) (Kirby, 1999; van de Wetering, 2009; Wheelock, 1995). This gave equally good results to the canvases on stretchers.

After the gesso layer, the canvas was rubbed with a pumice stone as indicated in Cennini's treatise (1398), and by de Mayerne (Fels, 2010; van de Wetering, 2009).

There are conflicting views as to the exact composition of the ground in Vermeer's *Girl with a Pearl Earring*, and all the variations described were hand ground in oil and applied with a knife on different canvases (Costaras, 1998; Groen *et al.*, 1998; Kühn, 1986; Mayer, 1951; Swillens, 1950; van Eikema Hommes, 2004; Wadum *et al.*, 1995). The proportion of chalk to pigment in the ground was not specified in any of the analyses, and so various ratios were tried and noted. All the mixtures worked equally well but varied slightly in tone and warmth. When tracing other images, the grounds for the canvases were matched with the known base of the paintings (Costaras, 1998).

De Mayerne illustrates a primer's knife in his manuscript (Fels, 2010), and notes in the margin that the blade was about 'a foot long' (van de Wetering, 2009). In the absence of such an implement, the grounds were applied to the canvas with a large culinary spatula. The direction and pressure of the priming knife, spreading the ground 'in large arcs' can be seen on the canvas Vermeer used for the *Girl with a Pearl Earring* (Groen *et al.*, 1998; Wadum *et al.*, 1995). Care was taken to apply the ground as smoothly as possible and in the same manner. It is possible that Vermeer may not have prepared all his own canvases, and could have bought some of them ready made and primed. Then he could have moderated them to his liking, and could have transferred them to smaller strainers (Costaras, 1998; Kirby, 1999; Levy-van Halm, 1998).

After about three months, the grounds on the canvases in the studio were dry, and the surface was smooth, skin-like and impervious. The small ridges left by the trails of the priming knife were rubbed down with a pumice stone, and the ground was abraded all over. It was found that this dusty surface helped in the transfer of the image, absorbing some of the oil and giving a clearer print.

10.2. Oil, Tracing Medium and Paint

Cold-pressed linseed oil was used for this experiment throughout, which corresponds with the analysis of the medium used in Vermeer's paintings (Fels, 2010; Groen *et al.*, 1998; Kühn, 1986).

Where a glaze was required, small amounts of pigment were ground finely into the linseed oil.

The paint for tracing needed to act like printing ink. This paint needed to be slow drying, to allow time to do the tracing and transfer, but also thick enough not to run when tracing on a vertical surface (Harley, 1982; Seymour, 2003). It could be any colour, but in order to be visible under the projection, it needed to be slightly darker than the area being traced. It also needed to be darker than the ground on the prepared canvas, in order to show on transfer.

A number of experiments were made with umber and black pigments (Berrie, 2007), hand ground into cold pressed linseed oil, after which bone black was chosen for its superior properties for tracing and transfer.

There were several sources for bone black in Vermeer's time. Cennini (1398) recommends old chicken bones, 'found under the table', but Rosamund Harley (1982) suggests that old ivory objects such as a broken comb, fan handle or knife shaft could have been burnt for a superior pigment (Seymour, 2003). The bone black used in this experiment was not real ivory black, but the less expensive pigment made from bones.

Bone black has a pigment particle that is about 10 microns in size, ten times larger than lamp black (Harley, 1982; van Eikema Hommes, 2004). When bone black is ground in linseed oil it produces a weak and gritty paint, which lacks body (Mayer, 1951; de Mayerne in Fels, 2010). This pigment worked much better than lamp black, which made a strong and oily paint, resulting in insensitive tracings that became smudged on transfer. In Vermeer's time, the painter would have been keen to follow the 'fat over lean' principle of painting, and would not have wanted the lower layers of paint on the canvas to have much oil in them (Mayer, 1951; Metzger).

After the bone black print had been made on the canvas, lamp black could be brushed on top to emphasise any areas that needed to be very dark, a technique used in the past to achieve deep tones (Fels, 2010; van Eikema Hommes, 2004).

10.3. Paper

Old French legal documents were acquired for this experiment. These must have been made before 1684, the date written in script on the paper (Fahy, 2003–2004). The tracings made on this worked extremely well, despite the age of the paper. Since there were few antique sheets, most of the tracings had to be made on new, laid, handmade paper, made of a cotton and flax mixture, which is internally sized, unbleached, and of a similar weight (RM 1790s laid, 65 gsm). In Vermeer’s time sheets of paper would have been sized individually, in gelatine, size, or starch (Kühn, 1986). Cennini (1398) states that paper made of cotton can be oiled.

Paper can be quickly and easily oiled with a brush, and becomes very transparent; so much so, it is possible to read something placed beneath it (see Figs 21 and 22). The transparency of oiled paper is reduced slightly once dry.

Experiments in the studio showed that in order to transfer images successfully, this paper should not have much oil sitting on the surface. This is because during the process of transfer, the pressure applied pushes excess oil out of the paper, as well as transferring the oil paint tracing. If there is too much oil in the paper then small puddles of oil sit on the surface of the canvas, making the print blurred and unstable. Blotting the oiled paper while wet, or using dried oiled paper, solves this problem. This is consistent with Cennini’s (1398) recommendation that oiled paper be left to dry ‘for the space of several days’ for it to be ‘perfect and good’. Whether wet or dry, oiled paper can be easily cut to size with scissors or a knife.

10.4. Tracing Technique

It is difficult to trace an image under a projection. As soon as any mark is made it affects the balance of tone, masking some of the image. It is then difficult to judge the tone of the adjacent area. For this reason it is easier to trace from the darkest areas to the lighter ones. A further difficulty is that it is necessary



Figure 21. Oiling a 17th century legal document using a hand-bound brush.



Figure 22. *The Times* seen through the oiled paper.



Figure 23. The same oiled paper as illustrated above, with a tracing of a detail of *Woman with Balance* at actual size (with the painted side underneath).

to work from the side; otherwise the painter’s shadow blocks the projection. Even then the hand and the brush cast a shadow of their own.

10.5. Print Quality

It took some time for this print transfer method to become reliable in quality. There were many variables to be taken into account. These included how much the surface of the ground was abraded, the strength and consistency of the paint, the size of the brushstroke, and the pressure exerted when transferring the tracing.

11. Possible Evidence for Print Transfers in Vermeer’s Work

There seem to be some interesting parallels to be drawn between the prints made in the studio and some observations made by art historians about the qualities of Vermeer’s paintings.

The biggest surprise was that the prints made in the studio onto prepared canvases (see Figs 11, 16 and 17) had a significant resemblance to Vermeer’s own underpainting. The effect was striking: the motif appeared sharply lit (see Figs 24 and 25). The prints were loose, grainy images of high tonal polarity with no contours: just dark shapes against the light of the ground, with some transferred brushstrokes visible. The handmade paper, with its surface inconsistencies, did not transfer a perfect image onto the dusty surface of the ground layer. The oil paint had spread and softened, and had been partly absorbed by



Figure 24. First proof in the studio (detail).



Figure 25. X-ray of the *Girl with a Pearl Earring* © KIK-IRPA, Brussels, in *Vermeer*, Lawrence Gowing, Giles de la Mare Publishing, 1997.

the slightly abraded chalk and lead white ground, so there was little evidence of line.

Monochrome underpainting is known to be beneath many paintings by Vermeer (Groen, 2007; Steadman, 2001), but art historians have found it difficult to reconcile Vermeer's careful planning with the appearance of confident and rough underpainting (Gifford, 1998; Laurenze-Landsberg, 2007).

However, a print from a tracing as made above has to be transferred all at once, and so not only does it appear to have been applied in an assured manner, but it also appears extreme in tone because gradations are almost impossible to achieve.

The use of a medium size brush required to transfer adequate paint to the tracing surface, and the bone black tracing paint, which needed to be subsequently fortified in some areas with the darker lamp black, corresponds with recent scientific analysis. Claudia Laurenze-Landsberg (2007) was astonished to find Vermeer's underpainting was done with the use of 'different blacks' and with a 'quick sketchy stroke... with a rather broad brush' (Groen *et al.*, 1998; van Eikema Hommes, 2004).

The dusty ground surface, required to absorb the oil from the transfers, is also consistent with methods contemporary with Vermeer. De Mayerne and Cennini both suggest that to increase the tooth of drawing surfaces, bone dust or pumice should be rubbed into the surface (Cennini, 1398; Fels, 2010).

The homogeneous quality of these prints can partly be explained by the necessity to trace everything in the projection in the same way, because the

connecting shapes are not identifiable when reversed and inverted (Gowing, 1952; Hockney, 2001).

12. The Impact of the First Print on Later Layers

Wheelock (1995) deduced that Vermeer applied a thin glaze straight over the imprimatura layer of the turban of the *Girl with a Pearl Earring* (Fig. 26), leaving the underpainting visible (Franits, 2001; Gifford, 1998; Groen, 2007).

If this part of his painting is compared with the turban of the girl printed and painted in the studio (Fig. 27), there seem to be textural similarities where the quality of the grainy black print shows through a single ultramarine glaze and helps define the form.

A first printed layer could affect the finished texture as well as the tone in a painting. Is it possible that the blurred look peculiar to Vermeer's work (Arasse, 1994; Williams, 1995) could be the consequence of a transferred print on the ground of the canvas? If this showed through subsequent thin layers of paint, such a highly tonal, grainy image, lacking edge or contour, could influence the final outcome (Costeras, 1998; Gifford, 1998; Groen *et al.*, 1998; Wheelock, 2001).

Very little paint was needed over the prints in the studio to give an impression of colour, and it was surprising how much information the print appeared to convey. Compare, for example, the girl's coat in Vermeer's painting (Fig. 3) and in the painted print made in the studio (Fig. 12), where a single thin ochre layer was applied on top of the print. Scientific evaluation has revealed that



Figure 26. Johannes Vermeer, *Girl with a Pearl Earring*, 1665 (detail). Oil on Canvas 44.5 × 39 cm, Royal Cabinet of Paintings, Mauritshuis, The Hague.



Figure 27. Studio print from the *Girl with a Pearl Earring* with some paint applied (detail).

Vermeer used few layers of paint on the *Girl with a Pearl Earring*. The most recent analysis counted only four, including the ground (Groen *et al.*, 1998).

Once the initial prints were put down in the studio, they could be easily moderated with impasto once dry. In the careful process of putting on an opaque layer on top of the studio print, a small edge or ‘halo’ of the dark paint was left. This effect may have some relevance to the observations of junctions of paint in Vermeer’s pictures, made by Hubert von Sonnenburg (1973), by Wald (2010), and by Gifford (1998).

13. Prints on the Dead Layer

Where further prints were made on top of dried previously painted areas, it was found that these did not transfer as successfully as those made onto a rubbed, dusty layer. This was because the unabsorbent surface allowed the paint to run. Obviously the painter would not want to abrade areas of paint he had worked on in order to receive a print, because that would be destructive to his picture, but such late prints, even if imperfectly transferred, could provide a way to add or strengthen the accuracy of a line or shape, or to try out an alteration in composition.

There may be evidence that Vermeer did this. The autoradiographs of *A Maid Asleep* show some grape leaves in the 4th layer (Fig. 28), under the tablecloth on the right hand side (Wheelock, 1977), possibly painted in azurite (Ainsworth, 2000). These have very uneven pigment distribution, and the well-defined edges of the leaves make the images look very like prints. Some of the trial transfers in the studio on unabsorbent surfaces had a texture similar to this (Fig. 29).

14. Highlights

This experiment showed that whereas tracings of thick paint would not transfer without puckering or distortion, it was easy to transfer thin guide marks to indicate the position of highlights onto top layers of paint. Double paint marks, thick over thin, have been observed in Vermeer’s paintings (Wadum, 1995; Wheelock, 1995). Might Vermeer immediately have painted over guide marks with the ‘heavily loaded spots of pigment’ that Charles Seymour Jr. (1964) observes? Vermeer’s total painting output suggests he was a slow worker (Montias, 1989), but passages of wet-in-wet painting commented on by Costeras (1998) and Gifford (1998) indicate that he sometimes worked at speed (Bailey, 2001; Wheelock, 1996). Although there is much argument about whether or not the pointillés seen in Vermeer’s painting actually came directly from the lens (Arasse, 1994; Franits, 2001; Wheelock, 1995), this tracing and transfer process makes this more than a theoretical possibility.

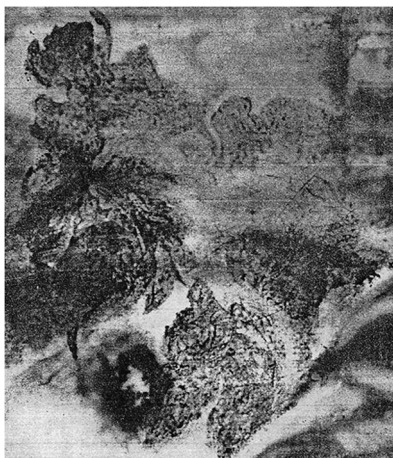


Figure 28. Detail of vine leaves from the 4th autoradiograph of *A Maid Asleep*, The Metropolitan Museum of Art, Bequest of Benjamin Altman, 1913 (14.40.611). Image © The Metropolitan Museum of Art, in: *Art and Autoradiography*, edited by M. W. Ainsworth, Yale University Press, New Haven, CT, USA (2000).

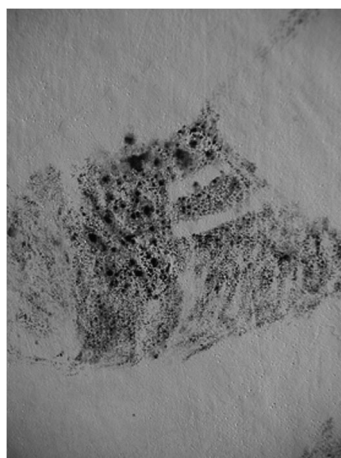


Figure 29. Detail of sleeve from a trial print of *Young Woman with Water Jug* on an unabsorbent surface.

Seventeenth-century painters were used to the waits between layers of impasto and glaze (van Eikema Hommes, 2004), but this stop–start printing technique would slow the process even further, because the whole surface of the picture has to be dry to receive a print. It was found that if oiled paper is applied to wet paint, it can pull paint already applied off the surface. In the damp cool climate of Delft, paint may have taken some while to dry completely (Kuhn, 1986; Massey, 1968).

15. Conclusion

“We are in the presence of the real world of light, recording, as it seems, its own objective print.” Lawrence Gowing (1952)

Within the prescribed limits of his time, it seems possible that Vermeer would have experimented as far as he was able, adapting materials and technology to suit his working method.

Should Vermeer have made use of a camera obscura, then oiled paper could have provided a convenient and simple ‘offset’ method of transferring monochrome images, from the projection straight onto the canvas. Because the image is corrected as it is transferred, he could have then worked using

colour, in the light of his studio, facing his subject, taking information from the lens as and when required.

This method is as far from pressing the button on the shutter of a modern camera as we can imagine it to be. It will neither provide an instant coloured image, nor a complete transcription of the motif. But the strength of this process lies in the fact it is incomplete, and that the painter's individuality and means of expression remain unfettered. The painter can use his judgement to decide what elements of a projection to use on the canvas, and how to enmesh these in a painting.

This process of transfer provides plausible explanations for outstanding puzzles about Vermeer's painting, not least the extraordinary tonal polarity and lack of line in his underpainting, the blurred effects, and the manner in which optical phenomena seen only through a lens could have been translated directly onto the top layers of paint. Possibly, it could explain some aspects of Vermeer's style.

Little is known about Vermeer's life or his working practice. Much is surmise, and the same could be said of the technique outlined here. However, this simple studio method is consistent with what is known of Vermeer's painting methods, and also reconciles some current theories that are presently at variance.

As an innovator, might Vermeer not have made direct use of the camera obscura, the new technology of his age?

Suppliers

Zecchi, *Firenze*

Tiranti, *London*

Arcobaleno, *Venezia*

Cornelissen, *London*

Ditta G. Poggi, *Roma*

Casa Hernanz, *Madrid*

Green and Stone, *London*

Great Art, www.greatart.co.uk

Shepherds Falkiners, www.store.falkiners.com

Anthony Davenport Prints, *Abingdon, Oxfordshire*

References

- Ainsworth, M. W. (Ed.) (2000). *Art and Autoradiography: Insights into the Genesis of Paintings by Rembrandt, Van Dyck and Vermeer*, pp. (plate 10a), 23, 102. Yale University Press, New Haven, USA.
- Alpers, S. (1983). *The Art of Describing: Dutch Art in the Seventeenth Century*, pp. 121–122. University of Chicago, Chicago, USA.

- Arasse, D. (1994). *Faith in Painting*, pp. 50–54, 69–75. Princeton University Press, Princeton, NJ, USA.
- Bailey, A. (2001). *Vermeer, A View of Delft*, pp. 124, 141–142. Chatto and Windus, London, UK.
- Berrie, B. (Ed.) (2007). *Artists' Pigments — A Handbook of Their History and Characteristics*, pp. 4, 20–21. Archetype Publications, London, UK.
- Butler Greenfield, A. (2005). *A Perfect Red, Empire, Espionage and the Quest for the Colour of Desire*, pp. 186–194, plate 6. Black Swan, London, UK.
- Cennini, C. (circa 1398). *Il libro dell'Arte o Trattato della Pittura*, transl. C. J. Herringham, *The Book of the Art*, pp. 20–21, 117–118, 238. George Allen and Unwin, London, UK (1930).
- Clark, K. (1961). *Landscape into Art*, p. 65. Penguin Books, London, UK.
- Cocquyt, T. (2007). The camera obscura and the availability of seventeenth-century optics — some notes and an account of a test, in: *Inside the Camera Obscura — Optics and Art under the Spell of the Projected Image, Preprint 333*, W. Lefèvre (Ed.), pp. 129–140. Max Planck Institute for the History of Science, Berlin, Germany.
- Cook, P and Dennin, J. (1994). Ships plans on oil and resin impregnated tracing paper, *The Paper Conservator: J. Inst. Paper Conserv.* **18**, 11.
- Costeras, N. (1998). A study of the materials and techniques of Johannes Vermeer, in: *Vermeer Studies*, I. Gaskell and M. Jonker (Eds), pp. 145–167. Yale University Press, New Haven, USA and London, UK.
- Fahy, C. (2003–2004). Paper making in seventeenth-century Genoa: the account of Giovanni Domenico Peri (1651), in: *Studies in Bibliography* **56**, pp. 199, 243–254. Bibliographical Society of the University of Virginia, Charlottesville, Virginia, USA.
- Feller, R. L. (1986). *Artists' Pigments*, Vol. 1, pp. 261–262. Oxford University Press, Oxford, UK.
- Fels, D. Jr. (2010). *Lost Secrets of Flemish Painters* (including the English translation of the Manuscript of Sir Theodore Turquet de Mayerne (1573–1655) B. M. Sloane 2052), pp. 7–8, 12, 82, 135–140, 145–146, 176–177. Alchemist Publications, Eijsden, The Netherlands.
- Fink, D. (1971). Vermeer's use of the camera obscura — a comparative study, *Art Bull.* **53**, 493–505.
- Franits, W. (Ed.) (2001). Johannes Vermeer: an overview of his life and stylistic development, in: *The Cambridge Companion to Vermeer*, pp. 16–18, 21–24. Cambridge University Press, Cambridge, UK.
- Gifford, E. M. (1998). Painting light: recent observations on Vermeer's technique, in: *Vermeer Studies*, I. Gaskell and M. Jonker (Eds), pp. 185–199. Yale University Press, New Haven, USA and London, UK.
- Gowing, L. (1952). *Vermeer*, 3rd edn. 1997, pp. 18–26, 46, 137–138 and 158. Giles de la Mare, London, UK.
- Groen, K. (2007). Painting technique in the seventeenth century in Holland and the possible use of the camera obscura by Vermeer, in: *Inside the Camera Obscura — Optics and Art under the Spell of the Projected Image, Preprint 333*, W. Lefèvre (Ed.), pp. 195–210. Max Planck Institute for the History of Science, Berlin, Germany.
- Groen, K. M., van de Werf, I. D., van den Berg, K. J. and Boon, J. J. (1998). Scientific examination of Vermeer's *Girl with a Pearl Earring*, in: *Vermeer Studies*, I. Gaskell and M. Jonker (Eds), pp. 169–183. Yale University Press, New Haven, USA and London, UK.

- Hammond, J. (1981). *The Camera Obscura: A Chronicle*, pp. 4, 39, 121. Adam Hilger, Bristol, UK.
- Harley, R. (1982). *Artist's Pigments c1600–1835*, pp. 158, 160. Archetype Publications, London, UK.
- Hicks, C. (2007). *The King's Glass*, p. 45. Chatto and Windus, London, UK.
- Hockney, D. (2001). *Secret Knowledge, Discovering the Secrets of the Old Masters*, pp. 28, 76–77, 200, 210, 250. Thames and Hudson, London, UK.
- Hockney, D. (2012). The mass media has lost its perspective, *Financial Times*, London, UK, October 26th, 2012.
- Huerta, R. (2005). *Vermeer and Plato*, pp. 129, 171. Bucknell University Press, Lewisburg, PA, USA.
- Hyatt Mayor, A. (1946). The photographic eye, *Metropolitan Museum of Art Bull* **5**, 17–20.
- Kemp, M. (1990). *The Science of Art*, pp. 192, 193, 196, 250. Yale University Press, New Haven, USA and London, UK.
- Kirby, J. (1999). The painter's trade in the seventeenth century, *National Gallery Tech. Bull.* **20**, 25–45.
- Kühn, H. (1968). A study of the pigments and grounds used by Jan Vermeer, *Report and Studies in the History of Art, Washington, National Gallery of Art* **2**, 191.
- Kühn, H. (1986). *Conservation and Restoration of Works of Art and Antiquities*, pp. 158, 173–174, 201–202. Butterworths, London, UK.
- Laurenze-Landsberg, C. (2007). Neutron-autoradiography of two paintings by Jan Vermeer in the Gemäldegalerie Berlin, in: *Inside the Camera Obscura — Optics and Art under the Spell of the Projected Image, Preprint 333*, W. Lefèvre (Ed.), pp. 211–225. Max Planck Institute for the History of Science, Berlin, Germany.
- Lefèvre, W. (Ed.) (2007). The optical camera obscura 1: a short exposition, in: *Inside the Camera Obscura — Optics and Art under the Spell of the Projected Image, Preprint 333*, pp. 5–11. Max Planck Institute for the History of Science, Berlin, Germany.
- Levy-van Halm, K. (1998). Where did Vermeer buy his painting materials? Theory and practice, in: *Vermeer Studies*, I. Gaskell and M. Jonker (Eds), pp. 137–141. Yale University Press, New Haven, USA and London, UK.
- Liedtke, W. (2001). *Vermeer and the Delft School*, pp. 124–125, 155–156. Metropolitan Museum of Art, New York, USA.
- Martin, W. (1905). The life of a Dutch artist in the seventeenth century, *Burlington Magazine* **8**, 13.
- Massey, R. (1968). *Formulas for Artists*, pp. 15–18, 23, 43, 208. B. T. Batsford, London, UK.
- Mayer, R. (1951). *The Artist's Handbook of Materials and Techniques*, E. Smith (Ed.), pp. 114–117, 123–130, 133–134, 201. Faber, London, UK.
- Metzger, C., National Gallery Washington, USA. <http://www.sandersstudios.com/instruction/tutorials/historyanddefinitions/nationalgallery>.
- Molesini, G. (2007). The optical quality of seventeenth-century lenses, in: *Inside the Camera Obscura — Optics and Art under the Spell of the Projected Image, Preprint 333*, W. Lefèvre (Ed.), pp. 117–126. Max Planck Institute for the History of Science, Berlin, Germany.
- Mollon, J. (1995). Seeing colour, in: *Colour, Art and Science*, T. Lamb and J. Bourriau (Eds), pp. 148–149. Cambridge University Press, Cambridge, UK.
- Montias, J. M. (1981). *Artists and Artisans in Delft*, p. 284. Princeton University Press, Princeton, NJ, USA.

- Montias, J. M. (1989). *Vermeer and His Milieu: a Web of Social History*, pp. 137, 181, 252–267, 326, 341. Princeton University Press, Princeton, NJ, USA.
- Nash, J. (1991). *Vermeer*, p. 112. Scala Publications, Amsterdam, The Netherlands.
- Pénot, S. (2010). Johannes Vermeer's *The Art of Painting*. A picture marked by light. Questions on pictorial invention, in: *Vermeer die Malkunst*, S. Haag, E. Oberthaler and S. Pénot (Eds), pp. 277–278. Kunsthistorisches Museum, Vienna, Austria.
- Saitzyk, S. (1987). *The Definitive Guide to Artists' Hardware*, <http://www.trueart.info/grounds.htm>.
- Schwarz, H. (1949). Vermeer and the camera obscura, in: *Art and Photography*, W. E. Parker (Ed.), pp. 119–131. University of Chicago Press, Chicago, USA (1985).
- Seymour, C. Jr. (1964). Dark chamber and light-filled room: Vermeer and the camera obscura, *Art Bull.* **46**, 325–328.
- Seymour, P. (2003). *The Artist's Handbook*, pp. 166–167, 245–254. Grange Books, London, UK.
- Stauber, K. (2007). Comments on 17th century lenses and projection, in: *Inside the Camera Obscura — Optics and Art under the Spell of the Projected Image, Preprint 333*, W. Lefèvre (Ed.), pp. 141–145. Max Planck Institute for the History of Science, Berlin, Germany.
- Steadman, P. (2001). *Vermeer's Camera, Uncovering the Truth Behind the Masterpieces*. Oxford University Press, Oxford, UK.
- Steadman, P. (2002). *Vermeer's Camera: Afterthoughts, and a Reply to Critics*, 'The orientation of the camera image'. www.vermeerscamera.co.uk.
- Stork, D. G. (2003). *Colour and Illumination in the Hockney Theory: A Critical Evaluation*. Stanford University, Stanford, CA, USA. www.diatrope.com/stork/CIC.pdf.
- Swillens, P. T. A. (1950). *Johannes Vermeer, Painter of Delft*, pp. 111, 121–127. Spectrum Press, Utrecht/Brussels.
- Taylor, P. (1992). The concept of houding in Dutch art theory, *J. Warburg and Courtauld Inst.* **55**, 210–232.
- van de Wetering, E. (1995). The use of the palette by the seventeenth-century painter, in: *Historical Painting Techniques, Materials, and Studio Practice: preprints of a symposium*, University of Leiden, The Netherlands, 26–29 June, A. Wallert, E. Hermens and M. Peek (Eds), pp. 196–202.
- van de Wetering, E. (2009). *Rembrandt: the Painter at Work*, pp. 17–45, 95–96, 117–122, 129, 131, 142. University of California Press, Berkeley, CA, USA.
- van Eikema Hommes, M. (2004). *Changing Pictures*, pp. 11–15, 18–50, 115, 142. Archetype Publications Ltd, London, UK.
- Vergara, A. (2003). Vermeer, context and uniqueness, in: *Vermeer and the Dutch Interior*, pp. 207–208. Museo Nacional del Prado, Madrid, Spain.
- von Sonnenburg, H. (1973). Technical comments, *Metropolitan Museum of Art Bull.* **31**, 223.
- Wadum, J. (1995). Johannes Vermeer and his use of Perspective, in: *Historical Painting Techniques, Materials, and Studio Practice: preprints of a symposium*, University of Leiden, The Netherlands, 26–29 June, A. Wallert, E. Hermens and M. Peek (Eds), pp. 26, 29, 152, 196.
- Wadum, J. (1996a). Vermeer in perspective, in: *Johannes Vermeer*, A. K. Wheelock Jr. (Ed.), pp. 69–74, 77–78. Yale University Press, New Haven, USA and London, UK.
- Wadum, J. (1996b). *Jan Vermeer, Light, Love and Silence*. Malone Gill Productions, LWTP, London, UK.

- Wadum, J. (1998). Contours of Vermeer, in: *Vermeer Studies*, I. Gaskell and M. Jonker (Eds), pp. 201, 204–205, 219. Yale University Press, New Haven, USA and London, UK.
- Wadum, J., Hoppenbrouwers, R. and van der Loeff, L. S. (1995). *Vermeer Illuminated: Conservation, Restoration and Research*. V+K Publishing, Mauritshuis, The Hague, The Netherlands.
- Wald, R. (2010). Observations on approach and technique, in: *Vermeer die Malkunst*, S. Haag, E. Oberthaler and S. Pénot (Eds), pp. 203, 315–316, 318, 320. Kunsthistorisches Museum, Vienna.
- Wallert, A. (1999). *Still Lifes, Techniques and Style*, p. 22. B. V. Waanders Uitgeverij, Amsterdam, The Netherlands.
- Welu, J. A. (December 1975). Vermeer: his cartographic sources, *Art Bull.* **57**, 529–547.
- Westermann, M. (2003). Vermeer and the interior imagination, in: *Vermeer and the Dutch Interior*, pp. 226–227. Museo Nacional del Prado, Madrid, Spain.
- Wheelock, Jr., A. K. (1977). *Perspective, Optics and Delft Artists around 1650*, p. 274. Garland Science, New York, USA.
- Wheelock, Jr., A. K. (1995). *Vermeer and the Art of Painting*, pp. 12, 17–19, 56, 68, 76, 94, 110–111, 122, 126 and Fig. 88. Yale University Press, New Haven, USA and London, UK.
- Wheelock, Jr., A. K. (Ed.) (1996). *Johannes Vermeer*, p. 166. Yale University Press, New Haven, USA and London, UK.
- Wheelock, Jr., A. K. (2001). Vermeer's craft and artistry, in: *Cambridge Companion to Vermeer*, W. Franits (Ed.), pp. 46–47. Cambridge University Press, Cambridge, UK.
- Wheelock, Jr., A. K. (2010). *The Art of Painting, Vermeer die Malkunst*, S. Haag, E. Oberthaler and S. Pénot (Eds), pp. 108, 267. Kunsthistorisches Museum, Vienna, Austria.
- Wheelock, Jr., A. K. and Kaldenbach, C. J. (1982). Vermeer's *View of Delft* and his vision of reality, *Artibus et Historiae* **3**, 20.
- Williams, Q. (1995). Projected actuality, *Brit. J. Aesthet.* **35**, 273–275.
- Wirth, C. (2007). The camera obscura as a model of a new concept of mimesis in seventeenth-century painting, in: *Inside the Camera Obscura — Optics and Art under the Spell of the Projected Image, Preprint 333*, W. Lefèvre (Ed.), pp. 167–178, 191, also illustration p. 10. Max Planck Institute for the History of Science, Berlin, Germany.