ILLUMINATING THE OBSCURE

THE RELATIONSHIP BETWEEN VERMEER'S WORKS AND SEVENTEENTH-CENTURY OPTICAL DEVELOPMENTS

PAUL J.C. VAN LAAR

Seeing a Vermeer painting for the first time is a memorable moment that may change one's perception of Early Modern art altogether. Consider, for example, the Rijksmuseum's *Woman in Blue Reading a Letter* [FIG. 1]. The way light flows over the whitewashed wall in multicoloured shades of grey, the precise chromaticity of the shadows and reflections, and the absence of harsh contours and transitions. Few artists paint with such optical acuity. In contrast to the sometimes-enigmatic topics of Vermeer's paintings, the physical spaces he depicts 'simply' appear convincing. But what is it that sets Vermeer apart from his contemporaries in this respect?

Both in academic reflections and popular writing, this remarkable optical acuity is often attributed to 'photographic' qualities. However, besides being an anachronistic term, it is also rather vague. What meaning does 'photographic' carry for works created in a pre-photography age? Vermeer depicted his world with a sense of refined precision, but he never truly approached the same level of microscopic scrutiny as his *fijnschilder* colleagues Frans van Mieris the Elder or Gerard Dou. Instead, he managed the optical problems that occurred, converting his observations into paint in his own convincing way.

Vermeer worked in a time characterized by revolutionary breakthroughs in optical theories, the invention of the telescope and microscope, and a profound evolution in the realistic depiction of the visual world by artists. Yet the precise connections between Vermeer's art and these developments, as well as advancements in the broader artistic community, remain a point of contention. It is not clear where Vermeer trained, or which painters and natural philosophers he was in contact with. This limited contextual information has historically led to a tendency to treat him as the 'Sphinx of Delft': an enigmatic, idiosyncratic genius with little to do with prevalent artistic tendencies. The camera obscura has taken a central role in many of these discussions, albeit often with rather speculative lines of argumentation. The type of work put forward in the present publication, as well as presented in other volumes in the recent past – employing a wide view combining technical research with (art-)historical insight – allows us to identify associations between Vermeer's way of working and that of other artists, moving beyond mere speculation in the absence of extensive archival and biographical knowledge.[1]

This same scrutiny must be applied to the Vermeer-Camera Obscura hypothesis, a topic of much confusion and speculation that continues to be raised with little nuance in both popular and academic discourse. Rather than looking at the optical aspects of Vermeer's works in isolation, situating them within the broader seventeenth-century artistic and intellectual environment provides deeper insight into the interplay between the artist's training, the work of his contemporaries and the optical influences of the time. Such a holistic approach, combining historical texts with visual analysis and experimental reconstructions, reveals that the relationship between optics and Vermeer's painting practice is far more complex than the single lens of a camera obscura could account for.[2]

OPTICAL DEVELOPMENTS IN THE SEVENTEENTH CENTURY

The seventeenth-century Dutch Republic was characterized by a remarkable cross-disciplinary interest in optics through the observation of nature. Opticians improved the quality of lenses, leading to the invention of the microscope and telescope, and natural philosophers formulated new theories of light and vision. The combination of these developments, and the new attitude towards empirical study, set the stage for a true 'age of observation'.[3] Artists of the period, who strove to recreate nature in a convincing manner, participated fully in this. They studied and recorded effects of light and colour in paint in much the same way that natural philosophers captured them in text. Although the precise connection between new optical theories and artistic practice is still rather obfuscated, it is important to consider the intellectual environment that artists like Vermeer were working in, as it gives insight into the kinds of optical phenomena and questions that people both inside and outside of the arts were interacting with.

OPTICS FOR NATURAL PHILOSOPHY

Fascination with optics has been a constant throughout human history, with natural optical phenomena like rainbows, shadows and reflections speaking to the imagination. By the sixth century BC, Greek philosophers began systematically studying these phenomena, laying the foundations of much of modern optics.[4]

Prevailing optical theories in sixteenth-century Europe were mainly a continuation from early Greek philosophers

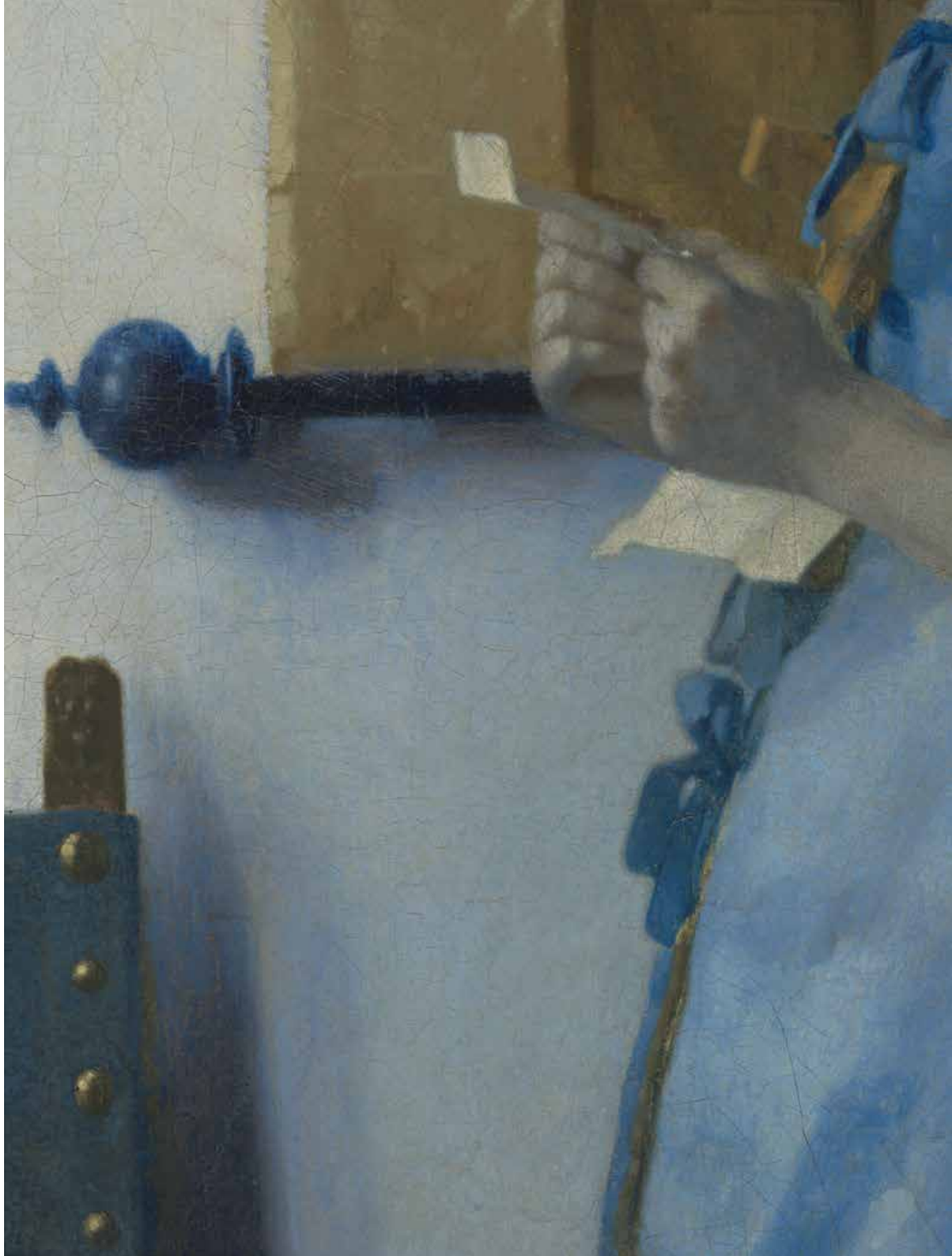


FIG. 1 *Woman in Blue Reading a Letter* (cat. 15), detail of the blue reflections on the white wall

such as Euclid (c. fourth century BC) and Ptolemy (c. 100 AD). The discussion of whether vision occurred through something entering (*intromission*) or exiting (*extramission*) the eye was prevalent, yet without clear consensus. The Greek theories reached medieval Europe through critical assessments by Islamic scholars such as Ibn al-Haytham (Latinized as Alhazen), who disproved the extramissionist point of view.[5] With certain theoretical elaborations by medieval philosopher Roger Bacon and his followers, who focused on the empirical study of nature, the Alhazian/pseudo-Ptolemaic model of vision remained dominant until roughly 1600, when Johannes Kepler's *Paralipomena* (1604) and *Dioptrice* (1611) resulted in a remarkable shift in emphasis.[6]

While earlier optical theorists described the lens as the eye's sensitive component, Kepler correctly identified the retina as the recipient of visual information, with the lens simply focusing incoming light. He also proposed that light enters the human eye through reflection from objects, after emission from a light source like the sun.[7]

Kepler arrived at his conclusions by comparing the eye to the camera obscura, a darkened room with an opening in one wall through which an image is projected onto the opposing wall. Despite the availability of (spectacle) lenses since the late thirteenth century, their properties were not well understood, resulting in hesitation to rely on them to augment the senses. Instead, images produced by optical tools were seen as occult, belonging to natural magic. In the sixteenth century, this reluctance gave way to a new trust in optical tools to reveal reliable information about the world, a shift made possible in part by Kepler's new theories. If the eye itself functioned as an optical instrument, images produced by other tools could also be relied upon.[8]

Besides discussions on the nature of light, natural philosophers also developed new theories of colour. Aristotle is known as the first to develop such a theory, in which he described colour as an inherent property of things (not of light), resulting from a mixture of white and black. This belief persisted until the late sixteenth and early seventeenth century, when the connection between light and colour was explored more extensively, eventually culminating in Isaac Newton's *Opticks* in 1704. By the turn of the century, there was a growing understanding that colours consisted of mixtures of primary colours, though the specifics varied among authors. For example, the Dutch scientist and polymath Christiaan Huygens believed that only yellow and blue were necessary to produce all others, whereas the Dutch philosopher and scientist Isaac Beeckman included red, green, white and *transparency* in this list. The Aristotelian interpretation of colour as an inherent property of objects was also gradually dropped in favour of a relative understanding, acknowledging how refraction and reflection of light could change its appearance.[9] Despite these advances, traditional descriptions of light and colour persisted for a considerable time. The coexistence of old and new ideas, with their gradual transition, tension and overlap, is characteristic of the development of knowledge in wider Early Modern scientific research. Consensus on the nature of light and colour was only reached decades after Vermeer's death, but the surviving texts reveal that the connection between the two and the effects of colour mixing were important topics of discussion.[10]

OPTICS IN ART THEORY

The understanding that advancements in optics also benefited artists is broadly recognized, although the specific details and breadth of this influence continues to be a subject

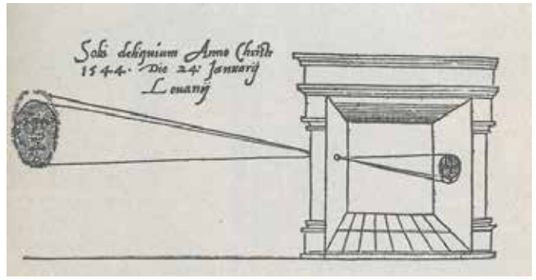


FIG. 2 First published picture of a (pinhole) camera obscura, used to observe a solar eclipse, in Reinerus Gemma Frisius, *De Radio Astronomica et Geometrica*, Antwerp 1545, p. 31v

of debate. Kepler's optical theories seem to have been adopted relatively quickly by scholars in the Dutch Republic, which, due to its relative religious tolerance, became a thriving hub for scientific exchange, allowing such ideas to spread rapidly.[11] For example, the French philosopher and scientist René Descartes, who lived in the Dutch Republic from 1628 until 1649, drew heavily from Kepler's optical theories in *La Dioptrique* (1637).[12] Other contemporaneous publications, such as Jacob Spoors's *Oratie van de nieuwe wonderen des wereldts, de nuttigheyd, de waerdigheyd, der wis- ende meet-konsten* (Oration on the New Wonders of the World, the Use and Dignity of Mathematics and Geometry, 1638), similarly demonstrate an awareness of Kepler's theories and incorporate them in their text.[13] In contrast, the influence of these developments is not as clear in art theoretical treatises, which occasionally presents rather conservative optical ideas.[14]

Samuel van Hoogstraten, a pupil of Rembrandt and writer of the *Inleyding tot de hooge schoole der schilderkonst* (*Introduction to the Academy of Painting*, 1678), owned several of Descartes's publications and was in contact with optical intellectuals through the Royal Society of London. Yet, he still advocated a Euclidean extramissionist model of vision. Regarding colour theory, Van Hoogstraten writes about 'proper colours, which the things have within themselves', a strict outdated Aristotelian notion.[15] However, he also shows more modern awareness of colour as a function of light: 'colours or pigments are variable because of different illuminations'.[16] Art historian Thijs Weststeijn points out that this balance between traditional and modern intellectual authorities is a primary characteristic of the whole book.[17]

A similar ambivalence exists in other treatises. For example, the painter Willem Beurs shows a keen interest in optics



FIG. 3 *Sketchbook on Military Art, Including Geometry, Fortifications, Artillery, Mechanics, and Pyrotechnics* [Italy? <1623]. Washington, DC, Library of Congress, Lessing J. Rosenwald Collection (Ms. No. 27), fol. 249r

in *De Groote waerelt in 't kleen geschildert* (The Great World Painted in Small, 1692). Yet, while he refers to philosophers like Robert Boyle to understand things that painters depict, he is not clear about whether artists should be aware of such ideas. Instead, he acknowledges that regardless of optical or natural philosophical theories, painters could just observe reality attentively themselves.[18]

References to Descartes, Boyle and other optical researchers reveal that writers of art theoretical texts were at least to some extent aware of contemporary optical advancements. However, the fact that they do not deal with the theories in extensive depth and sometimes hold on to more conservative notions, indicates that an extensive understanding was not the main objective. Indeed, Van Hoogstraten acknowledges that painting, not the philosophical understanding of light, is his focus: 'We will pass over what philosophers say of lux (light [*licht*]) or of lumen (illumination [*schijnsel*]), and only deal with light and illumination as far as it pertains to our art.'[19]

It is the observational disposition of natural philosophers in particular that artists concur with, benefiting from the increased emphasis on observational and empiricist practice in general.[20] After all, the aim of painting was very closely related to that of natural philosophers: the latter observed nature to understand and formulate new theories, while the former studied nature to depict it convincingly. Van Hoogstraten describes the aim of painting, stressing the ideal that artists should explore ways to make objects so real that they could be confused with nature itself: 'The art of painting is a science for depicting all the ideas or mental images, which the entirety of visible nature can provide, and for deceiving the eye with outline and colour. … For a perfect painting is like a mirror of nature; it makes things that are not there appear to exist and deceives in a permissible, pleasurable and praiseworthy way.'[21]

Such convincing realism finds its introduction in the fifteenth century with the development of linear perspective and an increased use of oil paint, which enabled artists to explore illusionistic effects with greater success. At the same time, the direct or indirect influence of advancements by natural philosophers meant that by Vermeer's time, the artist's toolkit had expanded beyond 'merely' linear perspective. Instead, a broader set of phenomena was explored, including the interplay of shadows, reflections and atmospheric effects, as well as the impact of colour and hue on the convincing illusion of space.[22] This shift is evident when comparing the content of Van Hoogstraten's *Inleyding* to that of Leon Battista Alberti's famous *Della Pittura* (On Painting, 1435).[23] While in the latter over a third of the book was devoted to perspective, by the seventeenth century, it was discussed in just a few pages.[24]

THE CAMERA OBSCURA

The most discussed relationship between Vermeer's works and optical developments is the hypothesized influence of a camera obscura. In 1891, the American artist and photographer Joseph Pennell first suggested Vermeer's use of an optical tool.[25] Since then, the theory has taken on a life of its own. Hypotheses are often put forward without sufficient experimental evidence, comparison to historical sources or consideration of seventeenth-century painting practice. Overly simplistic statements, such as 'Vermeer used a camera obscura' or 'it influenced his work', which continue to appear routinely in both popular media as well as academic discussions, do little to advance the debate and instead only perpetuate general confusion.

The basic principle of the camera obscura was already recorded in classical antiquity, based on a simple naturally occurring phenomenon: light passing through a small hole could project a reversed and inverted image of the outside onto any carrier inside a darkened room. It is this simple format that is depicted in the oldest-known illustration of the

principle from 1545 [FIG. 2]. The tool stays the same until the mid-sixteenth century, when a new and significant technical development was introduced: the placement of a glass lens in the aperture.

As no seventeenth-century material evidence survives, we must consider historic textual sources to understand the appearance and capabilities of a camera obscura.[26] A description in the *Schat der Ongesontheyt, ofte Genees-Konste van de Sieckten* (Treasure of Disease, or the Art of Healing Diseases, 1st ed. 1642), a treatise by the Dordrecht-based doctor and writer on medicine Johan van Beverwijck, gives a detailed example of the relevant properties: 'man will then obscure a room completely, and drill a hole in the window, and put in front of it a spectacle glass … to allow the light with the vision of that which is outside, to come through.'[27]

Firstly, Van Beverwijck explicitly mentions the use of a spectacle glass. These commonly available lenses would have had a diameter of about 4 centimetres, and while larger lenses did exist, they would only become commercially available in the eighteenth century.[28] In the seventeenth century, such larger lenses should be considered unique feats of craftsmanship, reserved only for advanced optical set-ups.[29] Even Kepler's camera is described with a hole of just 'about an inch and a half in the Diameter', roughly reflecting the size of a spectacle glass.[30]

Secondly, Van Beverwijck clearly describes projecting an outdoor scene. The second edition of his book includes an engraving that shows a projection of people and trees on a large sheet of paper. Importantly, other contemporaneous texts and illustrations exclusively point towards the use of the camera obscura looking out at outdoor scenes [FIG. 3]. At present, there is no known historic source that describes or shows the use of a camera indoors, and it is still ambiguous where and when this hypothesis in relation to Vermeer first appeared.

There are few documented occasions of seventeenth-century Dutch artists experiencing an optical tool. Van Hoogstraten describes how he encountered a camera obscura at least twice, both times explicitly looking at outdoor scenes. He writes how the projected image may be of use to young artists, as they can acquire 'knowledge of nature through it'.[31] However, he makes no direct mention of using the projection beyond an instructive tool as a practical aid to painting or drawing.[32]

In 1622, Constantijn Huygens acquired a camera obscura from Dutch inventor Cornelis Drebbel. Huygens was not only a keen student of mathematics and the sciences, but also a well-connected art lover in contact with Peter Paul Rubens, Anthony van Dyck, and Rembrandt van Rijn.[33] Famously, Huygens wrote about showing the camera in The Hague to his neighbour Jacques de Gheyn II, along with his son Jacques de Gheyn III and Johannes Torrentius, all acclaimed painters. After the display, Huygens and the De Gheyns suspected Torrentius of feigning ignorance towards the apparatus, perhaps to conceal his familiarity with the device.[34]

For Vermeer, no such evidence exists. In the 1676 inventory drawn up after his death, no evidence of lenses was found, although it should be noted that no more than a spectacle lens and rudimentary objects to occlude light would have been necessary: items of little value that most likely would not be included in an inventory.[35] More tellingly, two recorded visits to his studio, including one by the French traveller and diplomat Balthasar de Monconys, who had an interest in optics, mention nothing that points towards a special set-up.[36]

To fill the gap of this absent evidence, it is often speculated that the famous microscopist Antoni van Leeuwenhoek



FIG. 4 Emblem 'Ut quid cogitatis mala in cordibus vestris?', from Henricus Engelgrave S.J., Lux Evangelica sub velum *Sacrorum Emblematum Recondita*, vol. 2, p. 732, Amsterdam (Colonia) 1655. Amsterdam, Allard Pierson, University of Amsterdam, OK 62-5091

might have been Vermeer's mentor in optics, but there is little to substantiate this theory.[37] Recent research by Huib Zuidervaart and Marlise Rijks has uncovered a wider active optical network in seventeenth-century Delft. Spectacle-maker Evert Harmansz van Steenwijck developed his own telescope in 1609, just a year after the earliest-known record of a telescope. The notary, surgeon and surveyor Jacob Spoors owned a telescope, and conducted optical experiments and published on them, too. His publication, *Oratie van de nieuwe wonderen des wereldts…* (Oration of the New Wonders of the World), shows evident knowledge of learned contemporaries. Lastly, Johan van der Wyck, a young military engineer, gained fame as a maker of optical instruments all over Europe. Christiaan Huygens ordered his telescope lenses, and in London he was described as 'an excellent Man at Delph in Optics and glass-grinding'.[38] In 1655, he also gave a demonstration in The Hague using two lenses to project light into a darkened room.[39]

While this research reveals an active optical network in Delft, the connections with Vermeer remain circumstantial. Research by Gregor J.M. Weber leading up to the 2023 Vermeer exhibition made the link significantly more concrete. Vermeer's household on the Oude Langendijk was a neighbour of the station and house church of the Jesuits, who were not only interested in light and optics, but also housed many travelling Jesuits who contributed to the spread of knowledge from abroad into Delft. Jesuit devotional literature is full of references to optical phenomena, and the camera obscura was even the subject of a specific Sunday sermon [FIG. 4]. While Vermeer was born Protestant, the presence of Jesuit symbolism in his later paintings, such as the reflective glass sphere in the *Allegory of the Catholic Faith* (CAT. 32), the fact that some of his children were named after important Jesuits and the vicinity to the Jesuit station makes it likely that Vermeer encountered prevailing optical theories, and perhaps the camera obscura, through his religious neighbours.[40]



FIG. 5 *Officer and Laughing Girl*, c. 1657–1658 (cat. 7), the annotated lines indicate the notable difference in depicted head size between the two figures, which is absent in fig. 6, an effect cited as evidence of Vermeer's possible use of a camera obscura.

While conclusive evidence of Vermeer's direct contact with a camera obscura may never be found, these historic testimonies reveal that knowledge of its existence was well-established by the time he started painting. Constantijn Huygens emphasizes this idea, as he noted that the camera obscura was 'now-a-days familiar to everyone'.[41]

VERMEER AND THE CAMERA OBSCURA

Despite this widespread knowledge, there is no historic evidence that points towards any actual use of a camera obscura during painting. A single early eighteenth-century account links Dutch painters to the effects produced by the camera obscura, although not as more than a tool for study: 'Several Dutch painters are said to have studied and imitated, in their paintings, the effect of the camera obscura and its manner of showing nature, which has led some people to think that the camera could help them to understand light or chiaroscuro.'[42]

What are these effects that are so interesting to be studied, and whose presence in Vermeer's paintings has led to such strong advocates for his active use of the camera obscura? The aforementioned Pennell based his initial hypothesis on the size difference between the two figures in *Officer and Laughing Girl* (CAT. 7). This is remarkable, he argues, as comparable scenes by other artists do not show such differences, and instead follow more closely the psychological perception, which would compensate for the large difference in size.[43] Note, for example, the similarity in size of the heads in a comparable scene by Pieter de Hooch [FIGS. 5, 6].

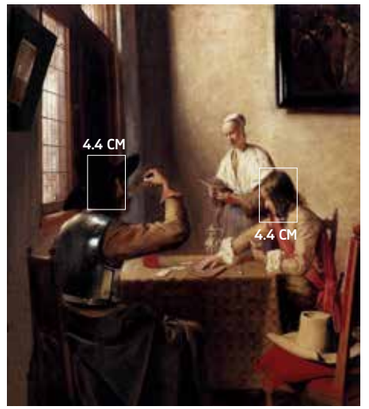


FIG. 6 Pieter de Hooch, *The Card Players*, c. 1657–1658, oil on panel, 50.5 × 45.7 cm. Private collection. The annotated lines indicate the similarity in depicted head size between the two figures, in contrast to fig. 5, reflecting a more psychologically natural perception of scale.

Throughout the late twentieth century, a wide variety of characteristics were added to the list. These range from the famous *pointillé*-like diffuse highlights on shiny surfaces, the soft contours, the precise use of perspective and the out-of-focus appearance of certain passages [FIG. 7], to slightly more ambiguous concepts, such as Vermeer's tonal accuracy, intense colouration and compositional refinement. Such theories reached their peak in the 1970s, as illustrated by Walter Liedtke's astute criticism of Arthur K. Wheelock Jr. at the time. 'Wheelock attributed to Vermeer's use of the camera both his tonal and intensely colored effects, his blurred forms and detailed passages, his shallow spaces and deep recessions, his silhouetting and cropping, and almost any kind of highlight – pretty much everything but the kitchen sink, and that only because

The Milkmaid doesn't have one.'[44] Even though Wheelock has since tempered his view, the point stands, which leads to the question of precisely what Vermeer could have learned from the camera obscura.

RECONSTRUCTIONS

The body of experimental research on the practical use of a camera obscura remains limited, and often lacks historicity in terms of its lens sizes and illumination conditions. To contextualize the further discussion and critique of prevalent theories, two reconstruction experiments were undertaken.

The first experimental set-up was conducted in June 2021 by the author and Tiemen Cocquyt, curator of Natural Sciences before 1800 at the Rijksmuseum Boerhaave in Leiden. The set-up, which used seventeenth-century spectacle lenses ([FIG. 8A], 3.1 cm diameter) from the collection of the Rijksmuseum Boerhaave, was designed to investigate whether the quality of commonly available seventeenth-century spectacle lenses was sufficient to produce optically coherent projections, or whether more specialized lenses were required.[45]



FIG. 7 *The Lacemaker* (cat. 27), detail showing the out-of-focus appearance of the loose threads in the foreground



FIG. 8 Detail of the two set-ups. Hinged spectacle lens in case, 1623, Leiden, Rijksmuseum Boerhaave, inv. no. V12083 (**A**); interior set-up with three modern lenses held in a custom plywood frame (**B**)

The lens was placed in front of a west-facing window looking out onto a brightly lit street on a cloudless June day [FIG. 9]. The projection clearly shows that any grinding deficiencies have no negative influence. All shapes and colours are clearly discernible, indicating that advancements in lens-grinding were only a requirement for highly sensitive tools like the telescope and microscope – the camera obscura worked perfectly well without them.

Due to the size of the windows, the room could not be obscured entirely, leaving some residual light spilling in around the blinds. Nevertheless, the projection strength of the outdoor scene – even through a small spectacle lens – was sufficient to render all parts of the outdoor view clearly. This is in line with historic testimonies, which exclusively point towards observing a wonderful variety of outdoor scenes.

A second set-up was designed to investigate the most peculiar part about the Vermeer-Camera Obscura hypothesis: the difference between projecting outdoor scenes and indoor ones, something routinely ignored in the literature without critical consideration. A room-type camera obscura was reconstructed by mounting a modern lens with a historically representative focal length (55 cm) and slightly larger diameter (5 cm) in a custom plywood support [FIG. 8B].[46] The set-up was positioned looking out into a room facing a white back wall at approximately 6 metres from the lens, with large east-facing windows on the left allowing natural light to enter. The projection was cast onto a white paper sheet in a room sealed from incoming light.

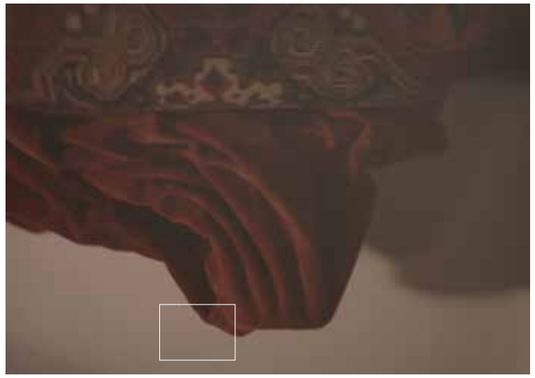
While the projection of an outdoor scene through the camera obscura created images that were engaging and visually clear, the experience of indoor projections was notably different. It immediately became clear that under natural lighting conditions, the projection was incredibly dim. After allowing the eye to adjust some time, the general shape and outline of objects became faintly noticeable but provided minimal enhancement over what the human eye would naturally perceive in terms of clarity, contrast or chromatic richness. This disparity underscores the inherent limitations of using a camera obscura in indoor settings, which probably explains why historical sources make no mention of its use in such contexts. Moreover, it was necessary for the darkness in the room to be of such intensity that one's own hands were barely visible, let alone a paint brush or the colours on a palette.

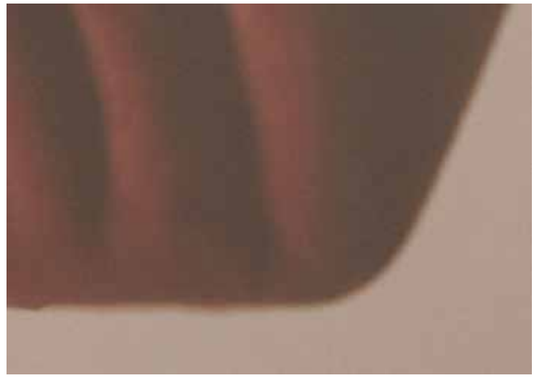


FIG. 9 Photograph of an outdoor camera obscura projection made with a 17th-century spectacle lens



FIG. 10 Still-life scene photographed from projection of a camera obscura with a modern lens





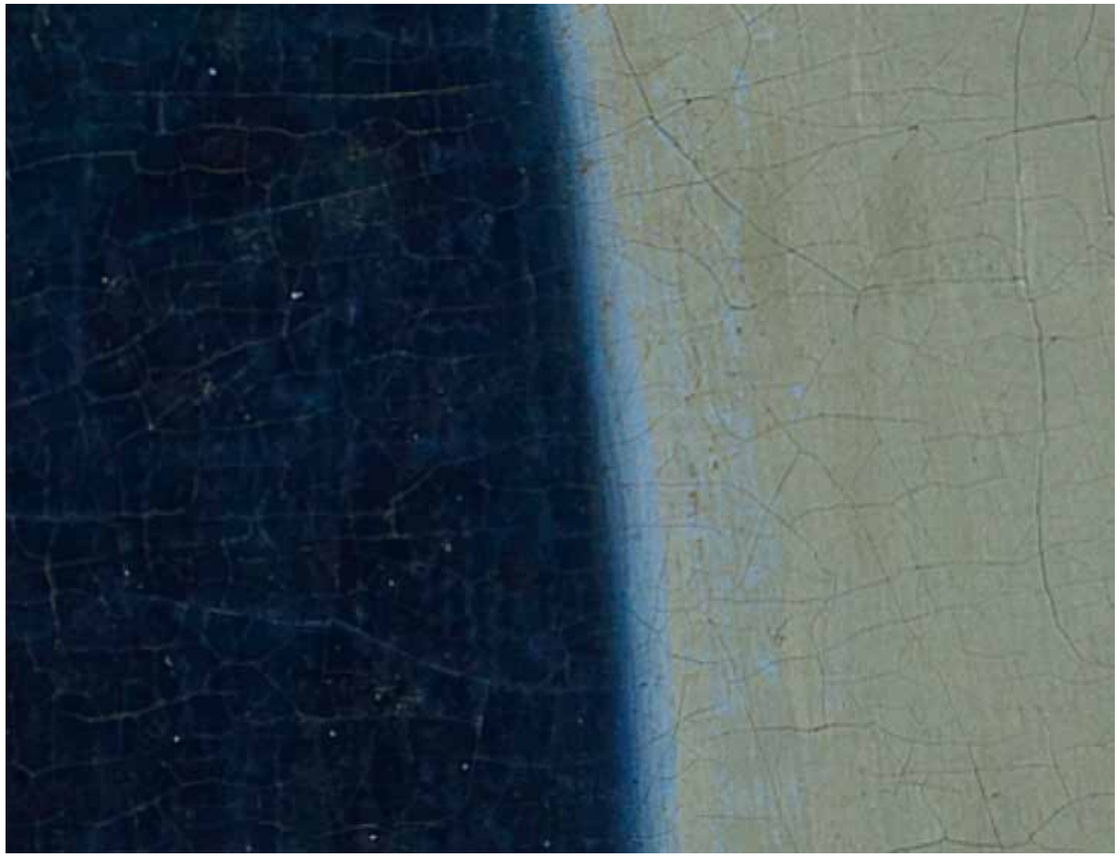


FIG. 11 Scene with red cloth photographed from projection of a camera obscura with a modern lens

FIG. 12 Detail of the same scene as FIG. 11 with increased exposure, to emphasize the lighter contour

FIG. 13 *Woman in Blue Reading a Letter* (cat. 15), detail showing the luminous blue contour at the back of the woman's jacket

This observation aligns with established principles of illumination, where indoor light intensity is significantly lower (by a factor of 100–1000) compared to direct sunlight outdoors.[47] Consequently, the light passing through the lens similarly diminishes in luminosity, reducing its usefulness. This inherent limitation explains the complete absence of historical testimonies indicating the use of the camera obscura in indoor settings, and greatly diminishes the strength of any theories relating to such use.

To further explore the characteristics of the projected image with a stronger light source, such as an outdoor scene, the set-up was augmented with strong artificial direct lighting on various still-life arrangements [FIG. 10].[48]

The examination revealed significant overlaps between the projected image and Vermeer's painted surfaces. The remarkably narrow depth of field results in large sections falling out of focus, with diffuse highlights on reflective surfaces. Even in-focus parts display soft diffuse contours, more so than modern camera pictures or one's own perception. Another intriguing discovery was the slight light envelopment or halo around the borders of fabrics, creating contours that appeared subtly lighter [FIGS. 11, 12]. While challenging to capture with a (photographic) camera, the effect – while rather subtle – was definitely perceptible, and is reminiscent of certain contours in Vermeer's mid-career works, such as *Woman in Blue Reading a Letter* [FIG. 13].

Some suggest that Vermeer's intense colours, perhaps one of the most characteristic aspects of his works, may be attributed to camera-obscura projections, though historical texts do not support this claim. Sixteenth-century Italian polymath Gerolamo Cardano even writes the complete opposite, stating that the 'colours are dull'.[49] In the naturally lit interior scene, the intensity of the colours was severely limited due to the dimness of the projection. However, even the strong outdoor projection at the Boerhaave, or the strong artificial lighting conditions in the indoor experiment did not result in colours that appear significantly more vibrant, saturated or alluring than what the human eye would naturally perceive. Absolute blacks are faded, and an overall hazy pale quality is present across the whole projection. As a result, even in optimal conditions, the blue skirt in *The Milkmaid* (**CAT. 8**) is more vibrant than anything that was observed with the camera obscura.

POPULAR THEORIES

These reconstruction experiments allow for a more substantiated critique of prevalent Vermeer-Camera Obscura hypotheses. While early experiments in the 1960s and 1970s first showed similarities between the projected image and the painted surface, they lacked significantly in their historicity, limiting their applicability to Vermeer's actual painting practices.[50] Besides research that points towards such visual overlap, practical explanations for how Vermeer might have utilized the camera obscura during painting remain sparse. Three prominent discussions are presented by architect Philip Steadman, in *Vermeer's Camera* (2001), artist Jane Jelley in *Traces of Vermeer* (2017) and inventor and entrepreneur Tim Jenison in the film *Tim's Vermeer* (2013).[51]

In his book, Steadman did not focus as much on pictorial elements as he did on geometric and mathematical evidence. Using the known dimensions of floor tiles and surviving objects, he managed to reconstruct the depicted rooms geometrically and argues that many of Vermeer's paintings most likely portray the same space. Steadman proposes Vermeer must have traced the scene to achieve such perspectival accuracy and precision in drawing, and suggests he might have painted on the same projection, too.[52] His proposal has been met with reluctance by researchers claiming other perspectival techniques, such as drawing frames and the pin-and-string method, would also have been available.[53] Others accept the theory based on the mathematical improbability of his calculations to be mere chance. While the mathematical part indeed stands strong, two important drawbacks to his practical hypothesis should be raised.

Firstly, besides being rather limited (1 page in a 200-page book), the life-size experimental part lacks historicity, as Steadman uses a lens with a diameter of 10 centimetres.[54] The area of such a lens is approximately a factor 10 larger than a simple spectacle lens, resulting in a much more luminous projection, circumventing the issues of indoors projection as highlighted by the experiments in this study. On top of that, the experiment was conducted with high-powered artificial lighting instead of non-direct sunlight. Despite his elaborate argumentation in most of the book, Steadman fails to acknowledge this critical divergence from historic sources in his shift from outside to inside.

Secondly, the tracing proposal is significantly complicated due to the limited depth of focus. Consider, for example, having to trace the precise perspective of the tiled floor. While the front is in focus, the back falls out of focus, complicating its tracing. One might refocus the scene, which, as Steadman claims, is easily done by moving the lens or the paper, but this changes the relative size of the projection, such that the already traced lines no longer line up with the now in-focus tiles at the back.[55]

Jane Jelley proposes using a projection to paint the general distribution of shadows onto an oiled paper sheet, which is then transferred to canvas.[56] While such preparatory layers are congruous with seventeenth-century painting technique, there are several shortcomings to her proposed methodology.[57] Most notably, she uses a modern projector to project pictures of finished paintings. Not only does this create a significantly more luminous projection, it also completely circumvents the issues outlined above with parts falling out of focus, and the need to continuously refocus.

Lastly, the 2013 film *Tim's Vermeer*, while testament to the protagonist's creative and steadfast mind, has little to

do with seventeenth-century painting at all. The Vermeer-like painting in the film is created using just a single opaque paint layer. It completely disregards how our final perception of works by Vermeer and his contemporaries is a combination of superimposed semi-transparent oil paint layers following a strict premeditated order, as was common in seventeenth-century painting practice. Moreover, the optical set-up Jenison proposes not only lacks any counterpart in seventeenth-century texts, but, if it had existed, would have been one of the most advanced optical systems of its time.[58] It is highly unlikely this would have gone unnoticed in recorded studio visits, or the 1676 inventory.

BEYOND THE CAMERA OBSCURA

Where does that leave us regarding the practical influence that a camera obscura could have had on Vermeer's painting process? The discussion of historical accounts, contemporary hypotheses and experimental reconstructions underscores the necessity for nuanced statements regarding Vermeer's potential engagement with this optical tool. While it is likely that Vermeer encountered the tool, any assertion of its active role during painting requires careful consideration.

First and foremost, the application of final, coloured paint layers onto a projected image is highly improbable due to the inherent dimness and subdued colour saturation of indoor projections. Additionally, the observed colour values of the projection would continuously alter as portions of the canvas start being covered by differently coloured paints. Any theory suggesting a painter like Vermeer working in a dark room with a palette full of coloured oil paints is unsubstantiated. At most, as suggested by Steadman, a tracing onto the projection might be attempted, albeit significantly complicated by its dimness. Furthermore, complications with refocusing and shifting projections remain unsolved, and a full painting resulting from such a method is yet to be successfully reconstructed.

Instead, the camera obscura should be viewed as an alternative mode of observation. While it may not have significantly aided Vermeer in capturing the precise colours of interior scenes, it offered other unique optical phenomena, such as diffuse contours and out-of-focus forms, that make the projection aesthetically and technically appealing. Vermeer appears to have been aware of these distinctive effects, and selectively incorporated them into his artistic repertoire.

It is crucial to acknowledge these differing interpretations: the former positing the camera obscura as an active participant in the artistic process, the latter as a passive tool for study and observation. While historic texts routinely support the latter view, the former has no historic backing. Importantly, later, eighteenth-century sources that do reference active use of the camera obscura by artists, pertain exclusively to the tracing of outdoor scenes by landscape painters and surveyors.

To fully understand the optical richness in Vermeer's works, it is therefore essential to broaden the perspective beyond the narrowly focused camera obscura debate and explore aspects in which Vermeer deviates from the 'optical truth'. The use of advanced imaging techniques – such as reflectance imaging spectroscopy (RIS), macroscopic X-ray fluorescence imaging spectroscopy (MA-XRF) and X-radiography – has yielded significant insight into pentimenti, or changes made during the painting process, allowing us to identify Vermeer's creative agency and the nuanced interplay between his optical understanding and artistic expression. Additionally, some physical elements in Vermeer's paintings are most likely imaginative rather than copied from life. Notably, the black-and-white tiled floors, distinctively featured in many of Vermeer's works and an important element in Steadman's argument, were exceedingly rare in Dutch interiors of the time and typically found only in the homes of the very wealthy.[59]

Another facet that shows deviation is the deliberate use of shadows as compositional elements. As Vermeer's treatment of light is generally so believable, one is often unaware of the artificiality of its pattern. In *The Milkmaid*, the tonal change on the back wall occurs more quickly than expected and is arranged to effectively serve the composition: the maid's brightly lit front borders the darker part of the wall, while her shadowed back offsets the brighter part behind her.[60] A digital 3D reconstruction of *The Music Lesson* (**CAT. 16**) by the National Gallery of Art revealed how Vermeer manipulated reality by removing certain shadows and emphasizing others to create calmness in the scene.[61] Similar artistic liberty has been suggested in *Woman in Blue Reading a Letter*, where the figure would be expected to cast a shadow on the back wall, similar to the chair and rod underneath the map.[62] A digital approximation shows how such a shadow would have negatively affected the composition [FIGS. 14, 15]. By omitting it, Vermeer successfully emphasized the woman's separateness from the wall.

In summary, Vermeer's approach to painting was far from a simplistic replication of camera obscura projections. While they served as an inspiration, providing unique optical phenomena, the final paintings were ultimately products of Vermeer's visual memory. This memory was informed by a variety of sources, including direct observation – with or without optical tools – his artistic training and broader artistic innovations of his contemporaries. His use of coloured reflections and light flowing through space looks revolutionary when compared to the preceding generation of genre interior painters, such as Anthonie Palamedesz and Jacob Jansz van Velsen. However, in the context of the artistic milieu of his time, these characteristics become clear as a part of wider developments in Netherlandish art. For instance, church interior painters such as Emanuel de Witte, Gerard Houckgeest and Hendrick van Vliet masterfully manipulated light and perspective in 1650s Delft [FIG. 16],



FIG. 14 *Woman in Blue Reading a Letter*, c. 1662–1664 (cat. 15)



FIG. 15 Digital reconstruction with added expected shadow in *Woman in Blue Reading a Letter* (cat. 15)

creating glowing light effects and velvety shadows that are reminiscent of similar characteristics in Vermeer's art. Still-life painters such as Willem Kalf painted reflections on metal objects that far exceeded those in Vermeer's works in terms of complexity. Likewise, the left-corner compositional scheme that is so strongly linked to Vermeer's works can be traced back to a regional type common in the procvince of South Holland, by painters such as Isaac Koedijck and Quiringh van Brekelenkam [FIG. 17].

The endless (modern) endeavour for a solution that could explain a one-to-one translation from a camera obscura projection to Vermeer's paintings overlooks the complexity of seventeenth-century Dutch painting practice. Art as a 'mirror of nature', as described by Van Hoogstraten,



FIG. 16 Gerard Houckgeest, *Interior of the Oude Kerk in Delft, with a Trompe-l'Oeil Curtain*, 1654. Oil on panel, 48.7 × 40.2 cm. Amsterdam, Rijksmuseum, inv. no. SK-A-1584; purchased with the support of the Vereniging Rembrandt



FIG. 17 Isaac Koedijck, *The Empty Wineglass*, 1648. Oil on panel, 66 × 54.3 cm. Middlebury, VT, Middlebury College Museum of Art, inv. no. 2010.022; purchased with funds provided by the Walter Cerf Art Fund and the Friends of Art Acquisition Fund

was never a simple process of naive observation and replication. Instead, after careful study, a skilled artist would synthesize perception and knowledge to create a work from the memory of things seen (*uit den geest*). Vermeer's true brilliance lies in his ability to blend observation and imagination, creating works that continue to captivate museum visitors all over the world with their intricate interplay of coloured light, reflections and shade – masterpieces that go far beyond any mere optical tool.

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to Prof. Dr Gregor J.M. Weber, Prof. Dr Erma Hermens and Tiemen Cocquyt for openly sharing their extensive expertise throughout this research, as well as Moorea Hall-Aquitania for her suggestions.

1 *Journal of Historians of Netherlandish Art* 14 (Summer 2022), no. 2, https://jhna.org/issues/vol-14-2-2022/ (last accessed 30 August 2024).
2 This chapter is derived from the author's final thesis for the Technical Art History MSc programme at the University of Amsterdam, supervised by Prof. Dr Erma Hermens and Prof. Dr Gregor J.M. Weber. Portions of the text and findings resemble or may replicate the original text from the unpublished thesis and have been reproduced as such with permission of the editors. See Van Laar 2021.
3 Huerta 2003, p. 16.
4 For the history of optical theories, see Pirenne 1970; Lindberg 1976; Park 1997; Wade 1998; Darrigol 2012; Smith 2015.
5 Smith 2001.
6 See a relevant discussion in Smith 2004.
7 Livingstone 2002, p. 14.
8 Huerta 2003, pp. 17–26.
9 Crone 2000, pp. 36–39 and 58–64.
10 For pre-Newtonian colour theories, see Kuehni and Schwarz 2008, pp. 1–52; Crone 2000, pp. 58–64. For Huygens's colour theory, see Van Broeckhoven 1970.
11 The 2020 biography of Christiaan Huygens provides a good overview of the thriving intellectual environment at the time, see Aldersey-Williams 2020.
12 Descartes 1637.
13 Spoors praised Kepler among a list of 'superb scholars of the whole world', including Galileo Galilei, Tycho Brahe, Simon Stevin, Philippus Lansbergen, Isaac Beeckman, Martinus Hortensius and Cornelis Drebbel. See Spoors 1638, pp. 24–25; Zuidervaart and Rijks 2015, p. 54.
14 Kemp 1990, pp. 197–181.
15 All translations are taken from Brusati and Jacobs 2021. Van Hoogstraten 1678, p. 217: 'eyge verwen, die de dingé in haer zelfs hebbe'.
16 Van Hoogstraten 1678, p. 257: 'de koleuren of verwen zijn veranderlijk door onderscheyde verlichtingen'.
17 Weststeijn 2008, p. 332.
18 Wiersma 2020, p. 263.
19 Van Hoogstraten 1678, p. 257: 'wy zullen overslaen wat de wijsbegeerigen van lux (licht) of van Lumen (schijnsel) zeggen, en alleenlijk van licht en verlichtinge, zoo veel het onze kunst betreft, handelen.'
20 Wiersma 2020, p. 258.
21 Van Hoogstraten 1678, pp. 24–25: 'de Schilderkonst is een wetenschap, om alle idëen, ofte denkbeelden, die de gansche zichtbaere natuer kan geven, te verbeelden: en met omtrek en verwe het oog te bedriegen. … Want een volmaekte Schildery is als een spiegel van de Natuer, die de dingen, die niet en zijn, doet schijnen te zijn, en op een geoorlofde vermakelijke en prijslijke wijze bedriegt.' See also the discussion in Wheelock 1995a, pp. 13–14.
22 For an insightful discussion linking developments in optics and vision with painting technique, particularly the increased use of coloured grounds, see Hall-Aquitania 2025.
23 Also known in Latin as *De Pictura*. There is no consensus whether Alberti first wrote the treatise in the local Tuscan dialect (as *Della Pittura*) and then translated it into the Latin *De Pictura*, or vice versa. For a discussion of this issue, see Sinisgalli 2011, pp. 3–16.
24 Schütz 2020, p. 89.
25 Pennell 1891, p. 295. Pennell did not refer to the camera obscura, but instead named another optical aid, the camera lucida, which was not known in the 17th century, and only became available on a large scale in the 19th century.
26 For a more detailed analysis of historic descriptions and illustrations in relation to the Vermeer-Camera Obscura hypothesis, see Van Laar et al. 2024.
27 The first edition of Van Beverwijck's text does not contain the passage yet. It must appear at some point between 1642 and 1650. Van Beverwijck 1651, p. 4: 'Men sal dan een Kamer gantsch doncker maken, ende in een venster een ront gat boren, en daer voor setten een brilglaesje … om het licht met het schijnsel van 't gene buyten is, door te doen komen.'
28 For more on the history of spectacles, see Ilardi 2007.
29 Cocquyt 2007.
30 Wotton 1651, p. 413.
31 Van Hoogstraten 1678, p. 263: 'kennis van de natuer verkrijgt.'
32 The same is true for all 16th- and 17th-century accounts, see also Delsaute 1998, pp. 113–114.
33 Wheelock 1977, p. 93; Janson 2020, p. 47.
34 Steadman 2001, p. 20. For a more detailed account of the demonstration by Huygens, see Wheelock 1977, p. 95; Barnouw 2021.
35 The inventory was drafted on 29 February 1676 and is held in Delft, Stadsarchief, Oud Notarieel Archief Delft 1574–1842, archiefnr. 161, akten van notaris J. van Veen, inv. no. 2224, 29 February 1676, akte 132. See a transcription in exh. cat. Amsterdam 2023, pp. 292–295.
36 There are two known accounts of visits to Vermeer. The first is by Balthasar de Monconys, a French diplomat, who visited Vermeer's house. De Monconys, raised Catholic by Jesuits, was connected to leading optical researchers in Europe and made improvements to the compound microscope. It is likely that any sort of optical set-up in Vermeer's studio would have sparked interest for such an optically-minded figure. See De Monconys 1666; Steadman 2001, pp. 55–58. The second account is by Pieter Teding van Berckhout, who met Vermeer on 14 May 1669, during a trip from The Hague to Delft with Constantijn Huygens, although the latter is not documented to have joined the visit. See Blaak 2009, pp. 115–116.
37 There is no evidence beyond speculation that Van Leeuwenhoek took any interest in lenses before 1668, when he visited England.
38 Van der Wyck was described as such by Samuel Hartlib in August 1655, in his *ephemerides* – a personal diary. Hartlib Papers, 29/5/29A–42B (40A). Cited from Zuidervaart and Rijks 2015, pp. 69–70.
39 Zuidervaart and Rijks 2015; Weber 2022, pp. 90–112; Roelofs 2023a, pp. 34–36.
40 Weber 2022.
41 Wheelock 1977, p. 95.
42 This is mentioned by natural scientist Willem Jacob 's Gravesande, in a later edition of his 1711 *Essai de perspective*. See the text cited in Jombert 1755, pp. 138–139: 'On peut remarquer à l'occasion de la chambre obscure, que plusieurs Peintres Flamands (à ce que l'on dit) ont étudié & imité, dans leures tableaux, l'effet que'elle présente, & la maniere dont elle fait voir la nature; de-là plusieurs personnes ont cru que'elle étoit capable de donner d'excellentes leçons pour l'intelligence de la lumiere, qu'on appelle claire-obscure.' Importantly, 's Gravesande repeatedly stresses that objects to be projected with a camera obscura should be in full sunlight.
43 Pennell 1891, p. 295.
44 W. Liedtke, 'Art & Optics Web Exhibit: Walter Liedtke', s.a., www.webexhibits.org/hockneyoptics/post/liedtke.html (last accessed 12 August 2024).
45 There have been claims that the quality of images produced by 17th-century single-lens tools would not have been sufficient for artistic purposes, see Mills 1998.
46 The support houses three different lenses, with different diameters and focal lengths. Only the middle one, with a focal length of 55 cm and diameter of 5 cm, was chosen for its historic representativity.
47 Norton and Siegwart 2013.
48 Two V-TAC VT-4911 (5777) LED floodlights were used, with 10W wattage, 50Hz frequency, 3000K colour temperature and 800lm luminous flux.
49 Cardano 1550, p. 107: '… sed cum obscuris coloribus'.
50 Seymour 1964, for example, uses a 19th-century box-type camera and does not report on the lens or illumination conditions, while Fink 1971 built a box-type camera with lenses with a diameter of 20–30 cm.
51 Steadman 2001; Jelley 2017; T. Jenison, *Tim's Vermeer* (2013) www.imdb.com/title/tt3089388/ (last accessed 30 August 2024).
52 Steadman 2001, p. 3.
53 On other possible methods of perspectival constructions, see especially Wadum 1995.
54 Steadman 2001, p. 134.
55 Ibid, pp. 17, 41.
56 Jelley 2017.
57 For a discussion on the monochromatic brown painted sketches in Vermeer's painting process, see Gifford et al. 2022, in particular n. 32.
58 For a rebuttal of much of Jenison's theory, see Stork et al. 2020, p. 5.
59 Fock 2001, pp. 87–90.
60 Wheelock 1995a, p. 65.
61 National Gallery of Art, 'Vermeer: Master of Light-The Music Lesson, Part 2', www.nga.gov/audio-video/video/vermeer-part-2.html (last accessed 1 July 2024)
62 Wheelock 1995a, p. 13 and Weber 2013, p. 32.