HISTORICAL PERSPECTIVE

Rembrandt's self-portraits

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Abstract

This paper initially presents a demonstration of the ability of 17th century artists to achieve self-portrait projections using concave and flat mirrors, and subsequently develops a case for the likelihood of this technique being employed by Rembrandt van Rijn and other old master painters.

(Some figures may appear in colour only in the online journal)

1. Introduction

The primary objective of this paper is to demonstrate that it is possible, using only 17th century materials and technology, to project one's own image onto a markable surface within the subject's reach. The authors further present the argument that this technique was employed by Rembrandt van Rijn in his celebrated series of self-portraits, and, by extension, the wider community of old master painters.

2. I. That it is *possible* that Rembrandt used projections in his self-portraits

2.1. Background

The Hockney–Falco thesis of 2000 presented compelling evidence for the use of lenses, concave mirrors, and camera obscuras in pieces dated as early as 1350 [1–3]. A major criticism of the proposal that old master painters used projected images lay in the realism achieved in self-portraits of the same period [4]. Working on the assumption that the use of projections for self-portraits was not possible [5, 6], it was argued that it was unnecessary for artists who created such 'realistic' self-portraits to use projections for other subject matter. By demonstrating that this assumption is false, this paper both supports and extends the proposal of the Hockney–Falco thesis.

2.2. Requirements

The authors understand the requirements for self-portrait projections as follows: that the artist is necessarily both subject and painter and remains in a single, stationary position; that the artist therefore be subject to sufficient direct lighting to render a clear projected image; that the projection surface be sufficiently shielded from 'environmental' light to achieve a sharp and clearly formed projected image; that the host surface is in some way markable to allow the image to be traced; and for this material to be located within reach of the artist. This summarizes to the requirement of a real image forming on a surface at less than 100 cm from the object (artist) being projected.

2.3. Equipment available to 17th century Dutch artists

2.3.1. Rembrandt and optics. We must first clarify the equipment available to 17th century Dutch painters before forming a convincing demonstration of, at the very least, their technical ability to produce self-portrait projections. This paper works on the assumption that these painters had access to the most modern, and possibly secret [7, 8], optical equipment of their time, predominantly for the following reason: that the guilds where they formed professional communities [9] were known to have included in their membership both leading painters and glass makers [10], implying a close and well-established relationship between the professional artistic and scientific worlds [11]. The Guild of St Luke, which in Amsterdam hosted Rembrandt among others, was, in Delft, overseen by the artist Vermeer [12], whose contemporaries in the guild included former students of Rembrandt's [13]. The pioneer of microscope lenses, van Leeuwenhoek, was Vermeer's immediate neighbour, and eventually the executor of his will [14]. It is known that Rembrandt owned at least one large mirror, and that Constantijn Huygens, a patron and

admirer of Rembrandt's [15–17], owned lenses up to 30 cm in diameter [18]. Lenses of 10 cm diameter were readily available in Holland in the 17th century [19]. Huygens also owned a portable camera obscura which he is known to have shown to at least one artist [20]. Literature was also available that explained lens theory (see section 2.3.2.).

In order to achieve the projections described below, Rembrandt would have required: a concave mirror, a flat mirror and daylight. We will work on the assumption that due to the close ties with the optical community, as well as the wide availability of optical equipment at the time he was painting [21–23], Rembrandt could access all of this equipment [24].

2.3.2. Context from the literature. To provide context for this investigation, we familiarize the reader with the following extracts from related literature, collected below:

Schama writes of Amsterdam in Rembrandt's time that:

'For those who could afford it, the lighting effect was enhanced even further by a generous supply of mirrors, oval, round or rectangular. For the first time, many of these mirrors were flat rather than convex, the glass ground to a degree of regularity that could accept a backing of tin or mercury' [25].

In his comprehensive study of Vermeer's use of camera obscuras, Philip Steadman writes:

'Even as early as the 1580s an English writer, William Bourne, had described the manufacture of 'perspective glasses' up to 12" (30 cm) across' [26].
'Two unequivocal descriptions of cameras with convex lenses appear very soon afterwards, the first in a perspective manual published in 1568 by Daniele Barbaro [...] Barbaro proposes explicitly that the camera be used for producing drawings in the correct perspective' [27].

Steadman also quotes Giovanni Battista della Porta (1535–1613) writing about using optics to draw and paint in 1589:

' "If you cannot draw a picture of a man or anything else, draw it by this means; if you can but onely make the colours. This is an art worth learning. Let the Sun beat upon the window, and there about the hole, let therebe Pictures of men, that it may light upon them, but not upon the hole. Put a piece of white paper against the hole, and you shall so long sit the men by the light, bringing them neer, or setting them further (i.e. adjusting the focus), until the Sun cast a perfect representation upon the table (i.e. drawing board) against it; one that is skill'd in painting, must lay on colours where they are in the table, and shall describe the manner of the countenance; so the Image being remove, the Picture will remain on the Table, and in the

superficies it will be seen as an Image in a Glass (i.e. reversed left-to-right)". Johnannes Kepler learned about the camera obscura from two sources: from reading della Porta and from working with Tycho Brahe' [28].

Steadman notes that Kepler traced from the image made by a camera obscura in 1620:

'Kepler showed Wotton a camera obscura of his own design: 'through which the visible radiations of all the objects without are intromitted, falling upon a paper, which is accommodated to receive them; and so he traceth with his Pen in their natural appearance, turning his little tent round by degrees, till he hath designed the whole aspect of the field; this I have described to your Lordship, because I think there might be good use of it for Chorography (the making of maps): for otherwise, to make landscapes by it were illiberal, though surely no painter can do them so precisely' [29].

Steadman further comments:

'Cameras of several types could be used for drawing, and were so, from early in the 17th if not late in the 16th century. No crucial invention was delayed until the 18th century. (If any feature or element was absolutely essential, it was the glass lens, introduced in the mid-16th century.) And there was technical advice directed specifically to artists, published from the 1580s onwards, about how camera images could be traced, and how correct perspective drawings could be made with the camera's help' [30].

Kemp quotes Leonardo da Vinci complaining that:

'There are some who look at things produced by nature through glass, or other surfaces or transparent veils. They trace outlines on the surface of the transparent medium [...] But such an invention is to be condemned in those who do not know how to portray things without it, nor how to reason about nature with their minds [...] They are always poor and mean in every invention and in the composition of narratives, which is the final aim of this science' [31].

On the subject of the camera obscura, da Vinci wrote:

'This is shown when the images of illuminated objects penetrate into a very dark chamber by some round hole. Then you will receive these images on a white paper placed within this dark room rather near to the hole; and you will see all the objects on the paper in their proper forms and colours, but much smaller; and they will be upside down by reason of that very intersection. These images, being transmitted from a place illuminated by the Sun, will seem

as if actually painted on this paper, which must be extremely thin and looked at from behind. And let the little perforation be made in a very thin plate of iron' [32].

Rembrandt's patron Constantijn Huygens wrote of his camera obscura that:

'It certainly produces admirable effects in painting by projection in a dark chamber. It is impossible to describe for you the beauty of it in words: all painting is dead in comparison, for here is life itself, or something more elevated, if only there were words for it. Shape, contour and movement come together naturally, in a way that is altogether pleasing' [20].

Steadman concludes that:

'From these examples it is clear that knowledge of the camera obscura was widely spread by the middle of the 17th century, not just among astronomers, but in the popular literature of "natural magic" and in manuals of perspective drawing methods circulating among architects and painters' [33].

2.3.3. Concave mirrors.
Concave mirrors have been in existence since antiquity when Archimedes is said to have used one to burn the Roman fleet [34]. They were initially made with metal. Concave mirrors were known to Leonardo da Vinci (1452–1519), as were camera obscuras [35]. da Vinci's notebooks contained 'drawings of machines for the grinding of mirrors of precise geometrical curvature' [36]. Galileo Galilei's (1564–1652) telescope had a concave eyepiece [37] and della Porta writes of concave lenses in 1586 [38]. Hockney comments that 'if they had convex mirrors, it is absurd to say they did not have concave mirrors —it is actually just the piece of glass the other side' [39].

2.3.4. Further evidence of familiarity with optical equipment.
Rembrandt's student Samuel van Hoogstraten created perspective boxes (now in the National Gallery, London) demonstrating a high level of understanding of optical effects and illusions [40]. 'van Hoogstraten is known to have seen cameras on at least two occasions. And in 1678 he published a book [...] in which he discussed the camera and its uses in art' [41]. Gerard Dou, another of Rembrandt's students 'employed a grid, lenses and mirrors to make his finely executed little paintings' [42].

That at least one artist contemporary with Rembrandt was familiar with developments in optics is suggested by the fact that 'Velasquez had a large library, which contained Durer's treatises on proportion and measurement, and many other books on perspective and optics. He also owned many measuring instruments and a grand total of 10 mirrors' [43].

3. II. That it is *probable* that Rembrandt used projections in his self-portraits

3.1. Evidence in Rembrandt's own paintings: the signatures of projection portraiture

3.1.1. Choice of material and technique at the small scale.
The earliest of Rembrandt's self-portraits are striking for the level of detail accomplished in such small images. A number of these smaller self-portraits are etched onto copper, a surface upon which projections can be seen extremely clearly. Two early *painted* self-portraits are also made on copper—an unusual choice of surface for a painting, but perhaps telling of an artist working from a projection[3]. We note that the etched images are never seen on the life-size scale of his late self-portraits, and suggest that this is because the edges in larger projected images are seen in soft focus, and become more difficult to record with a sharp stylus. Smaller projections on copper are clear and highly defined. Employing the techniques of figure 2, projections of this size could be created using small, and hence cheap, mirrors, perhaps indicative of a young artist experimenting with projections for the first time.

3.1.2. Off-centre eye focus.
Employing any of the self-portrait projection schemes illustrated in this paper, the eyes of the artist never look directly out of the projected image, but always to very slightly one side, unlike the reflection seen in a single flat mirror. This is due to the artist looking *at* the projection surface and not *into* the mirror. It is possible to make this feature less noticeable on a small scale, where the equipment is very close together and the flat mirror can even be behind the projection surface, as in figure 7. Nevertheless this is a feature that is evident in a number of Rembrandt's early self-portrait etchings[4]. On a larger scale, this off-centre eye focus can be corrected by the artist, but it is noticeable in Rembrandt's paintings in[5], and may have caused a widening

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[3] Examples of small-scale etchings and paintings. (i) Rembrandt, Rembrandt laughing, 1628. Oil on copper, 22.2 × 17.1 cm. Private Collection. J Paul Getty Museum, Los Angeles. (ii) Rembrandt, Self-portrait with Saskia, 1636. Etching, 10.4 × 9.5 cm. Rijksmuseum, Amsterdam. (iii) Rembrandt, Self-portrait with wide open eyes, 1630. Etching, 5 × 4.5 cm. Rijksmuseum, Amsterdam. (iv) Rembrandt, Self-portrait leaning on a stone wall, 1638. Etching, 36.9 × 29.8 cm. The British Museum. (v) Rembrandt, Self-portrait at the window, drawing on an etching plate, 1648. Etching, 16 × 13 cm (first state). The British Musem, London. (Click 'Back to object details' to see curator's comments.) (vi) Rembrandt, Self-portrait at the window, drawing on an etching plate, 1648. Etching, 16 × 13 cm (second state). The British Museum, London. (vii) Rembrandt, Self-portrait, 1630. Oil on copper, 120 × 155 cm. Nationalmuseum, Sweden.

[4] Examples of Rembrandt's early self-portrait etchings: (i) Rembrandt, Self-portrait, rare-headed, 1629. Etching, 17.4 = 15.5 cm. Rijksmuseum, Amsterdam. (ii) Rembrandt, Self-portrait with fur hat and light-coloured coat, 1630. Etching, 9.2 = 6.8 cm. Rijksmuseum, Amsterdam. (iii) Rembrandt, Self-portrait with fur hat and dark coat, 1631. Etching, 6.3 = 5.7 cm. Rijksmuseum, Amsterdam. (iv) Rembrandt, Self-portrait with cap pulled forward, 1631. Etching 5.6 = 4.2 cm. Rijksmuseum, Amsterdam. (v) Rembrandt, Self-portrait as a beggar, 1630. Etching 11.6 = 7 cm. Rijksmuseum, Amsterdam.

[5] Examples of off-centre eye focus (Rembrandt): (i) Rembrandt, Self-portrait at the age of 34, 1640. Oil on canvas, 102 × 80 cm. National Gallery, London. (ii) Rembrandt, Self-portrait, 1657. Oil on canvas, 53 × 43 cm. National Gallery of Scotland, Edinburgh.
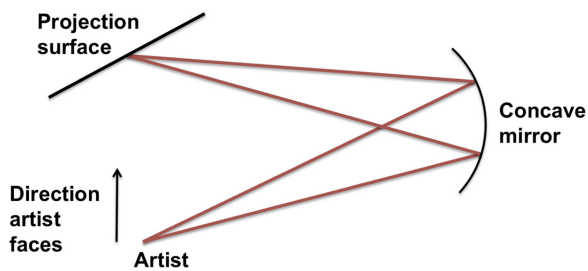
Figure 1. Diagram of set up for a self-portrait projection using a single concave mirror. This method may have been used by old masters such as Durer, but not by Rembrandt. It would allow the projection of profile self-portraits. For all projections illustrated in this paper, the image on the projection surface is inverted. This abstraction may have been beneficial to the artist, where, by following the areas of light and dark, they were free to record the reality of the subject's face, without being misguided by any preconceptions.

of the irises in[6(i)], and in the self-portrait of Rembrandt's student Carel Fabritius, in[16(i)]. In contrast, we see the direct gaze from the flat mirror self-portraits of van Gogh in[7].

More explicit examples of off-centre eye focus are evident in the self-portraits of da Vinci, Hans Holbein the Elder, Hans Baldung and Titian[8,9]. Indeed, the direction of the eyes in these poses would have been difficult, if not impossible, to see even with two flat mirrors. If we reject the use of projections and imagine a set up using only two flat mirrors, the images we see depicted would have been still more difficult to paint given their increased (virtual) distance and reduced size, as well as the necessarily complicated arrangement of mirrors and easels. Similar difficulties would have been encountered by Annibale Carracci[10(iv)], and by Artemisia Gentileschi in the taxing pose of her self-portrait in[10(ii)]. All these images would be much more simply

achieved using one of the self-portrait projection systems described in figures 1–3.

Albrecht Durer noted on his self-portrait[10(v)] that 'this I drew myself from a mirror in the year 1484, when I was still a child' [44]. It is not possible for him to have seen himself as he is depicted using only one flat mirror. It would, however, have been possible for him to record this image, using only one *concave* mirror to make a projection as described in the self-portrait system in figure 1. Further documentary evidence of the use of unusual amounts of mirrors by artists to make self-portraits is suggested in the work of Giotto (d.1337), who was the subject of 'the first post-classical reference to the painting of a self-portrait by an artist using a mirror—or in this case, mirrors,' when he was mentioned by Filippo Villani. 'To underscore Giotto's status as both polymathic and literate, Villani says he "also painted with the help of mirrors himself and his coeval Dante Alighieri on a wall of the Palazzo del Podesta" ' [45]. In an age in which curved mirrors were more readily available than flat ones, the authors note that painting a self-portrait (and a sitter) with the 'help' of more than one mirror is suggestive of the use of a projection system, and therefore more worthy of remark than merely painting one's reflection, which would require only one mirror.

3.1.3. Chiaroscuro. Chiaroscuro, the contrast of light and dark, is a well known feature of Rembrandt's portraiture work. It is also a necessary quality in the lighting for self-portrait projections [46]. Here, the face must be brightly lit while keeping the room as dark as possible to minimize illumination of the projection surface, resulting in an image with strong light-and-dark contrast. The lack of detail in the shadows of the early self-portraits is also characteristic of projections, where low light corresponds to low resolution, or an area of relative blindness within the projected image [47]. *'Shadows occlude the face like a carnival mask, while the hair glows in exuberant gilded autonomy'* [48]—this is typical of the projected image. We also note the absence of Rembrandt's paintings made in lighting conditions other than those conducive to projections. (See images[11].)

3.1.4. The physical discipline of Rembrandt's poses. In *Rembrandt laughing* and *Self-portrait with wide open eyes* (see figure 4 and [3(i), (iii)]), extraordinary physical discipline would be required to depict these poses using only a flat mirror. Projections would enable the artist to hold the position without moving, while looking directly at the image they are trying to record. In contrast, the use of only a flat mirror would require the artist to move continuously, in order to quickly alternate between looking at their reflection and the drawing surface.

3.1.5. The edges of the projected image. In Rembrandt's *Self-portrait with Saskia*[3(ii)], we see a roughly circular area

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6 Examples of the contrast between interlocked and separated hands: (i) Rembrandt, Self-portrait, 1659. Oil on canvas, 84 × 66 cm. National Gallery of Art, Washington. (ii) Rembrandt, Self-portrait, 1658. Oil on canvas, 113.7 × 103.8 cm. Frick Collection, New York.
7 Examples of conventional flat-mirror self-portrait painting (van Gogh): (i) van Gogh, Self-portrait in front of the easel, 1888. Oil on canvas. 65.5 × 50.5 cm. Rijksmuseum, Amsterdam. (ii) van Gogh, Self-portrait with dark felt hat at the easel, 1886. Oil on canvas, 42 × 32 cm. Van Gogh Museum, Amsterdam.
8 Examples of off-centre eye focus (others): (i) Hans Baldung, Self-portrait as Head of Saturn, or The Melancholic Temperament, 1516. Black chalk on paper, 33.2 × 25.5 cm. Graphische Sammlung Albertina, Vienna. (ii) Hans Holbein the Elder, Self-portrait, 1517. Silverpoint and red chalk on paper, 13 × 10 cm. Musée Condé Chantilly. (iii) Leonardo da Vinci, Self-portrait, 1510. Red chalk on paper. 33.3 × 21.4 cm. Palazzo Reale, Turin.
9 Examples of off-centre eye focus (Titian): (i) Titian, Self-portrait, 1560. Oil on canvas, 96 × 72 cm. Berlin. (ii) Titian, Self-portrait, 1568-71. Oil on canvas, 86 × 65 cm. Madrid.
10 Self-portrait paintings by other artists, indicating the use of combinations of mirrors and projections: (i) Johannes Gumpp, Self-portrait, 1646. Oil on canvas, circular format diameter 89 cm. Uffizi, Florence. (ii) Artemisia Gentileschi, Self-portrait as an allegory of painting, 1635-7. Oil on canvas, 98.6 × 75.2 cm. Cumberland Art Gallery, Hampton Court Palace. (iii) Bernardino Licinio, Self-portrait, 1580-90. Oil on canvas, 81 × 62 cm. Martin von Wagner Museum, Wurzburg. (iv) Annibale Carracci, Self-portrait, 1665. Oil on canvas. 45.5 × 37.9 cm. Uffizi, Florence. (v) Albrecht Durer, Self-portrait at the age of 13, 1484. Silver point on paper, 27.5 × 19.6 cm. Graphische Sammlung Albertina, Vienna.

11 Chiaroscuro — an early and a late example: (i) Rembrandt, Self-portrait with gorget, 1629. Oil on board, 38 × 30.9 cm. Germanisches Nationalmuseum, Nuremburg. (ii) Rembrandt, Self-portrait, 1669. Oil on canvas, 86 × 70.5 cm. National Gallery, London.
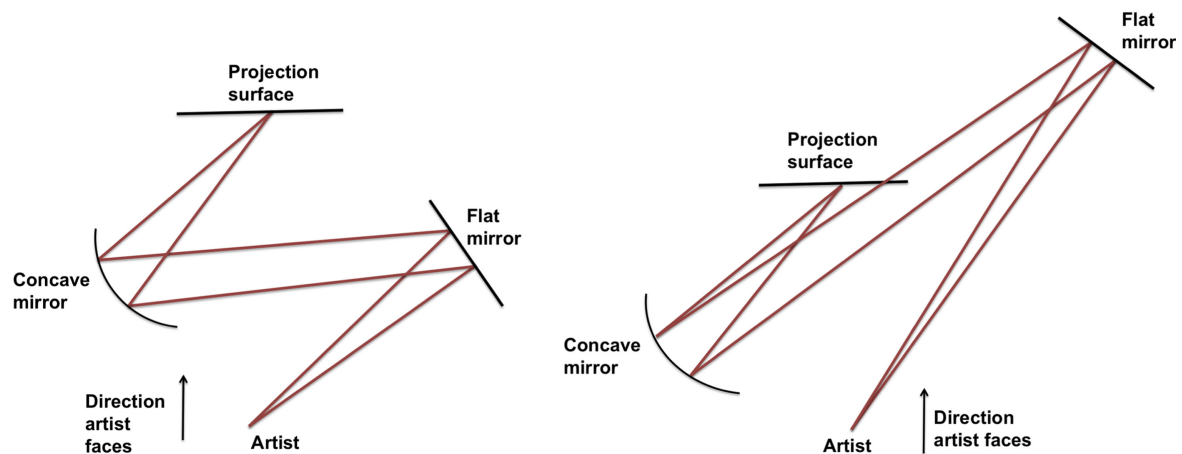
Figure 2. Two illustrations for smaller self-portrait projections. (left to right) (i) Arrangement for a projection of the face, such as in *Self-portrait with wide open eyes*[3(iii)]. (ii) Set-up for a projection including more of the body, where the image is smaller, such as in *Self-portrait leaning on a stone wall*[3(iv)]. In both, the artist is set back from the apparatus, enabling the projection surface to be shielded. Clear projections were achieved with concave mirrors of focal lengths ranging from 14 to 25 cm, and of diameter 5 to 17.5 cm, in conjunction with a circular flat mirror of diameter 7 cm or greater. For arrangement (ii), a flat mirror with a minimum diameter of 16.5 cm was used.
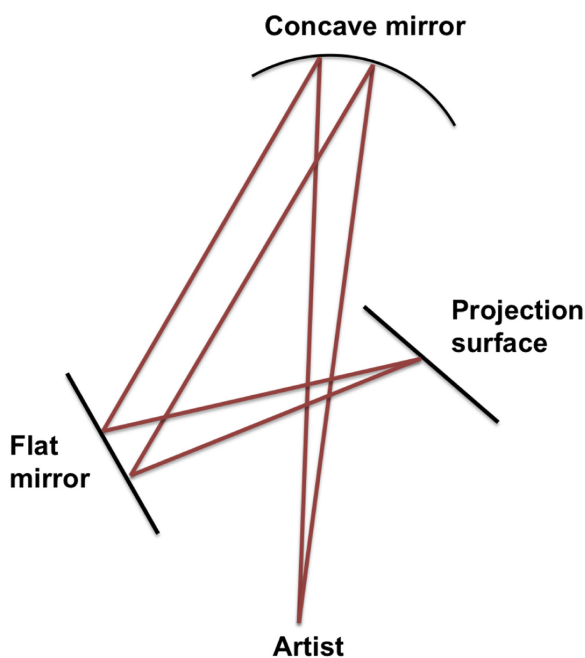

Figure 3. Diagram of set up for life-size self-portrait projections. In this arrangement, the artist stands at $2\times$ focal length of the concave mirror, which is equal to the sum of the distances between the concave mirror and flat mirror, and the flat mirror and projection surface. A clear, life-size projection was achieved using a 10 cm diameter mirror with focal length 100 cm. A concave mirror with a larger diameter would achieve a larger and more detailed projection. Mirrors of this size or greater are likely to have been available to Rembrandt. In all the described self-portrait systems, a lens placed over a circular flat mirror of the same diameter as that lens, may be used as an alternative to the use of a concave mirror.

outside of which the quality of the etching noticeably deteriorates, particularly at the hand. The authors suggest that this circular boundary marks the edge of the (circular) projected image. Outside this edge, the lines in a projection become curved, less bright, and poorer in focus—an effect

known as 'vignetting' [49]. This effect is also seen in the self-portraiture of da Vinci and Hans Holbein the Elder, and is particularly evident in da Vinci's *Arno landscape* drawing[4(ii),12].

Although it is plain that Rembrandt was a highly skilled draughtsman, the fact that it is possible for an artist to produce accomplished images with the use of lens projections and to be significantly less capable without the use of a camera was noted as early as 1622 by Rembrandt's patron Constantijn Huygens [50, 51].

3.1.6. The size of his late self-portraits. The increasing size of Rembrandt's self-portraits over time is another element that could indicate the use of projection techniques. The authors suggest that as Rembrandt's career progressed, he was able and willing to invest in larger concave mirrors with greater focal lengths, allowing the scale of his portraiture to increase accordingly[6,13]. His ability to maintain the realism and detail of his smaller, earlier images as well as the sheer scale of his later self-portraits, is what remains so striking [52]. In a simple, flat-mirror reflection, the distance from artist to mirror required to achieve visibility of the torso, let alone the whole body, would leave the details of the face and hands difficult to see, as the reflected image would necessarily be formed at a distance that precludes such close scrutiny. The further the reflected image from the artist, the greater it appears reduced in size, and yet, in his late works, Rembrandt consistently paints himself at a minimum of life size. The use of concave mirror projections enables the artist to be close to the projection of a life size composition, and hence able to

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12 Example of vignetting: Leonardo da Vinci, Arno Landscape, 1473. Pen and ink over a partially erased pencil sketch, 190 × 285 cm. Uffizi Gallery, Florence.

13 Examples of soft-focus: (i) Rembrandt, Self-portrait with two circles, 1665. Oil on canvas, 114.3 × 94 cm. Kenwood House, London. (ii) Rembrandt, Self-portrait at the easel, 1660. Oil on canvas, 111 × 90 cm. Musée du Louvre, Paris.

Figure 4. Examples of small-scale etchings and paintings. (i) Rembrandt, *Self-portrait with wide open eyes*, 1630. Etching, 5 × 4.5 cm. Rijksmuseum, Amsterdam. (ii) Rembrandt, *Rembrandt laughing*. 1628, Oil on copper, 22.2 × 17.1 cm. Private Collection, Paul Getty Museum, Los Angeles[3].

observe the details of his features, albeit in the soft focus of the projected image. We also see the effects of changing focus in relation to spatial depth within very small areas of an image, where the artist paints in sharp focus in one plane and in considerably softer focus elsewhere. This is noticeable, for example, in the contrast found between the clarity of the nose and the diffuse handling of the ears [53]. Soft focus is already cited as evidence of projection employment by Vermeer [54–56], and is present in Rembrandt's self-portraits. It is especially evident in *Self-portrait with two circles*, and *Self-portrait, 1669*[11,13].

van de Wetering writes of Rembrandt's self-portrait (1659)[6(i)] that 'some elements are so to speak, "in focus", while the passages in which they are placed still have a degree of "cloudiness" which give the viewer the feeling that they are ' "out of focus" ' [57].

3.1.7. Editing projected images. Evidence for the editing of projection images may be seen in the progression of the etchings of Rembrandt's *Self-portrait at the window*[3(v), (vi)], where the authors propose that the artist recorded the primary image by reaching over towards the vertical projection surface, and then altered the etching in later states to include 'imagined' proportions of his right arm and shoulder to fit with a desired image i.e. showing him working at a horizontal surface and without projections (inferring a view he could have seen in a flat mirror). That such an alteration has occurred is argued by Christopher White, who 'suggests that the mark which can be seen on the book is probably an earlier version of Rembrandt's right elbow' (see curator's comments in[3(v)]). This editing process

would account for the odd proportion of the head in relation to the body seen in the print.

It is important to remember here that the human eye is much more forgiving to the imagined positioning of shoulders than it is to the intricate details of a person's face. A major purpose of the use of a projection in a self-portrait (we contend) was to help the artist render the complexities of the face convincingly. If the artist then wished to show him- or herself doing something other than using the self-portrait projection system, some artifice would be necessary. On larger works, outside the central area of focus, the projected image may have been less clear. We see Isaac de Jouderville, one of Rembrandt's students, using what is likely to be similar equipment, failing to convincingly connect the edges of the traced projected image in his efforts to create the impression of a self-portrait view seen in a flat mirror[14]. X-rays of *Self-portrait with two circles*[13(i)] have also shown how Rembrandt changed the activities of his hands [58], presumably so the image would appear right-handed. Left-right reversal is a feature of self-portrait projections, as it is for self-portraits made with only a flat mirror, but this demonstrates both a willingness on Rembrandt's part to edit his optical reality, and that his initial painting layer seems to have been dictated by that reality. We note how the changed hands are not rendered with the sense of optical reality evident in the head.

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[14] Rembrandt's student, Jouderville: (i) Isaac de Jouderville. Self-portrait, 1630. Oil on panel, 48 × 37 cm. National Gallery of Ireland, Dublin. (ii) Isaac de Jouderville. Self-portrait, young man in gorget, laughing, 1629-30. Oil on panel, 52 × 49 cm. The Hague, Bredius Museum.

Figure 5. Rembrandt, *Self-portrait*, *1659*. Oil on canvas, 84 × 66 cm. National Gallery of Art, Washington[6].

Table 1. Approximate measurements of head sizes in Rembrandt's self-portraits (calculated from reproductions of each entire painting surface).

Year of painting	Eyebrow to chin (cm)	Chin to brim of hat or top of forehead (cm)
1652	15.8	20.5
1655	15.5	19.6
1657	15.3	21.7
1658	17.9	21.7
1659	14.8	20.7
1660	17.2	21.9
1661	17.1	22.1
1663	18.6	22.7
1665	16.1	20.1
1669	14.5	21.2

We therefore suggest that evidence of the wider image being edited does not constitute sufficient reason to assume the absence of a projection to depict the face. In fact the opposite—for an image to later require altering in terms of posture, we can infer that the original positioning must have been advantageous in some other aspect, such as allowing the tracing of the face, to render the activity worthwhile.

3.1.8. Interlocked hands. Frequently, it is Rembrandt's interlocked hands that are less clearly depicted in his self-portraits (see figure 5). To paint and simultaneously pose with hands clasped would be impossible, and so the painter must

rely on memory. In a self-portrait otherwise made from the close observation of a reflection or projection, we would therefore expect to see a difference in quality at the hands. In order to record the hands with the same realism as the rest of the self-portrait, the artist would need to separate and paint each hand using the opposite hand, by observing either a reflection or a projection. It is only in[6(ii)] where we see Rembrandt's hands separated and brightly lit, in the manner necessary for clear projections, that the skill and detail so familiar in the faces of the self-portraits is also apparent.

3.1.9. Consistency of head size in late self-portraits. Rembrandt's late self-portraits, small and large, have little variance in head size. The authors suggest that this is due to the same projection equipment and arrangement being used which would render a focused image of a very similar size. (See [6,13] and table 1).

3.1.10. Execution of paintings. The apparent confidence with which some of Rembrandt's paintings are produced is an indication of the use of projections. To place few and accurate markings quickly is the reward of the artist who works from a projected image, enabling the depiction of exacting facial expressions without the need to rely on high levels of concentration and memory. This technique could explain the level of realism we see in such fleeting expressions as those held in *Rembrandt laughing*, *Rembrandt with wide open eyes*[3(i), (iii)] and *Rembrandt, self-portrait open-mouthed*[15(i)]. The limited colour palette evident in these pieces may also indicate both the need and ability to paint quickly and in an uncomplicated way. Further, the simple and sparing technique is evidence of direct colour-matching to the projected image, where a single layer of paint could render the corresponding section of that projected image unidentifiable. Using a projection in this way would serve to position the whole image before more subtle layers were added, if desired. These later modifications could be added without the use of a projection.

Evidence for the economy of Rembrandt's apparently carefree brushwork and its unerring accuracy [59, 60] lies in the exposed ground/primer undercoat in some of his paintings[16], which suggests that his first brush strokes on a painting were also sometimes his last [61]. The absence of initial under-drawing is now so well recognized in Rembrandt's paintings that it is used to authenticate his work [62], although it seems clear to the authors that he did sometimes use paint to initially delineate his images [63]. The authors contend that Rembrandt did not use extensive preliminary drawing in his painted self-portraits because he had the aid of projections, which provided the desired

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[15] Examples of absence of detail in shadows: (i) Rembrandt, Self-portrait, open-mouthed, 1630. Oil on board, 15.6 × 12.7 cm. Alte Pinakothek, Munich. (ii) Rembrandt, Self-portrait, 1628-9. Oil on board, 22.5 × 18.6 cm. Rijksmuseum, Amsterdam.

[16] Examples of paintings indicating virtuoso brushwork: (i) Rembrandt, Detail of Self-portrait, 1659. Oil on canvas, 84 × 66 cm. National Gallery of Art, Washington. (ii) Rembrandt, Self-portrait with gorget, 1629. Oil on board, 38 × 30.9 cm. Germanisches Nationalmuseum, Nuremburg.

Figure 6. Example of a flat-mirror self portrait. van Gogh, *Self-portrait in front of the easel*, 1888. Oil on canvas, 65 × 50.5 cm. Rijksmuseum, Amsterdam[7].

Figure 7. Francis O'Neill, self-portrait projection. Upper section: reflection in flat mirror. Lower section: inverted projection onto copper plate 2015.

template and rendered such drawing unnecessary. A similar working method is attributed to Vermeer [64].

van Gogh is among the commentators who have remarked upon the apparent speed and carefree execution of

Rembrandt's paintings [65]. These remarks are similar to those made by Hockney in relation to artists he suspects of using projections [66, 67]. van Gogh is a notable example, as his own self-portraits are typical of images rendered from flat mirror reflections, where the artist's eyes necessarily flick between canvas and mirror. van Gogh's self-portraits are smaller than life-size and, unlike Rembrandt's [68], they show his canvas close to his face (see figure 6 and[7]).

The authors feel that 'the combination of the casual manner in which Rembrandt's hand sets to work and the impression of great precision with which painterly intentions seem to be realized' [69] is best explained by the use of projections. It is notable that Rembrandt's student Carel Fabritius displays a comparable level of accomplishment and confidence in his similarly lit self-portraiture, and that Carel's brother, Barent, also displays proficiency in the art form[17].

3.2. Claudius Civilis and The Nightwatch: evidence beyond the self-portraits

The authors believe that there exist two contrasting paintings that show Rembrandt's work with and without the use of projections. *The Nightwatch*[18(i)] was painted in a purpose built outhouse on Rembrandt's property, and depicts precise and clear features of its subjects [70]. Chiaroscuro is present, and we propose that this painting was created with the use of lenses and mirrors, using 'collages' of projections in the manner Hockney suggests of Caravaggio [71] and Steadman considers in relation to Vermeer [72]. It is a typical example of Rembrandt's famous artistic skill. In contrast, *Claudius Civilis*[18(ii)], which was painted after Rembrandt's bankruptcy and the loss of the house in which he painted *The Nightwatch* [73], is nearly unrecognizable as a piece of work by the same artist [74, 75]. We suggest that *Claudius Civilis* was made without the use of projections due to the dire financial situation Rembrandt was struggling with at the time, which may have led to him being unable to afford models [76]. In the year that this painting was made, Rembrandt was forced to sell the grave of his much loved first wife in order to service his debts [77]. Perhaps he was also unable to afford a suitable workspace in which he could privately use projections on his enormous painting of *Claudius Civilis*.

It is recorded of Hans Holbein the younger, a contemporary of Rembrandt's, that he so aggressively protected the secrecy of his workspace that he threw one of Henry VIII's Lords down the stairs when they tried to enter [78]. Perhaps Rembrandt, similarly, would not wish to expose his techniques by using lens projections in a public space [79].

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[17] Work from Rembrandt's students: (i) Carel Fabritius, Self-portrait 1645. Oil on canvas, 65 × 49 cm, Museum Boijmans Van Beuningen, Rotterdam. (ii) Barent Fabritius, Self-portrait as a shepherd, 1654-6. Oil on canvas, 79 × 64 cm. Akademie der bildenden Knste, Vienna.

[18] Possible examples of paintings with and without the use of lenses (Rembrandt): (i) Rembrandt, The Nightwatch, 1642. Oil on canvas, 363 × 437 cm. Rijksmuseum, Amsterdam. (ii) Rembrandt, The Conspiracy of Claudius Civilis, 1661-2. Oil on canvas, 196 × 309 cm. Nationalmuseum, Stockholm.

4. Conclusion

It seems clear that the technology and knowledge to create a self-portrait projection existed in Rembrandt's time. It also seems clear that he would have been exposed to this knowledge either through his training, guild, patrons, students, or literature. The question is then whether he made use of it. To believe that Rembrandt's self-portraits were not made using lenses is to believe that a man at the top of his profession, in an age where lenses were used in that profession, rejected their usage and then produced images that displayed all the features of compositions made with lenses, which also surpassed in quality the representations made by others using lenses.

The evidence, therefore, suggests that Rembrandt used lens and mirror technology to make his self-portraits. Similar evidence for the use of projections is found in the self-portraiture of other Renaissance old masters. This suggests that the use of lenses and concave mirrors was common practice for Renaissance artists.

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