Evidence That Leonardo da Vinci Had Strabismus

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Beginning with Rembrandt, a number of famous artists have been identified as having strabismus on the basis of the eye alignment evident from their self-portraits, including Rembrandt Harmenszoon van Rijn,1 Albrecht Dürer,2,3 Giovanni Francesco Barbieri (who was also known as Il Guercino, Italian for “the squinter”),4,5 Edgar Degas,6,6 and Pablo Picasso.7 Some forms of strabismus are thought to facilitate artistic work by suppressing the deviating eye, which creates 2-dimensional monocular vision advantageous to painting and drawing.8

In surveying famous artists for this condition, a particularly difficult case is Leonardo da Vinci, because there are few validated portraits of him from life. No work has an unimpeachable attribution as his likeness, so attributions are necessarily probabilistic. Nonetheless, this study assesses 6 candidate images, including 2 sculptures, 2 oil paintings, and 2 drawings, to determine the likelihood that da Vinci had strabismus.

Taking the lead of the sculpture of David by Andrea del Verrocchio (Figure 1) as a portrait of da Vinci,9 we may follow the line of circumstantial evidence to identify the candidate paintings and drawings as self-portraits.10 Although several have not generally been considered to be self-portraits, da Vinci himself was very clear that artists’ work is likely to reflect their own appearance, writing in the Codex Atlanticus, “[The soul] guides the painter’s arm and makes him reproduce himself, since it appears to the soul that this is the best way to represent a human being.”11(p1359) Thus, any of his portraits may be considered to reflect his own appearance to some extent.

Salvator Mundi (Figure 2), an image recently attributed to da Vinci, sold in November 2017 for the highest price of any painting in history.12 First listed in the collection of

**Methods**

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**RESULTS**

This study assesses 6 candidate images, including 2 sculptures, 2 oil paintings, and 2 drawings. The mean relative alignments of the pupils in the eyelid apertures (where divergence is indicated by negative numbers) showed estimates of −13.2° in David, −8.6° in Salvator Mundi, −9.1° in Young John the Baptist, −12.5° in Young Warrior, 5.9° in Vitruvian Man, and −8.3° in an elderly self-portrait. These findings are consistent with exotropia ($t_5 = 2.69; P = .04, 2$-tailed).

**CONCLUSIONS AND RELEVANCE**

The weight of converging evidence leads to the suggestion that da Vinci had intermittent exotropia with the resulting ability to switch to monocular vision, which would perhaps explain his great facility for depicting the 3-dimensional solidity of faces and objects in the world and the distant depth-recession of mountainous scenes.

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Charles I in the early 1600s, it reemerged for sale by New York art dealer Robert Simon in 2005. Meticulous restoration by Diane Dwyer Modestini revealed numerous details that led to its widespread acceptance as a work of da Vinci’s later period, around 1500 (interestingly, the same half-millennial date as Dürer’s *Salvator Mundi*). While it would represent extreme conceit to represent himself as the religious savior of the world, by the same token as for his *Young John the Baptist* portrait, it would have been difficult for da Vinci to avoid projecting his own physiognomy into the *Salvator Mundi*, particularly given its traditional full-frontal pose.

*Young John the Baptist* (eFigure 1 in the Supplement) is an established da Vinci painting from his later period. It has a remarkable similarity to *David*, by del Verrocchio, including curly hair and a quizzical *Mona Lisa*-style smile. Moreover, da Vinci is known to have a lifelong affinity with the pre-Christian figure of John the Baptist, further increasing the likelihood that some of his young appearance found its way into the painting. A terracotta bust often called *Young Warrior* by del Verrocchio (eFigure 2 in the Supplement), in the period when da Vinci was an apprentice in the studio and known to

**Figure 1. David by Andrea del Verrocchio**

A. David by del Verrocchio, full view

B. David by del Verrocchio, eyes only

C. David by del Verrocchio, full face

Bronze sculpture of *David* (1473-5, Bargello, Florence), reputed to be a depiction of the young Leonardo da Vinci. A. Full image. B. Exotropic eye alignment delineated by the eyelid aperture, iris, and pupil boundaries. C. Frontal view of the face of the sculpture. Picture credit: Rufus46, August 26, 2014, under the Creative Commons Attribution-Share Alike 3.0 Unported license.

**Key Points**

**Question** Did Leonardo da Vinci, the preeminent artist-scientist of the Italian Renaissance, have a form of strabismus that could have facilitated his artistic work?

**Findings** Examination of 6 likely portraits and self-portraits of da Vinci in which the direction of gaze of each eye is identifiable shows that most paintings exhibit a consistent exotropic strabismus angle of −10.3°, supported by a similar Hirschberg angle in the recently identified da Vinci painting *Salvator Mundi*.

**Meaning** The presence of exotropia, particularly if it was intermittent, may have contributed to da Vinci’s exceptional ability to capture space on the flat canvas.
be the model there, bears a striking resemblance to the *David* modeled on da Vinci and may be expected to provide corroborating evidence of his appearance.

One of da Vinci’s most famous works is his *Vitruvian Man* (eFigure 3 in the Supplement), which is even reproduced on the ubiquitous Euro coin of Europe. It is not generally recognized as an explicit self-portrait, although the resonances with his elderly self-portrait (eFigure 4 in the Supplement) are quite striking, with the exception of the beard, which he would have to have grown later in life. But even the later work has been questioned as a self-portrait, although mainly on the questionable grounds that it appears to depict a man too old for da Vinci’s estimated age of about 63 years when it was drawn.

Thus, there are 6 works with notable internal consistencies as a progression of portraits reflecting the appearance of Leonardo da Vinci as a model for his master and as a depicter of allegorical and autobiographical works. Strabismus was assessed by fitting circles and ellipses to the pupils, irises, and eyelid apertures images identified as portraits of Leonardo da Vinci and measuring their relative positions. To allow inspection of the eye alignment closely, the 6 portraits are shown in close-up in Figure 1 and Figure 2 and eFigures 1 through 4 in the Supplement, with the estimated eyelid, iris, and pupil positions indicated by the overlays in a panel of each figure.

**Results**

Converting the pupil position in the eye aperture from each figure to the angular rotation (assuming a typical eyeball radius of 125 mm and an interpupillary distance of 60 mm) quantifies the implied strabismus angles as $-13.2^\circ$ in *David*, $-12.5^\circ$ in *Young Warrior*, $-9.1^\circ$ in *Young John the Baptist*, $3.17^\circ$ in *Salvator Mundi*, $5.9^\circ$ in *Vitruvian Man*, and $-8.3^\circ$ in the elderly self-portrait (where divergence is indicated by a negative number). Note that the eyes would be expected to be somewhat convergent (indicated by a positive number) if the person depicted was fixating on a canvas closer than infinity (eg, $3.44^\circ$ for fixation at 1 m).

Thus, Figure 1 and eFigures 1 and 2 in the Supplement all show a divergent strabismus, whereas the examples dated to his middle age (Figure 2 and eFigure 3 in the Supplement) show an angle consistent with near fixation, perhaps on the mirror image of the painter (if they are indeed self-portraits). However, an important indicator of strabismus is the Hirschberg reflex, the pinpoint reflection seen at the same location within the pupils if the eyes are straight. This reflex is visible in only 1 of the 6 candidate images, *Salvator Mundi* (Figure 2B and C), in which the reflection is centered in the subject’s left eye but close to the nasal pupil margin in the right, a divergence of approximately $-8.6^\circ$. Such a shift is almost never made by por-
trait artists, so this should be regarded as quite telling in the present circumstance, because in Salvator Mundi, the pupil aperture and Hirschberg reflex are much clearer than either the iris or scleral boundary or the inner and outer canthi.

The image of da Vinci’s self-portrait in old age (eFigure 4 in the Supplement) is more difficult to quantify because of a partial turn of the head and some occlusion by bushy eyebrows. Nevertheless, the alignment angle is again estimated as divergent by ~8.3°, which is at the lower end of the range of the earlier cases.

Thus, the resulting mean estimate (Figure 3) is consistent with exoptotism ($t_{22} = 2.69; P = .04, 2$-tailed). Excluding the outlier esodeviation of 5.9° on the intermittent exotropia hypothesis gives a mean esodeviation of ~10.3° (approximately ~18 prism D).

Discussion

The analyses of eye alignment are consistent with a diagnosis of intermittent exotropia, suggesting that Leonardo da Vinci had an exotropic tendency of approximately ~10.3° when relaxed but could revert to orthotropia when attentive, as when inspecting his own visage for a self-portrait. Intermittent exotropia is generally associated with good stereoscopic vision when the eyes are straight but allows for its elimination when exotropic, with suppression of awareness of the deviating eye (avoiding diplopia). This condition is therefore rather convenient for the painter, since viewing the world with 1 eye allows direct comparison with the flat image being drawn or painted. Conversely, viewing the world stereoscopically gives the painter the full appreciation of its 3-dimensional spatial depth, which was characteristic of da Vinci’s thinking as represented in his book, A Treatise on Painting: “The first thing to be considered is whether the figures have their proper relief, according to their respective [3-dimensional] situations.”

Limitations

This analysis does not account for the presence of anisocoria, which is noted in Salvator Mundi (R:I = 1.22) and Vitruvian Man (R:I = 1.50) (Figure 2 and eFigure 3 in the Supplement). However, this is interpretable as an artistic trope to indicate a dominant eye rather than evidence of a neurological condition. Additional images can be found in eFigures 5, 6, and 7 in the Supplement. These images were not suitable for inclusion in the statistical analysis.

Conclusions

The weight of converging evidence suggests that da Vinci had intermittent exotropia, with a resulting ability to switch to monocular vision. This would perhaps explain his great facility for depicting the 3-dimensional solidity of faces and objects in the world and the distant depth recession of mountainous scenes.

REFERENCES

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Dr Tyler had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. Concept and design: Tyler. Acquisition, analysis, or interpretation of data: Tyler. Drafting of the manuscript: Tyler.

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Supplementary Online Content


eFigure 1. Analysis of the oil portrait of ‘Young John the Baptist’ by Leonardo da Vinci (1513-16, Louvre, Paris).

eFigure 2. Analysis of the terracotta sculpture of a ‘Young Warrior’ by Andrea del Verrocchio (1470, Bargello, Florence).

eFigure 3. Analysis of the ‘Vitruvian Man’ drawing by Leonardo da Vinci (~1490, Accademia, Venice).

eFigure 4. Analysis of the reputed self-portrait drawing when old by Leonardo da Vinci (~1515, Biblioteca Reale, Turin).

eFigure 5. Analysis of the oil on wood painting ‘Portrait of a Musician’ attributed to Leonardo da Vinci (~1485, Pinacoteca Ambrosiana, Milan).

eFigure 6. Analysis of the bronze sculpture of ‘Jesus Blessing St Thomas’ by Andrea del Verrocchio (1482, Orsanmichele, Florence).

eFigure 7. Analysis of the painted wood sculpture of ‘John the Baptist’ by Benedetto da Maiano (~1480, National Gallery, Washington, DC).

This supplementary material has been provided by the author to give readers additional information about the work.
eFigures 1 through 4 illustrate the eye alignment analysis of four likely depictions of Leonardo da Vinci that are included in the quantitative analysis described in the main text.

eFigures 5 through 7 illustrate a qualitative analysis of three further possible depictions of Leonardo da Vinci that were in too oblique view or to indistinct to be included in the statistical analysis, but offer qualitative support to the hypothesis that he had some form of exotropia. In eFig. 5, a small exotropia is evident relative to the Hirschberg reflexes (white arrows), although the pupils themselves do not appear to be properly centered in the irises. The two sculptures in eFigs. 6 and 7 also have possible attributions to da Vinci as the model, as described in the captions, and both exhibit a pronounced exotropic eye alignment.

eFigure 1. Left: Oil portrait of 'Young John the Baptist' by Leonardo da Vinci (1513-16, Louvre, Paris). Lower right: Rectified view of the face. Upper right: Exotropic eye alignment delineated by the eyelid aperture, iris and pupil boundaries. (This work is in the public domain and has been identified as being free of known restrictions under copyright law, including all related and neighboring rights.)
eFigure 2. Left: Terracotta sculpture of a ‘Young Warrior’ by Andrea del Verrocchio (1470, Bargello, Florence), plausibly another depiction of the young Leonardo da Vinci. Lower right: Frontal view of the face of the sculpture. Upper right: Exotropic eye alignment delineated by the eyelid aperture, iris and pupil boundaries. (This work is in the public domain and has been identified as being free of known restrictions under copyright law, including all related and neighboring rights.)
eFigure 3. Left: The ‘Vitruvian Man’ drawing by Leonardo da Vinci (~1490, Accademia, Venice) in a frontal pose that would naturally be assumed to be based on himself as the exemplar of the universal man. Lower right: Detail view of the face. Upper right: Anisocoric pupil configuration delineated by the iris and pupil boundaries. (This work is in the public domain and has been identified as being free of known restrictions under copyright law, including all related and neighboring rights.)
eFigure 4. Left: Reputed self-portrait drawing when old by Leonardo da Vinci (~1515, Biblioteca Reale, Turin). Lower right: Detail view of the face. Upper right: Exotropic eye alignment delineated by the eyelid aperture, iris and pupil boundaries. (This file is licensed under the Creative Commons Attribution-Share Alike 3.0 Unported license by Sailko, the copyright holder of this work.)
eFigure 5. Left: Oil on wood painting ‘Portrait of a Musician’ attributed to Leonardo da Vinci (~1485, Pinacoteca Ambrosiana, Milan), possibly another self-portrait of the maturing Leonardo da Vinci. Lower right: Detail view of the face. Upper right: Slight exotropic eye alignment delineated in oblique view by the Hirschberg reflex (white arrows). This work is in the public domain in its country of origin and other countries and areas where the copyright term is the author’s life plus 100 years or less. (This file has been identified as being free of known restrictions under copyright law, including all related and neighboring rights.)
eFigure 6. Left: Bronze sculpture of ‘Jesus Blessing St Thomas’ by Andrea del Verrocchio (1482, Orsanmichele, Florence), on which Leonardo da Vinci would have been Verrocchio’s lead studio assistant and was likely to have been the model for the figure of St Thomas. Lower right: Frontal view of the face of the St Thomas figure. Upper right: Exotropic eye alignment implied by best-estimated eyelid aperture, iris and pupil boundaries. (GNU Free Documentation License, Version 1.3, November 3, 2008. Copyright © 2000, 2001, 2002, 2007, 2008 Free Software Foundation, Inc. <https://fsf.org/>.)
eFigure 7. Left: Painted wood sculpture of ‘John the Baptist’ by Benedetto da Maiano (~1480, National Gallery, Washington, DC). Maiano was part of the circle of artists and artisans that included Leonardo da Vinci, who was famous for his preference for pink clothes and for acting as an artist’s model, particularly for the rough-hewn John the Baptist based on his country heritage from Vinci. Thus, depicting John the Baptist in pink attire would be a radical break with tradition unless it had the link of deriving from da Vinci as a model. Lower right: Detail view of the face. Upper right: Exotropic eye alignment delineated by by the eyelid aperture, iris and pupil boundaries. (his file is licensed under the Creative Commons Attribution 3.0 Unported license by Ser Amantio di Nicolao)