

Evidence That Leonardo da Vinci Had Strabismus

Christopher W. Tyler, PhD, DSc

 Supplemental content

IMPORTANCE Strabismus is a binocular vision disorder characterized by the partial or complete inability to maintain eye alignment on the object that is the target of fixation, usually accompanied by suppression of the deviating eye and consequent 2-dimensional monocular vision. This cue has been used to infer the presence of strabismus in a substantial number of famous artists.

OBJECTIVE To provide evidence that Leonardo da Vinci had strabismus.

DESIGN, SETTING, AND PARTICIPANTS In exotropia, the divergent eye alignment is typically manifested as an outward shift in the locations of the pupils within the eyelid aperture. The condition 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.

MAIN OUTCOMES AND MEASURES Geometric angle of alignment of depicted eyes.

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.

JAMA Ophthalmol. doi:10.1001/jamaophthalmol.2018.3833
Published online October 18, 2018.

Author Affiliation: Division of Optometry and Vision Sciences, School of Health Sciences, City University of London, London, United Kingdom.

Corresponding Author: Christopher W. Tyler, PhD, DSc, Division of Optometry and Vision Sciences, School of Health Sciences, City University of London, Northampton Square, London EC1V 0HB, United Kingdom (cwtyler2020@gmail.com).

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,^{3,6} 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.

Methods

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(p359)} 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

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 paint-

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.

ing. 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.

Figure 2. *Salvator Mundi* by Leonardo da Vinci (attributed)A *Salvator Mundi* by da Vinci (attributed), full viewB *Salvator Mundi* by da Vinci, eyes onlyC *Salvator Mundi* by da Vinci, face detail

Recently restored oil painting *Salvator Mundi*, attributed to Leonardo da Vinci (circa 1500). A, Full image. B, Exotropic eye alignment delineated by the Hirschberg reflex relative to the eyelid aperture, iris, and pupil boundaries.

C, Detail view of the face. 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 fewer.

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.

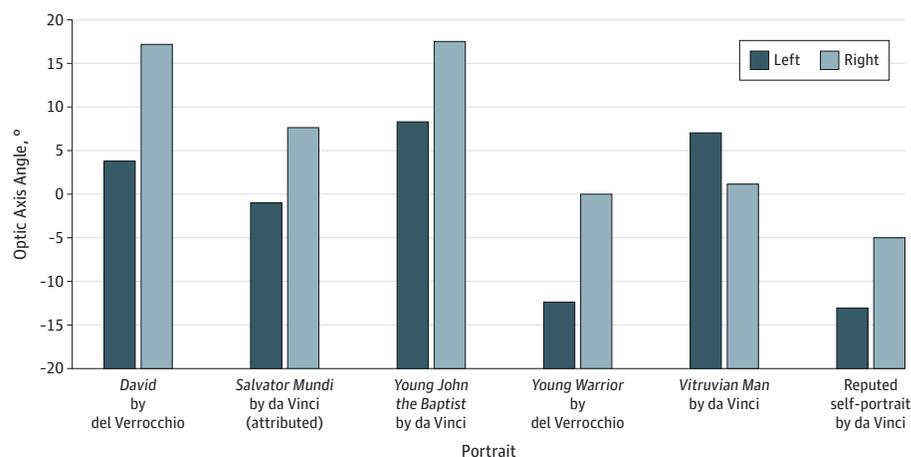
Thus, there are 6 works with notable internal consistencies as a progression of portraits reflecting the appearance of Leonardo da Vinci as a model for his master and as a depicter of allegorical and autobiographical works. Strabismus was assessed by fitting circles and ellipses to the pupils, irises, 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° in *David*, -12.5° in *Young Warrior*, -9.1° in *Young John the Baptist*, 3.17° in *Salvator Mundi*, 5.9° in *Vitruvian Man*, and -8.3° 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° 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° . Such a shift is almost never made by por-

Figure 3. Left-Eye and Right-Eye Optic Axis Angles Relative to Primary Position for 6 Portraits of da Vinci



Images of the 6 portraits named in this graph appear in Figure 1, Figure 2, and eFigures 1 through 4 in the Supplement.

trait artists,⁵ 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 exotropia ($t_5 = 2.69$; $P = .04$, 2-tailed). Excluding the outlier esodeviation of 5.9° on the intermittent exotropia hypothesis gives a mean exodeviation 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.¹ 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."^{13(p151)}

Limitations

This analysis does not account for the presence of anisocoria, which is noted in *Salvator Mundi* (R:L = 1.22) and *Vitruvian Man* (R:L = 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.

ARTICLE INFORMATION

Accepted for Publication: July 12, 2018.

Published Online: October 18, 2018.

doi:10.1001/jamaophthalmol.2018.3833

Author Contributions: 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.

Critical revision of the manuscript for important intellectual content: Tyler.

Statistical analysis: Tyler.

Administrative, technical, or material support: Tyler.

Conflict of Interest Disclosures: The author has completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest. No disclosures were reported.

REFERENCES

- Livingstone MS, Conway BR. Was Rembrandt stereoblind? *N Engl J Med*. 2004;351(12):1264-1265. doi:10.1056/NEJM200409163511224
- Aronson JK, Ramachandran M. The diagnosis of art: Durer's squint—and Shakespeare's? *J R Soc Med*. 2009;102(9):391-393. doi:10.1258/jrsm.2009.09k043
- Trevor-Roper PD. *The World Through Blunted Sight: An Inquiry Into the Influence of Defective*

Vision on Art and Character. London, England: Bobbs-Merrill, 1970.

4. Stampfle F, Bean J. *The Seventeenth Century in Italy: Metropolitan Museum of Art*. New York, NY: Pierpont Morgan Library; 1967:37.
5. Lanthony P. *Art & Ophthalmology: The Impact of Eye Diseases on Painters*. Mailer C, trans. Amsterdam, the Netherlands: Wayenborgh; 2009:200.
6. Kendall R. Degas and the contingency of vision. *Burlingt Mag*. 1988;130:180-216.
7. The Nerve Blog. Inside the mind of creative geniuses. <http://sites.bu.edu/ombs/2012/02/21/inside-the-mind-of-creative-genius/>. Published February 21, 2012. Accessed October 10, 2017.
8. Livingstone MS, Lafer-Sousa R, Conway BR. Stereopsis and artistic talent: poor stereopsis among art students and established artists. *Psychol Sci*. 2011;22(3):336-338. doi:10.1177/0956797610397958
9. Valentiner WR. Leonardo as Verrocchio's coworker. *Art Bull*. 1930;12(1):43-89.
10. Tyler CW. How did Leonardo perceive himself? metric iconography of da Vinci's self-portraits. *Proceedings: Human Vision and Electronic Imaging*. 2010;XV(7527):1D. doi:10.1117/12.846850
11. Vallentin A. *Leonardo da Vinci: The Tragic Pursuit of Perfection*. Dickes EW, trans. New York, NY: Viking Press; 1938.
12. Henderson B. Leonardo da Vinci painting sells for world record \$450 million despite lingering doubts over its authenticity. *The Telegraph*. <https://www.telegraph.co.uk/news/2017/11/16/leonardo-da-vincis-salvator-mundi-sells-450-million-342-million/>. Published November 16, 2017. Accessed July 24, 2018.
13. da Vinci L. *A Treatise on Painting*. Rigaud JF, trans. London, England: George Bell & Sons, 1877.