

## Editorial essay

### Molyneux's answer II

Molyneux's letter to Locke on 2 March 1693 asked the question for which Molyneux is now justly renowned owing to the immense amount of research and writing generated by it (Wade and Gregory 2006). In the letter, he addressed possible corrections, amendments, and suggestions for the revision of Locke's *Essay Concerning Humane Understanding*. It was in the second edition that Locke (1694) printed Molyneux's question. Moreover, in the same letter Molyneux corrected Locke on a matter concerning the limits of visual resolution (see George 2006; Wade 2004). He cited the location in the first edition and the correction required:

“Pag. 96. sec. 9. you assert what I conceive is an Error of Fact, viz, that a Mans Eye can distinguish a Second of a Circle whereof its self is the Center. whereas tis certain that few Mens Eyes can distinguish les than 30 Seconds, and most not under a Minute or 60 Seconds. as is manifest from what Mr Hook lays down in his Animadversions on the first part of Hevelii Machina Cælestis. pag. 8. 9. etc but this as I said before is only an Error in Fact, and Affects not the Doctrine laid down in the said section.” (De Beer 1979, page 650)

Locke corrected the error in the second edition. The reference to Robert Hooke (1635–1703; 1674) concerned his demonstration of the limits of visual acuity. Like Molyneux, Hooke was exercised by difficulties involved in astronomical observations and drew attention to the fact that it is impossible to see with the naked eye structures on the moon that can be seen with the aid of a telescope. In order to assess the value for visual acuity he described both a stimulus and a procedure for determining it. The stimulus he used (figure 1) is equivalent to a square-wave grating; the procedure was the time-honoured one of increasing the distance of observation until the lines of the grating could not be discriminated from one another. Hooke found that for most people the value was a separation that subtended 1 min of arc. He described the stimulus and procedure thus:

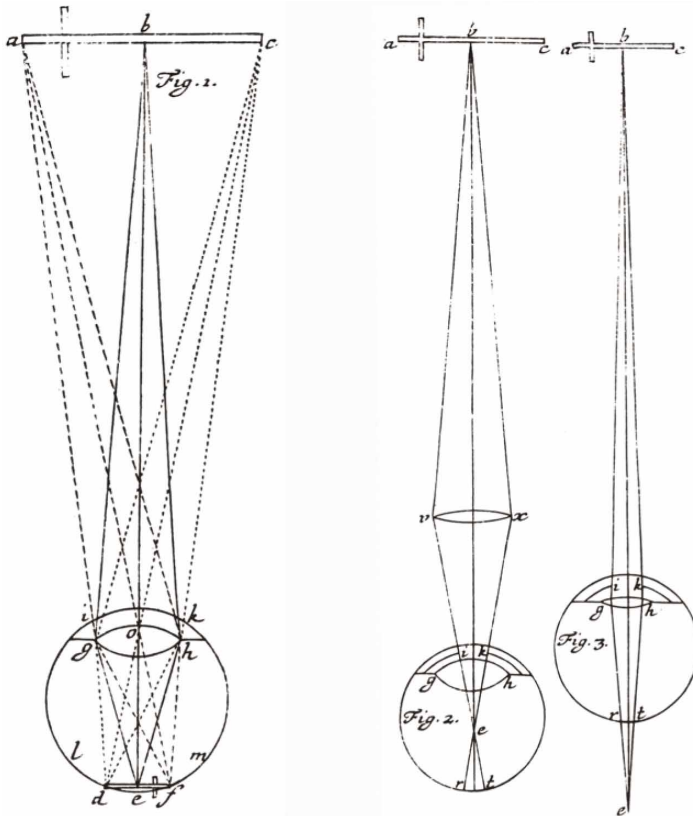
“Now that any one may presently satisfie himself of the truth of what I assert, concerning the limited power of the naked eye, as to the distinguishing of Angles; Let him take a sheet of white Paper, and thereon draw two parallel Lines, as OO, and PP, in the 28<sup>th</sup>. Figure, at four or five inches distance, then draw as many other small lines between them at right angles to them, and parallel one with another, as he thinks convenient, as aa, bb, cc, dd, ee, ff, gg, hh, ii, andc. and let them be drawn distant from each other an inch, then let him alternately blacken or shadow the spaces between them, as between aa and bb, between cc and dd, between ee and ff, between gg and hh, between ii and kk, between ll and mm, andc. leaving the other alternately white, and then let him expose this Paper against a Wall open to the light, and if it may be so that the Sun may shine on it, and removing himself backwards for the space of 287  $\frac{1}{3}$  feet, let him try whether he can distinguish it, and number the dark and light spaces. And if his eyes be



Figure 1. Hooke's (1674) figure for determining the limits of visual resolution.

so good that he can, then let him still go further backwards from the same, till he finds his eyes unable any longer to distinguish those Divisions, then let him make a stand, and measure the distance from his eye to the aforesaid Paper, and try by calculation under what Angle each of those black and white spaces appears to his eye, so by that means it will be manifest how small an Angle his eye is capable of distinguishing, and beyond which it cannot reach.” (Hooke 1674, page 8).

Despite the fact that William Molyneux is best known for the question he posed to Locke concerning perceptual recognition with restored sight, he answered many questions regarding perception in his book *Dioptrica Nova. A Treatise of Dioptricks in two Parts*. For example, he displayed a thorough understanding of the dioptrics of the eye (figure 2, left) and in the corrections for myopia and presbyopia (figure 2, right).



**Figure 2.** Left, Molyneux’s diagram of image formation in the eye. He wrote: “We are likewise to observe, that the Representation of the Object *abc* on the Fund of the Eye *fed* is *Inverted*. For so likewise it is on the Paper in a dark Room; there being no other way for the Radious Cones to enter the Eye or the dark Chamber, but by their Axes *ao*, *bo*, *co*, crossing in the Pole *o* of the Crystalline or Glass” (1692, page 105). Right, corrections for myopia and presbyopia: “And this is the Fault of their Eyes, who are called *Myopes*, *Purblind*, or *Short-sighted*. For in them the Crystalline is too Convex (as in *figure 2*. both the Convex Glass and Crystalline joyn’d together make too great a Convexity) uniting the Rays before they arrive at the *Retina*. and therefore they are helped by Concave glasses .... On the contrary, the Eyes of Old Men have their Crystalline too Flat (*figure 3*) and cannot correct the Divergence of the Rays *bi*, *bk*, to make them meet on the *Retina* *rt*, but beyond the Eye at *e*. Wherefore for their Help ‘tis requisite they add the Adventitious Convexity of a Glass; that both it and the Crystalline together, may be sufficient to unite the Rays just at the *Retina*: And from hence it appears, that Spectacles help Old Men, not by magnifying the Object, but by making its Appearance Distinct; for Old Men cannot read the largest Print without Spectacles, and yet with Spectacles, they read the smallest, though these with Spectacles do not appear so large, as those without Spectacles” (1692, pages 108–109, original italics).

However, it is in the context of perception that Molyneux displayed considerable acumen, presenting observations and viewpoints that have a modern ring to them. For example, he distinguished between the consequences of stimulating the senses and the subsequent experience: “For in Vision there is a Difference between *looking* and *seeing*, what ever Object I *look* at with both Eyes appears *single*, and all others more remote or nigher, the I *see*, appear *double*, for upon the Object, I *look* at, the Optick Axes do concur, but not so on those I only *see*” (1692, pages 288–289, original italics). This was supported by an instance of poorer performance with one eye than with two—in the dynamic context of sport: “... the best [tennis] Player in the World Hoodwinking one Eye shall be beaten by the greatest Bungler that ever handled a Racket; unless he be used to the Trick, and then by Custom get a Habit of using one Eye only” (1692, page 294). At that time there was great debate regarding differences between monocular and binocular vision. The ancient view that vision with one eye was superior to that with two (because the visual spirit was channelled to one eye) was slowly being replaced by evidence of inferior performance on tasks performed with one eye only. Robert Boyle (1627–1691; 1688/1966) had described the errors made in pouring liquids by someone who had lost an eye. Molyneux was making a speculative addition to this body of evidence, although his belief in the powers of practice for redressing the binocular superiority remains questionable.

For Molyneux, seeing referred to the stimulation of the retina, whereas looking involved an awareness of the objects in direct vision. The distinction between looking and seeing was also brought to bear on another question that had puzzled students of vision since the time of Kepler. How is vision upright if the image on the eye is inverted? Kepler (1604) would not be drawn on such speculation, considering that the question was beyond the scope of optics: “I leave it to the natural philosophers to discuss the way in which this image or picture is put together by the spiritual principles of vision” (Crombie 1964, page 147). Molyneux was similarly constrained as the question was taken to be one addressed to the soul rather than to the eye. Nonetheless, he did propose an answer that the terms up and down are relational and do not need to correspond to the parts of the retina stimulated:

“How then comes it to pass that the Eye sees the Object *Erect*? But this Quæry seems to encroach too nigh the enquiry into the manner of the Visive Faculties *Perception*; For ‘tis not properly the Eye that *sees*, it is only the Organ or Instrument, ‘tis the *Soul* that *sees* by means of the Eye. To enquire then, how it comes to pass, that the Soul perceived the Object *Erect* by means of an *Inverted* Image, is to enquire into the Souls Faculties; which is not the proper subject of this Discourse. But yet that in this Matter we may offer at something, I say, *Erect* and *Inverted* are only Terms of *Relation* to *Up* and *Down*, or *Farther from* and *Nigher to* the Centre of the Earth, in parts of the same thing ... . The Image of an *Erect* Object being Represented on the Fund of the Eye *Inverted*, and yet the sensitive Faculty judging the Object *Erect*; it follows that when the Image of an *Erect* Object is painted on the Fund of the Eye *Erect*, the sense Judges the Object *Inverted*.” (1692, pages 105–106, original italics)

Locke pointed out that no special mechanism is needed for seeing the world as upright, because the retinal images are not seen. All that matters is the relation between seen external objects and their representation in the brain. So we may ask: What is the need for physiological mechanisms keeping the world upright when the head is tilted? How could such a mechanism be useful or needed, if there is no problem to solve? This might be compared with filling in the blind-spot and scotomas. It has been suggested that no special process is needed, and does not exist, as all the brain needs to do is ignore regions of retina which do not supply useful information. Active filling in by physiological processes has also been suggested. These active and passive accounts are very different. Either is feasible—but can *both* be true? How could

the brain both *ignore* and *fill in* blind regions? How could there be no need to compensate tilts of the head, and have active compensating mechanisms?

Molyneux's and Locke's positions were upright, and they did not consider the consequences of viewing the world with an inclined retinal image. The means by which the direction of the centre of the earth was determined was taken as self-evident, owing to the maintenance of an upright posture. How this was maintained was not appreciated for almost another two centuries, when the functioning of the vestibular system was better understood (see Wade 2000). When Helmholtz addressed the same question, he gave essentially the same answer as Molyneux (without citing him), and also demonstrated the reliance on touch as providing the signals for upright: "... we should have no difficulty about the explanation as to how objects appear to be erect, although their images on the retina are inverted. The sense of touch by itself is capable of forming perfect apperceptions of space, without any help whatever from the sense of sight" (Helmholtz 1925, page 251). When Helmholtz was writing (1867) experiments on vertigo following body rotation had already cast doubt on this conclusion (see Tatler and Wade 2003) but the feelings of disorientation and dizziness were not localised to the vestibular system until the 1870s (Wade 2003).

The answer given by Molyneux about upright vision with an inverted retinal image has probably had as much impact on visual science as his query about vision when sight is restored.

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